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# The Duck and The Camel: Tracing the Net Load on the Indian Power Grid



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# The Duck and The Camel: Tracing the Net Load on the Indian Power Grid

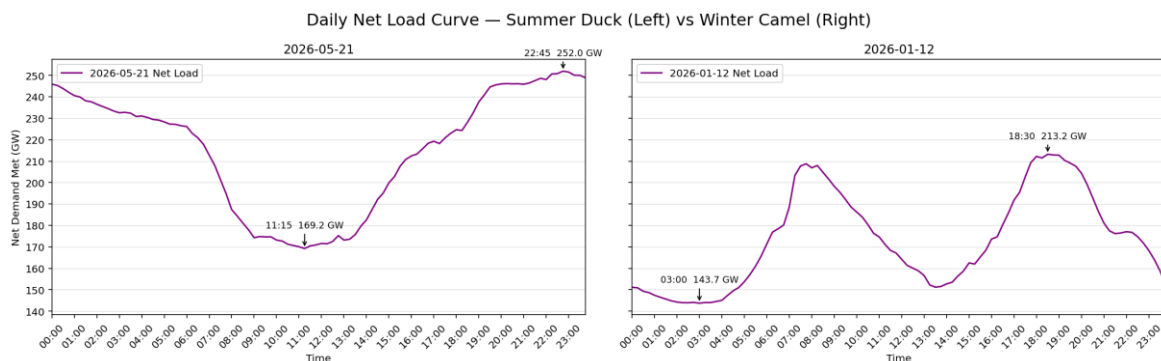
## EXECUTIVE SUMMARY

On 21 May 2026, India's power grid set an all-time record. At 3:45 PM, the peak demand met reached 270.8 GW, a level greater than any single moment in its history. As striking as the quantum of the load was the speed of its change. At 8:00 AM on the same day, demand sat at 224.1 GW. In less than 8 hours, the grid took on an additional load of 46.7 GW, more than the entire British grid drew at its peak in all of 2025. India's demand for power is not only large, but also extremely volatile even within the duration of a single day.

The price of electricity tells a similar story. On the same day, i.e. 21 May 2026, on the Indian Energy Exchange's day-ahead market, a unit of power scheduled for delivery at 1:00 PM cleared at just Rs 1.56. The same unit scheduled for 6:30 PM cleared at Rs 10.00, the market's price ceiling. More than six times the price, for the same electricity, a few hours apart. Importantly, the record demand peak at 3:45 PM was not the moment of highest price, because the sun was still up. The price did not hit its ceiling until 6:30 PM, once solar had faded. Peak demand and peak price often fall at different hours of the day, and the gap between them has become an important feature of the modern Indian grid.

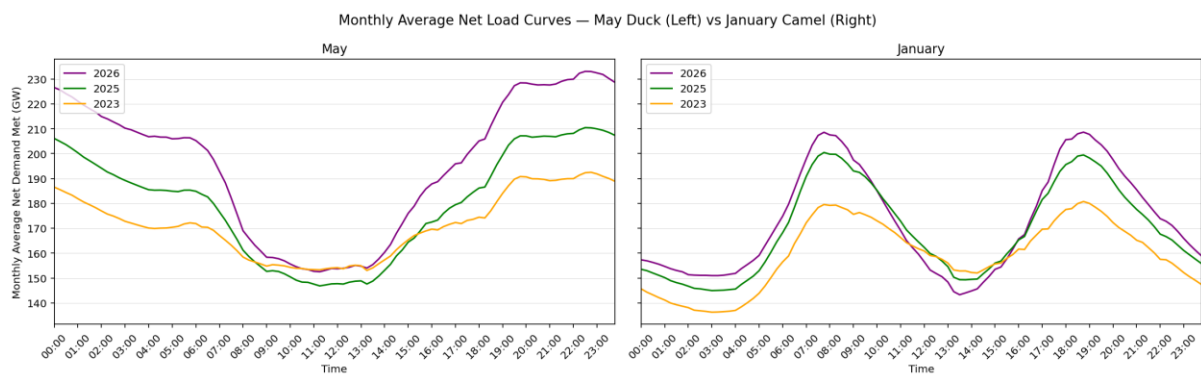
This paper argues that the best way to smoothen these fluctuations in demand and price is to store electricity when it is abundant and release it when it is scarce. The paper establishes this by mapping the different shapes of the net-load curve (total demand met minus solar output) by using high-frequency grid data for every 15-minute interval during a 24-hour period. We start with describing single summer and winter days, and then go on to generalize those patterns using monthly averages for each of those 15-minute intervals. This eliminates any single day peculiarities and gives us a representative picture for the season. These monthly patterns are then compared across years to discern structural changes with policy implications.

Grid operators worldwide use the moniker 'duck curve' for the daily net-load profile of a grid (total load minus renewable output) with significant solar penetration: a deep midday trough, when solar supplies a large share of demand, and a steep climb each evening, as the sun withdraws and conventional sources must rapidly ramp up. The Indian grid produces both a 'duck', in the summer, and a 'double humped Bactrian camel' in the winter.



During the summer, when demand is driven by cooling needs and solar generation runs at its strongest, the net load on the country's conventional fleet traces a single midday belly and a single evening climb. The shape is recognisably the duck. But in the winter, the same grid looks completely different. Demand spikes twice, once in the morning, as households wake to the cold and switch on the heat and lights; and again in the early evening, as darkness falls and the lights and televisions come on. In between sits a midday trough fed by what solar generation the short winter day provides. This leads to a Bactrian camel: two humps with a saddle between them.

Across three comparable summers (2023, 2025, 2026), the belly of the summer duck has deepened sharply. 2024 is kept out of the analysis since it was one of the hottest years on record and does not yield comparable figures. The evening climb has doubled in three years, from about 36 GW (May 2023) to 74 GW (May 2026). The morning ramp-down, as solar floods in, has nearly tripled across the same window, from 18 GW to 53 GW. Across three winters (2024 is again ignored), both flanks of the camel have steepened to nearly identical magnitudes: a 64 GW descent into the midday trough, and an equivalent climb back out.



Three market signals corroborate the above picture. First, the **price for electricity** on the day ahead market operated by the Indian Energy Exchange on an average day in May has fallen from ₹2.81 (2023) to ₹1.11 (2026) at the midday trough, while the evening peak has risen from ₹8.08 to ₹9.71. The intraday spread has widened from ₹5.27 to ₹8.60 in three years; the peak-to-trough ratio is now nearly 9×, and would be wider still were it not for the ₹10 market ceiling. Second, **curtailment**. Solar generation that the grid could not absorb averaged 24 GWh per day in May 2026, more than a quarter of Delhi's average daily electricity consumption. Third, **shortage**. Across April–May 2026, the grid fell short of demand on 36 of 61 days at the non-solar-hour peak and on only 6 of 61 days at the solar-hour peak. The three signals confirm that India is not running short of electricity in the middle of the day. Instead, the stress on the grid emerges when the sun is not shining. And the stress is increasing every year.

Putting together all the data points shows that the grid is now bound by when it can generate the electricity required, and how fast it can change what it generates. In other words, the active constraint for the grid has shifted from generation capacity to flexibility.

Storage is the obvious solution. However, the storage gap is large and needs to be filled quickly. Flattening even a single summer day's evening ramp by half requires about 130 GWh of discharge across the 1 PM to 8 PM window. India's entire pumped-storage

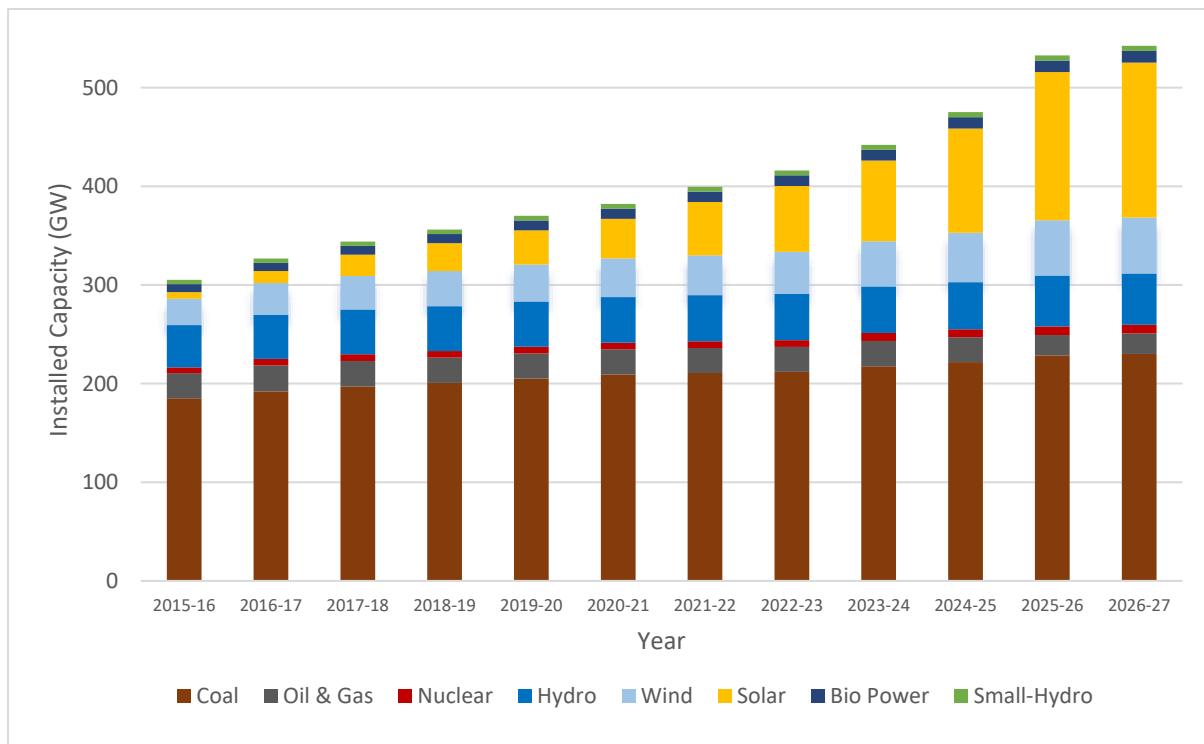
*and battery fleet discharged only about 23.8 GWh across an average day in May 2026. The shortfall is overwhelmingly a battery shortfall: against the National Electricity Plan's projection of 8.68 GW of grid-scale batteries for 2026-27, only 0.27 GW was in operation till January 2026, even as pumped hydro very nearly reached its mark at 7.2 GW of the 7.45 GW projection. Significant capacity additions in recent months have increased BESS capacity to 2.7 GW, but the gap still remains large. That a battery build-out can help ease the stress on the grid is not merely conjecture. California, with a battery fleet large enough to discharge over 10 GW, charges into its midday solar surplus and discharges into the evening, converting an evening net-load swing of nearly 28 GW into about 10 GW, adjusted for battery discharge. This is the very capability India will need as its own solar fleet expands.*

*The regulatory foundation is already being re-laid to enable the grid to handle these challenges. The draft Electricity (Amendment) Bill, 2025, read with the draft Electricity (Rights of Consumers) Amendment Rules, 2026, contains proposals that speak directly to the flexibility problem. They write energy storage into the Electricity Act and into the definition of the 'power system' for the first time; direct the regulator to deepen the power market, including through contracts for difference; convert the renewable-purchase obligation into a nationally-floored non-fossil obligation backed by a monetary penalty defined in the Act itself; introduce demand response (including demand response from prosumers); and set firm deadlines for time-of-day tariffs. These provisions harden the support for renewables, especially solar. This is a good thing and the paper supports it. However, this paper tries to point out that growth in renewables, without concomitant and adequate growth in storage, and without implementation of other net load smoothing policies, will add to grid stress.*

## I. BACKGROUND

A power grid has to perform a continuous balancing act. At every moment, the total electricity being produced (the ‘generation’) must match the total being consumed (the ‘load’). For most of its history, the central worry about the grid was whether there was enough generation capacity. Over the last decade, India has answered that question emphatically. It added generating capacity at remarkable speed, and built a large fleet of solar power, rising to over 157 GW by May 2026<sup>1</sup>.

*Figure 1: Source-wise electricity installed capacity trend (as on 31<sup>st</sup> May 2026)*



*Source: India Climate and Energy Dashboard, Niti Aayog*

That success, however, has quietly changed the nature of the problem. The share of solar in total installed capacity has increased from a meagre 2% in 2015-16 to 29% as of May 2026. Solar enjoys ‘first-run’/‘must-run’ status in India, as in other countries. Solar power is dispatched before other conventional sources like coal and gas. However, solar panels generate only when the sun shines. During non-solar hours, the conventional sources must respond to make up for the absent solar. The increasing penetration of solar demands an ever-increasing quantum and speed of this response. Therefore, the grid's challenge is now about when power is available relative to when it is needed. The question has shifted from quantity to timing and flexibility.

This paper examines that shift using electricity demand and generation data at 15-minute intervals (SCADA data) published by Grid-India's National Load Dispatch

<sup>1</sup> Physical Achievements, Ministry of New and Renewable Energy, <https://mnre.gov.in/en/physical-progress/>

Centre<sup>2</sup>, and the day ahead market price of power published at the same frequency by the Indian Energy Exchange. The paper uses both these data sources to describe the grid flexibility challenge. This challenge is presented in the context of recent legislative developments which seek to reshape the regulatory architecture governing electricity in India. The draft Electricity (Amendment) Bill, 2025 and the draft Electricity (Rights of Consumers) Amendment Rules, 2026 propose certain changes which speak directly to this paper’s analysis. One of the objectives of the paper is to better inform the discussion around these proposed changes.

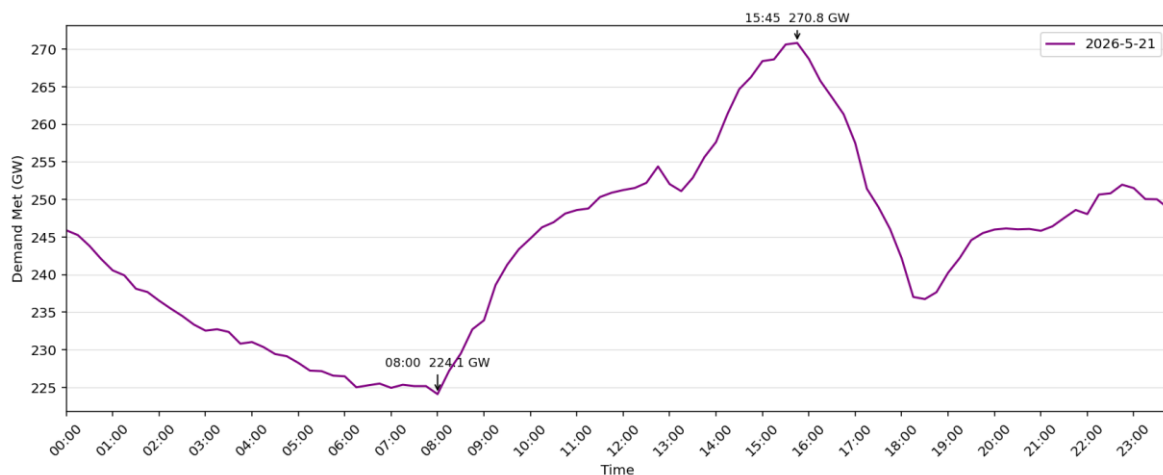
## II. A DAY ON THE INDIAN GRID

We start by looking at a single day on the grid, i.e. 21 May 2026. This is the day the Indian grid achieved its all-time high demand met (or load) record of 270.8 GW. The purpose of looking at a single day is to illustrate the concepts of ‘load’ (total demand met) and ‘net load’ (total demand met minus solar generation<sup>3</sup>) and how these two important metrics vary throughout the day. In Section III of the paper, we look at the shapes of these curves averaged over entire months and compare them over several years to discern the underlying structural changes.

### A. The Load Curve

**Figure 2** shows a snapshot of a single day on the Indian grid (21 May 2026), the day India set its all-time peak electricity demand record. The curve (called the ‘load curve’) shows how much electricity was consumed across India at each point (measured at 15-minute intervals) throughout the day.

*Figure 2: Load Curve for 21-May-2026*



*Source: SCADA data from National Load Despatch Centre, Grid India*

<sup>2</sup> GRID-INDIA (formerly POSOCO) has been operating the power system of the country through National Load Despatch Centre (NLDC) located at New Delhi and Regional Load Despatch Centres (RLDCs) located at New Delhi, Kolkata, Mumbai, Bengaluru and Guwahati/ Shillong.

<sup>3</sup> Net demand or net load means the total demand minus the output of solar and wind. However, to isolate the impact of solar on the grid, this paper defines net load as total demand minus solar output only.

At midnight, demand equals 245.9 GW. Thereafter, the curve drifts steadily downward as the country settles into sleep and only the unavoidable loads remain: street lighting, emergency services etc. The descent finally bottoms out at 8 AM, the lowest point of the entire day (224.1 GW).

From just after 8 AM the curve turns sharply upward. Offices open, factories start their shifts, and, most importantly, as the temperature climbs the air conditioners switch on across homes, shops and workplaces. Demand climbs almost without interruption through the morning and into the afternoon, easing only very slightly around 1 PM before pushing on to the maximum of the whole day, i.e. 270.8 GW at 3:45 PM, a level India's grid had never reached before. That is a swing of 46.7 GW from the morning low in under eight hours. To put that in perspective, it is larger than the highest demand met by the entire British grid at any moment in 2025<sup>4</sup>. Then comes a sharp and sustained fall. Between 3:45 PM and about 6:30 PM, as the workday comes to a close, demand drops by some 34 GW, down to a trough of 236.7 GW at 6:30 PM.

The pause is short. From the early evening demand begins climbing again, as crores of people return home, and switch on lights, cooling, and appliances. This evening rise pushes demand back up to a second peak of about 252 GW near 10:45 PM. Only after this does the curve begin its slow overnight descent, ending the day near 248.8 GW.

## **B. The Net Load Curve**

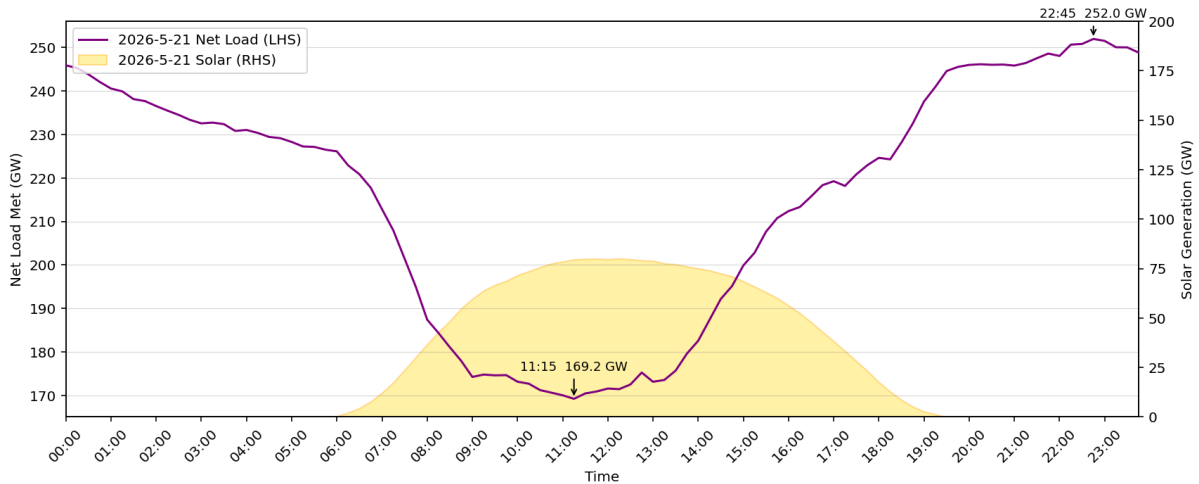
The load curve in the previous section shows the total electricity being consumed at any point of time during a day. But on any given day, a large portion of that demand is being met by solar panels. The incremental cost of this power is zero. Solar power in India is, by law, a 'first-run'/'must-run' generator, i.e. power from solar must be requisitioned first, and before other non-renewable sources<sup>5</sup>. This raises a natural question. Once you subtract solar from the total demand met, how much electricity does the rest of the power system, comprising mainly thermal, hydro and nuclear, need to provide at any given moment? The answer is what is called the net load. For this paper, we define net load as total demand minus solar output, ignoring wind, to isolate the impact of solar generation on the grid. **Figure 3** shows the net load curve for 21-May-2026, the same day for which we plotted the load curve above. Solar output is also plotted on the right-hand axis of the same graph.

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<sup>4</sup> Peak demand met on the UK grid in 2025 was 45.9 GW, as per historic demand data for 2025 available on the National Energy System Operator, UK website: [https://www.neso.energy/data-portal/historic-demand-data/historic\\_demand\\_data\\_2025](https://www.neso.energy/data-portal/historic-demand-data/historic_demand_data_2025)

<sup>5</sup> Central Electricity Regulatory Commission (Indian Electricity Grid Code) Regulations, 2023.

Figure 3: Net Load (Total Load minus solar) and Solar Output for 21-May-2026



Source: SCADA data from National Load Dispatch Centre, Grid India

The shape tells the central story of running a grid with a lot of solar on it. At midnight, net load sits at around 246 GW and drifts gently downward through the night, reaching roughly 226 GW by the early morning. In the dark, solar contributes nothing, and the net load (demand minus solar) is simply equal to total load. The whole of the country's night-time appetite falls on the conventional plants, i.e. thermal, hydro and nuclear.

Everything changes after about 6 AM. As the sun rises and climbs through the morning, solar panels across the country begin pouring power into the grid, and that supply is subtracted from what the rest of the system must provide. The net load curve plunges, dropping by roughly 50 GW in a few hours. It reaches the lowest point of the day, 169.2 GW, at 11:15 AM. This deep midday dip is the 'belly' of the curve, when the conventional plants are pushed into the background and solar is doing much of the work.

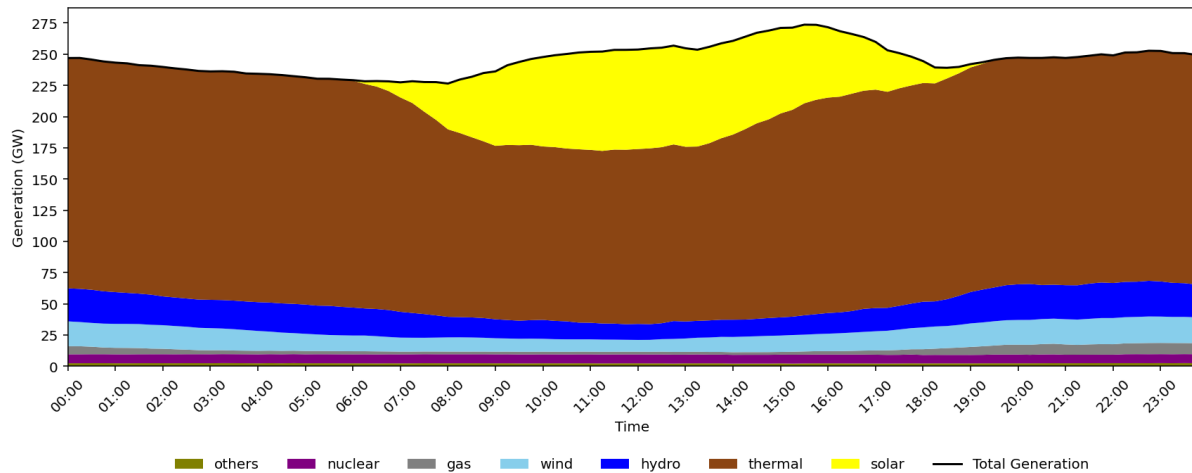
From the belly onward the curve only rises. Through the afternoon the sun weakens and solar output shrinks, so conventional plants must steadily pick up the slack. Then, after sunset, solar contributes nothing at all, and the evening surge in demand arrives. The two effects combine to drive the net load sharply upward to the peak of the entire day: 252.0 GW at 10:45 PM. It eases back only slightly to end the day near 249 GW.

Between the 11:15 AM trough and the 10:45 PM peak, the net load rises by about 83 GW in roughly eleven and a half hours. Solar pushes the midday demand on conventional plants very low, but it does nothing for the evening peak, which arrives precisely when solar has faded. The result is a deep midday dip followed by a steep evening climb, implying that the grid must quickly bring on tens of gigawatts of other supply.

## C. The Power Mix

**Figure 4** stacks up every source of electricity generation across the same day, 21 May 2026, so the height of each coloured band shows how much that source was contributing at any moment, and the black line on top is the total of everything combined.

*Figure 4: Contribution of different power sources in total generation on 21-May-2026*



*Source: SCADA data from National Load Despatch Centre, Grid India*

The first thing the chart makes plain is how much India still leans on thermal power (brown), which is mostly coal fired thermal power plants. It is the single biggest source at every hour without exception, supplying somewhere around 138 to 185 GW. Overnight, when no solar is available, thermal alone carries roughly three-fourths of the entire load.

Solar is the yellow band. It is completely absent at night, appears after sunrise, swells to a midday bulge of around 80 GW, and disappears again by evening. Notice what happens to the brown band underneath it during the middle of the day. Thermal visibly shrinks, dipping to its daily low around 11:15 A.M. This is coal generation being 'backed down' to make room for solar while the sun is high. As solar fades in the late afternoon, thermal climbs straight back up to meet the evening demand. The remaining sources, viz. wind, gas, hydro, and nuclear, are much smaller in comparison. The overall picture is therefore of a grid that runs on a large, always-on coal base, topped up by a big but strictly daytime contribution from solar, with hydro, wind, nuclear and gas filling supporting roles.

## III. THE SUMMER DUCK AND THE WINTER CAMEL

Section II looked at a single day to introduce the shapes that matter: the load, the net load (demand minus solar), and the generation mix. To see the structural picture, this section steps back and looks at the same patterns averaged over whole months, and tracks them across several years.

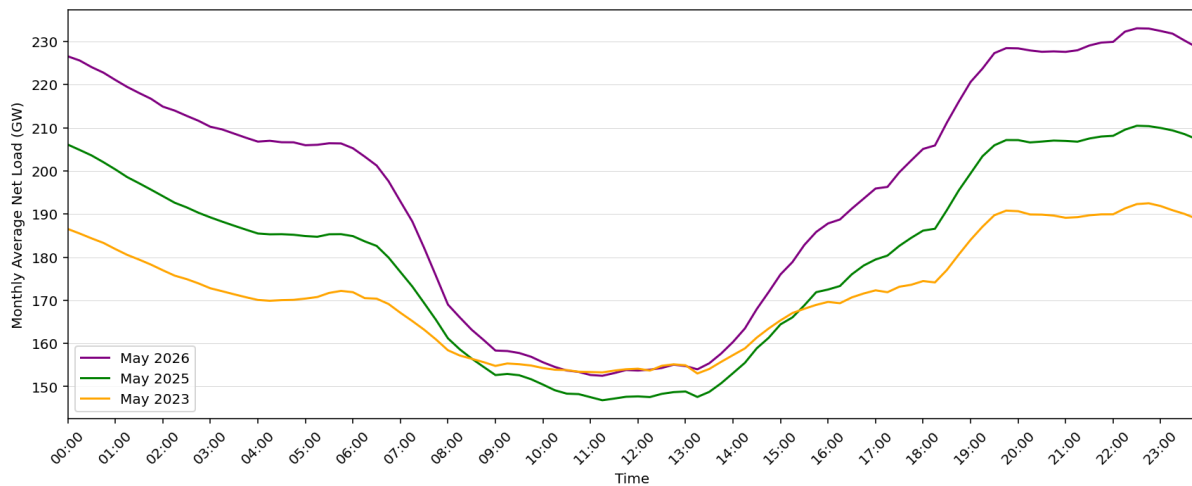
For each calendar month in a year, we build a single ‘average day’, a representative 24-hour profile for that month. The underlying data, obtained from Grid India’s SCADA database<sup>6</sup>, are at 15-minute resolution, meaning each day is described by 96 readings, one every quarter-hour. To form the average day for a month, we take a given quarter-hour slot and average the values at that slot across every day in the month. Repeating this for all 96 slots produces one ‘average day’ curve that captures the typical shape for that month while cancelling the noise of any individual day.

Electricity demand is strongly seasonal. Therefore, comparing, say, May with December would mostly reveal the weather rather than any real change in how the grid behaves. To isolate genuine year-on-year change, we compare the same calendar month across different years. Holding the season/month fixed in this way means the differences that remain reflect structural shifts rather than seasonal variation. Constructing the average day for a month, rather than for the whole year, helps preserve the seasonal properties of the net load.

### A. The summer net load: the duck

Comparing the shape of an average summer day across several years requires choosing years that are comparable. May 2024 was distorted by an exceptional, record-breaking heatwave. The all India mean temperature in May 2024 of 31.08 degrees Celsius was the 4<sup>th</sup> highest since 1901<sup>7</sup>. Therefore, we compare 2023, 2025 and 2026. **Figure 5** plots the net load curve for an ‘average’ day in May of each year.

*Figure 5: May Average Net Load (Total Demand minus Solar) comparison for 3 years – the ducks*



*Source: SCADA data from National Load Despatch Centre, Grid India, and authors’ calculations*

The first and clearest signal is steady demand growth, and it shows up most cleanly at night. In the non-solar hours net load is simply equal to demand, and here the three curves are evenly spaced: the midnight average climbs from about 187 GW in 2023 to

<sup>6</sup> Grid Controller of India, Daily Power Supply Position Reports, 15 Min (Instantaneous) All India Grid Frequency, Generation & Demand Met (Scada Data)

<sup>7</sup> India Meteorological Department, Climate Summary for May 2024

206 GW in 2025 to 227 GW in 2026, roughly 40 GW of growth across the span. The middle of the day behaves completely differently. One might expect the whole curve to rise by the same 40 GW. Instead, the midday trough, when solar generation is strongest, barely moves. It sits at about 153 GW in 2023, 147 GW in 2025, and 153 GW in 2026. The belly of the duck has stayed pinned near 150 GW from 2023 to 2026. The reason is solar. The extra electricity the country now draws in the middle of the day is being supplied almost entirely by the growing fleet of solar panels, leaving the conventional system with no more to do at noon than it did in 2023.

At the same time, the grid is being asked to work harder every year outside the solar hours. The steepening of both flanks of the duck can be measured directly. **Table 1** measures the two daily ramps the conventional fleet must perform: the morning ramp-down, as solar floods in between 6 AM and 11 AM and the evening ramp-up, between 1 PM and 8 PM, as solar withdraws. Both have grown dramatically across the three summers. The morning fall has nearly tripled, deepening from about 18 GW in 2023 to 53 GW in 2026. This means that conventional plants must now back down three times as much power, over the same five morning hours, as they did three years earlier. The evening climb has roughly doubled, from about 36 GW in 2023 to 74 GW in 2026. In both directions the grid is being asked to swing harder and faster every year.

*Table 1: Average net load ramp-up and ramp-down in May*

<b>Avg. Changes in Net Load (GW)</b>	<b>May-23</b>	<b>May-25</b>	<b>May-26</b>
<b>Ramp-down (6 AM to 11AM)</b>	-18.51	-37.35	-52.57
<b>Ramp-up (1 PM to 8PM)</b>	35.73	58.30	73.67

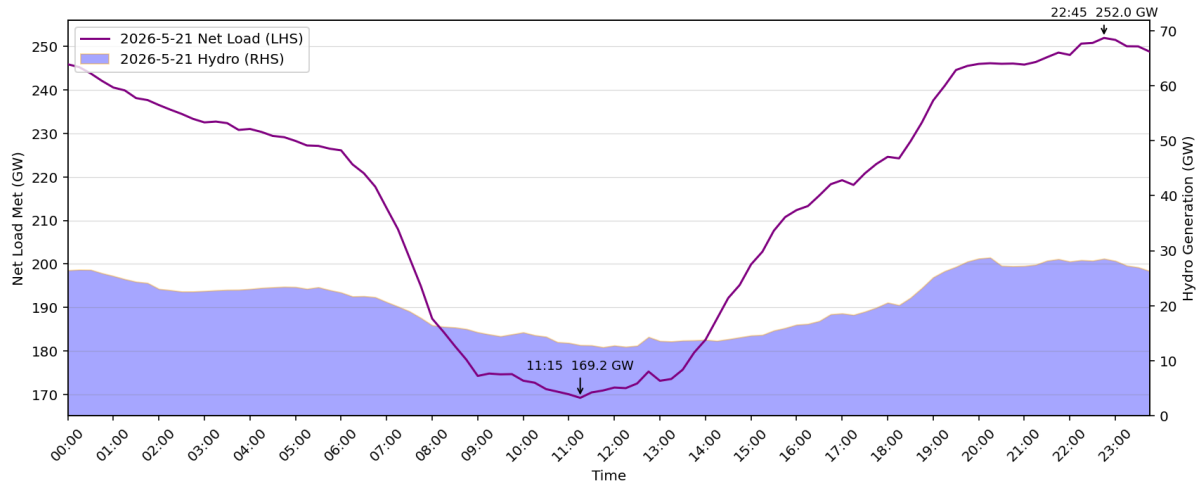
*Source: SCADA data from National Load Despatch Centre, Grid India, and authors' calculations*

Why does the increase in ramp-up and ramp-down rates matter? Coal-fired plants, which dominate India's conventional fleet, become costlier to run the further they operate below their maximum load<sup>8</sup>. Forcing them to follow the net-load, i.e. ramping down output through the morning as solar rises, then ramping it up between midday and the evening peak, is expensive. The legislation governing the flexible operations of coal plants is the Central Electricity Authority (Flexible Operation of Coal based Thermal Power Generating Units) Regulations, 2023. As per the regulations, coal based thermal power generating units shall have flexible operation capability with minimum power level (technical minimum load – TML) of forty percent. Coal plants that are not capable of achieving the TML of forty percent are required to do so in a phased manner. However, in practice, most generators have currently achieved a TML of fifty five

<sup>8</sup> Flexible Operation of Thermal Power Plant for Integration of Renewable Generation, Central Electricity Authority, January 2019

percent only<sup>9</sup>. This is why the grid leans on other sources (primarily hydro) to absorb the steepest parts of the net-load swing. Hydro is well suited to the task because it can change output quickly and at low cost, and because water can be held back and released on demand. **Figure 6** below makes this complementary role visible.

*Figure 6: Net load (Total Demand minus Solar) for 21 May 2026 with hydro (excluding pumped storage) on the right axis*



*Source: SCADA data from National Load Dispatch Centre, Grid India, and authors' calculations*

Movements in the blue hydro curve track the purple net-load curve closely across the whole day. Both sit high overnight, both fall through the morning as solar pushes net demand down to its midday trough, and both climb together through the afternoon. The clearest evidence is the evening ramp. Between roughly 5 pm and 8 pm, as solar fades and demand rises toward the evening peak, net load climbs steeply and hydro output is ramped up over the same window, rising from about 19 GW to 29 GW. The co-movement of the two curves, especially during the sharp evening transition, is direct evidence of hydro being dispatched to cover the technical and commercial limits of the coal fleet.

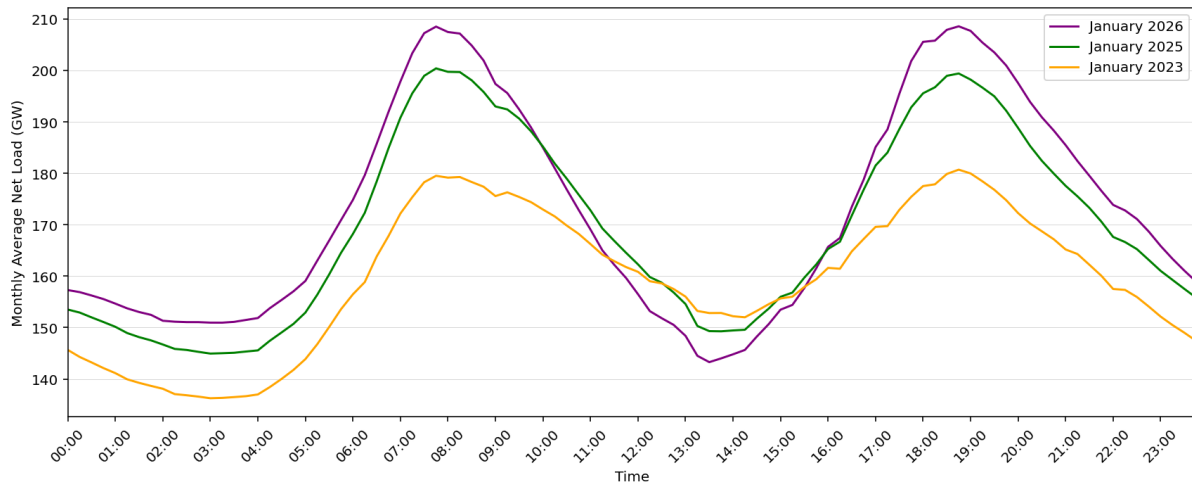
However, it must be noted that the hydro capacity being dispatched here (that excludes pumped storage) is drawn from a largely fixed and geographically concentrated resource base, and new large projects face long gestation periods alongside significant land, environmental, and rehabilitation constraints. Also, the role that hydro can play in following the net load during periods of low precipitation is limited. As solar penetration deepens, the net-load ramps that must be absorbed will grow both steeper and larger, and the hydro fleet cannot be expected to expand at a comparable pace. Therefore, hydro alone cannot be relied upon to perform this role at an ever-greater scale.

<sup>9</sup> Draft report of the Committee on Wear & Tear, O&M and Plant Lifespan Implications due to flexible operation, Central Electricity Authority, 2025

## B. The winter net load: the double humped Bactrian camel

Summer's net load curve was a classic duck, with one midday trough and one evening climb. Winter is different. **Figure 7** shows the average net load curve for the month of January in three years (2023, 2025 and 2026). As before, each point is averaged across every day of that January at that time of day. 2024 is ignored, as earlier, to maintain consistency. The resulting curve has two peaks with a dip between them, a shape closer to a double-humped Bactrian camel than a duck.

*Figure 7: January Average Net Load (Total Demand minus Solar) comparison for 3 years – the Bactrian camels*



*Source: SCADA data from National Load Dispatch Centre, Grid India, and authors' calculations*

As in summer, the whole curve has lifted with growing demand, and the lift is clearest at night. The midnight average rises from about 146 GW (2023) to 154 GW (2025) to 157 GW (2026). The two daytime humps rise even more sharply: the morning hump climbs from about 180 GW to 201 GW in 2025 and to 209 GW in 2026, and the evening peak from about 181 GW in 2023 to 200 GW in 2025 to 209 GW in 2026. Year on year, winter demand is growing at every part of the day.

The two humps come from winter's particular rhythm. The first builds before dawn, peaking around 7:45 AM, as the country wakes to the cold and switches on the heat and lights, and industry begins its day, all while the low winter sun contributes almost nothing. The net load then sinks into a midday trough, in the early afternoon, when the modest winter sun is at its strongest and the heating demand fades. Then, as the early winter darkness falls and solar vanishes entirely, the second hump builds to the day's evening peak, around 6:45 PM, driven by lighting and heating across homes.

The most striking change is what has happened to the midday trough. The trough has deepened steadily, year after year: from about 152 GW in 2023 to 149 GW in 2025 to 143 GW in 2026. But the deeper point is structural. In January 2023 the lowest average net load of the entire day occurred at night, around 136 GW and the midday dip, at 152 GW, sat well above it. By January 2026 this had inverted. The midday trough, now

around 143 GW, has fallen below the pre-dawn floor of about 151 GW. Solar has pushed the belly of the camel down beneath the night-time base.

The consequence is the familiar flexibility problem, but in winter the grid faces it twice a day. The evening climb has more than doubled in three years, from about 27 GW in 2023 to 50 GW in 2025 to 65 GW in 2026. And winter adds a second steep haul that summer lacks: the pre-dawn morning ramp, from the overnight floor up to the morning hump. The midday descent has also grown about two and a half times over, from roughly 25 GW in 2023 to 50 GW in 2025 to 64 GW in 2026, as a deepening solar dip pulls the net load further below the morning hump each year. The growing magnitude of these oscillations is captured directly in **Table 2** below.

*Table 2: Average net load ramp-up and ramp-down in January*

<b>Avg. Changes in Net Load (GW)</b>	<b>Jan-23</b>	<b>Jan-25</b>	<b>Jan-26</b>
<b>Morning Ramp-up (4 AM to 7.30 AM)</b>	41.31	53.44	55.45
<b>Morning Ramp-down (7.30 AM to 1.30 PM)</b>	-25.47	-49.69	-64.03
<b>Evening Ramp-up (1.30 PM to 6.30 PM)</b>	27.07	49.69	64.69
<b>Evening Ramp-down (6.30PM to 11:45 PM)</b>	-32.52	-43.20	-49.05

*Source: SCADA data from National Load Despatch Centre, Grid India, and authors' calculations*

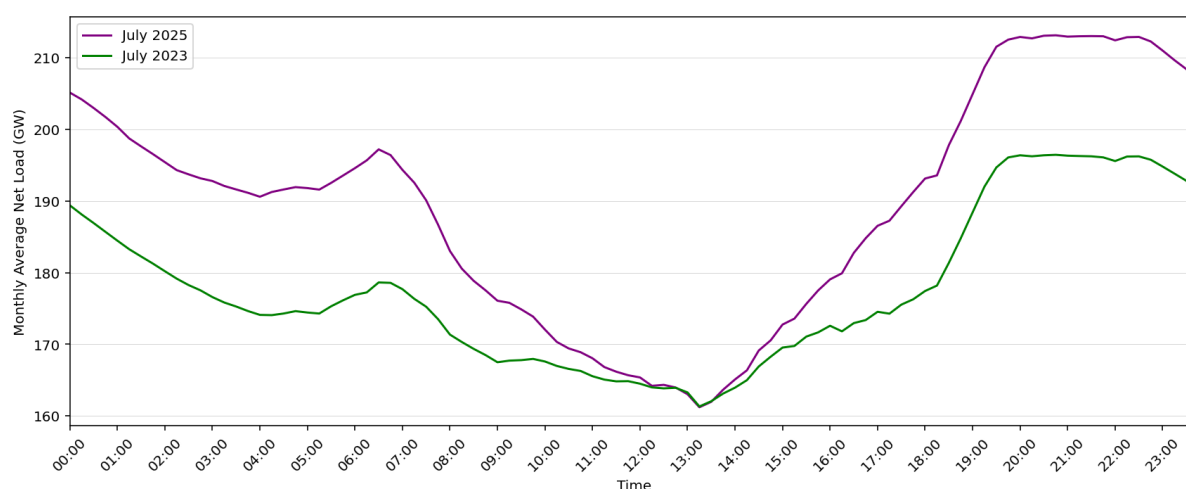
### **C. The monsoon net load**

The third of India's defining seasons is the monsoon. For this we use July, the first month in which the monsoon blankets the entire country for its full duration. Two recent comparable years anchor the comparison: 2023 (rainfall 13% above Long Period Average - LPA)<sup>10</sup> and 2025 (rainfall 5% above LPA)<sup>11</sup>. Data for July 2026 was not available at the time of writing this paper, and 2024 is ignored to maintain consistency with the rest of the analysis. The results are given in **Figure 8** below.

<sup>10</sup> India Meteorological Department, Climate Summary for the month of July, 2023

<sup>11</sup> India Meteorological Department, Climate Summary for the month of July, 2025

*Figure 8: July Average Net Load (Total Demand minus Solar) comparison for 2 years*



*Source: SCADA data from National Load Dispatch Centre, Grid India, and authors' calculations*

The monsoon day still has the shape of a duck rather than the winter camel. The July 2025 net load starts the day high, around 205 GW at midnight, eases to a pre-dawn floor near 190 GW, rises into a small morning shoulder around 6:30 AM, and then slides through the late morning to its lowest point of the day, about 161 GW, at around 1:15 PM. From there it climbs steadily to the day's maximum near 213 GW in the evening, around 8:45 PM, before settling back a bit to end the day at 207 GW.

But this is a noticeably flatter duck than the one summer produces, and that is the defining feature of the monsoon. The reason is cloud. Through the monsoon the sky is heavily overcast for much of the day, so the solar panels generate far less than they do under May's clear skies. With less solar to subtract, the midday dip is far less deep.

Even so, the impact of growing solar is visible from 2023 to 2025. Demand rose at almost every hour, yet the midday trough has remained the same at 161 GW. That can only be the work of solar meeting all the extra demand. The effect is that the evening climb grew from about 35 GW to 52 GW in two years: a 17 GW steepening.

For completeness, the monthly net load comparison plots for all months for the years 2023, 2025 and 2026 are placed at **Annexure-I**. The plots for the months from June to December have only two lines (2025 and 2023), while the others have three (2026, 2025, and 2023).

## **IV. THE PRICE, CURTAILMENT, AND SHORTAGE SIGNALS**

### **A. What the market price for electricity tells us**

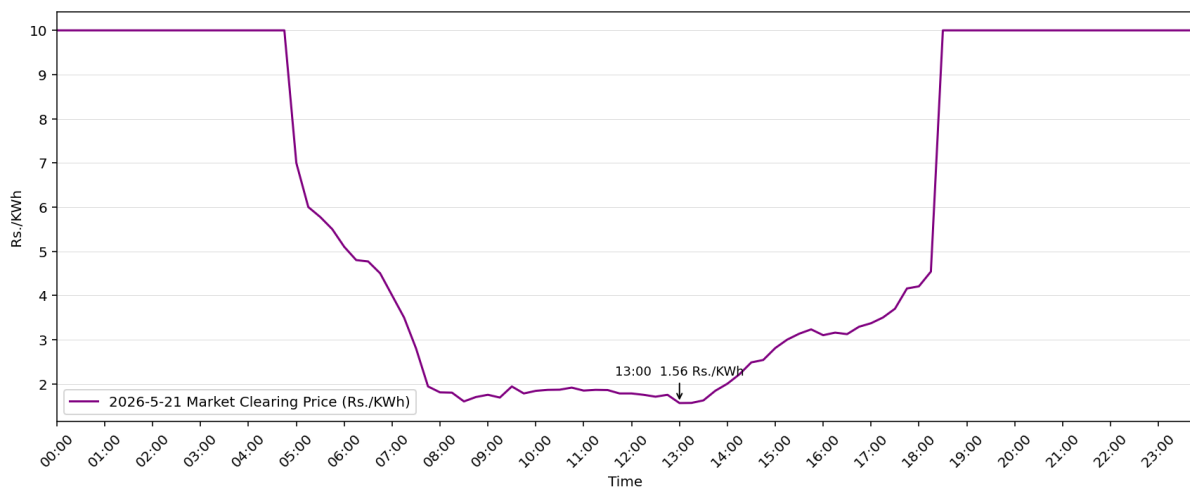
The clearest evidence that India's grid is now structurally constrained by the timing of solar generation is the price the day-ahead market settles at over the course of a single day. For the purpose of the analysis, this paper relies upon the market clearing price data from the Day Ahead Market (DAM) operated by the Indian Energy Exchange

(IEX), which publishes a settlement-block-level market snapshot for every day. Each day is divided into 96 fifteen-minute blocks, the same frequency as Grid India’s SCADA data, and for each block, the exchange reports the market clearing price<sup>12</sup>.

IEX is the largest of India's CERC-regulated power exchanges, accounting for a significant majority of the volumes exchanged<sup>13</sup>. The IEX DAM price series is analytically useful because it sits outside the contracting structure that delivers most of India's electricity. Roughly 85-90% of electricity generation is supplied either under long-term contracts (e.g. Power Purchase Agreements) or short-term intra-state transactions. The short-term power exchange market is the residual layer<sup>14</sup>. Because participation is voluntary and prices are free to move, the MCP is the cleanest available signal of where the supply-demand balance actually sits.

To understand the price movements, we plot the Market Clearing Price (MCP), reported as Rupees/KWh, for the same date for which we started the analysis in this paper, i.e. 21-May-2026. This is shown in **Figure 9** below.

*Figure 9: Day Ahead Market (DAM) Clearing Price on IEX for 21-May-2026*



*Source: Day Ahead Market (DAM) data from the Indian Energy Exchange*

Two features dominate the curve. From midnight until 5:00 AM, and again from 6:30 PM through the end of the day, the clearing price sits at Rs 10/kWh, the binding price ceiling on the IEX day-ahead market<sup>15</sup>. It would almost certainly have cleared higher were the ceiling not capping it. For roughly six hours in between, from about 7:45 AM to 2:00 PM, the price collapses below Rs 2/kWh, bottoming at the day’s minimum of Rs 1.56/kWh at 1:00 PM, when solar is flooding the grid. The energy market spends the day at one of two extremes, rock-bottom while the sun is up, and pinned to the ceiling once it sets. Another point worth noticing is that the demand record on this day, i.e. 21

<sup>12</sup> Indian Energy Exchange, Day Ahead Market Snapshot, <https://www.iexindia.com/market-data/day-ahead-market/market-snapshot>

<sup>13</sup> Report on Short Term Power Market In India, CERC, 2023-24

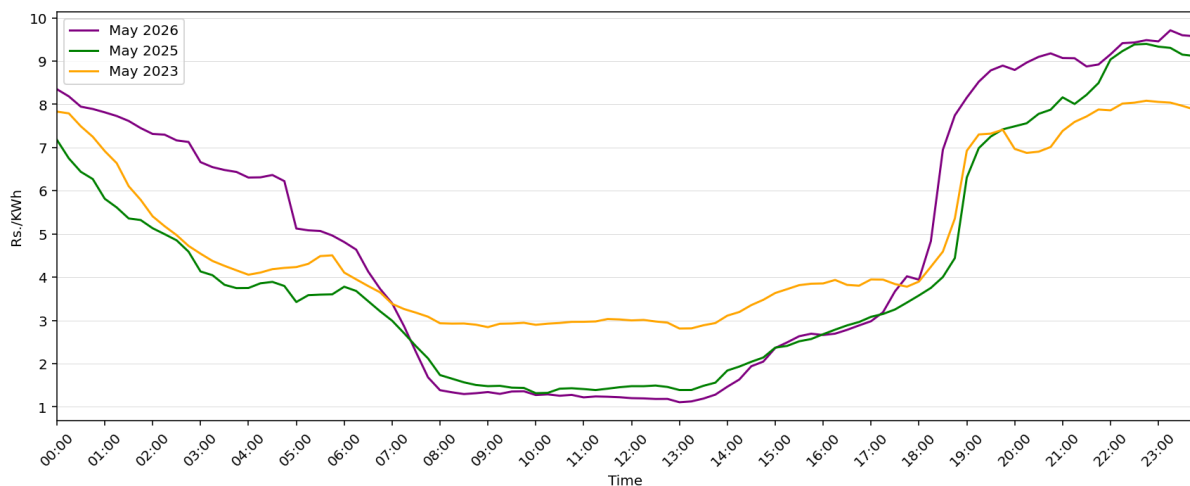
<sup>14</sup> Ibid.

<sup>15</sup> CERC order dated 31.03.2023 in Petition No. 04/SM/2023 (suo-motu)

May 2026, was set at 3:45 PM (see **Figure 2** above), yet the price at that moment was only about Rs 3/kWh, because solar was still generating. The price does not hit the ceiling until 6:30 PM, after solar fades. So peak demand and peak price fall at different times of day.

This shape is not an artefact of a single day. To establish this empirically, we looked at the monthly average DAM prices for May, the peak summer month, and compared them for several years, similar to the methodology described earlier in the paper for net load. **Figure 10** settles the question by overlaying the monthly average market clearing price for May 2023, May 2025 and May 2026: the same calendar month in three different years, with each curve representing the average price at each fifteen-minute settlement block taken across all days of that month.

*Figure 10: May Average DAM Price on the IEX – 3 year comparison*



*Source: Day Ahead Market (DAM) data from the Indian Energy Exchange and authors' calculations*

Three observations follow. First, the duck shape of the average price curve is consistent across years, almost replicating the shape of the net-load curve. This is not the behavior of any single day. It is the average behavior of the market across an entire month, replicated across three separate years. The day-on-day aberrations wash out and the structural pattern remains.

Second, the solar-hour trough is deepening in prices too. The lowest average price during solar hours has fallen from Rs 2.81/kWh at 13:00 in May 2023, to Rs 1.32/kWh at 10:00 in May 2025, to Rs 1.11/kWh at 13:00 in May 2026, a decline of over 60% in three years. The market is signaling, in unambiguous terms, that the system already has more solar generation at midday than it knows what to do with.

Third, the evening peak is climbing. The daily peak in the May monthly average has risen from Rs 8.08/kWh in 2023 to Rs 9.40/kWh in 2025 to Rs 9.71/kWh in 2026. As a consequence, the peak-to-trough spread within a single average day has widened from Rs 5.27/kWh in 2023 to Rs 8.60/kWh in 2026, a 63% increase in absolute terms. This

can be seen even more clearly in **Table 3** below. The spreads would undoubtedly have been even higher had it not been for the 10 Rs/KWh price cap imposed by CERC with effect from April 2023.

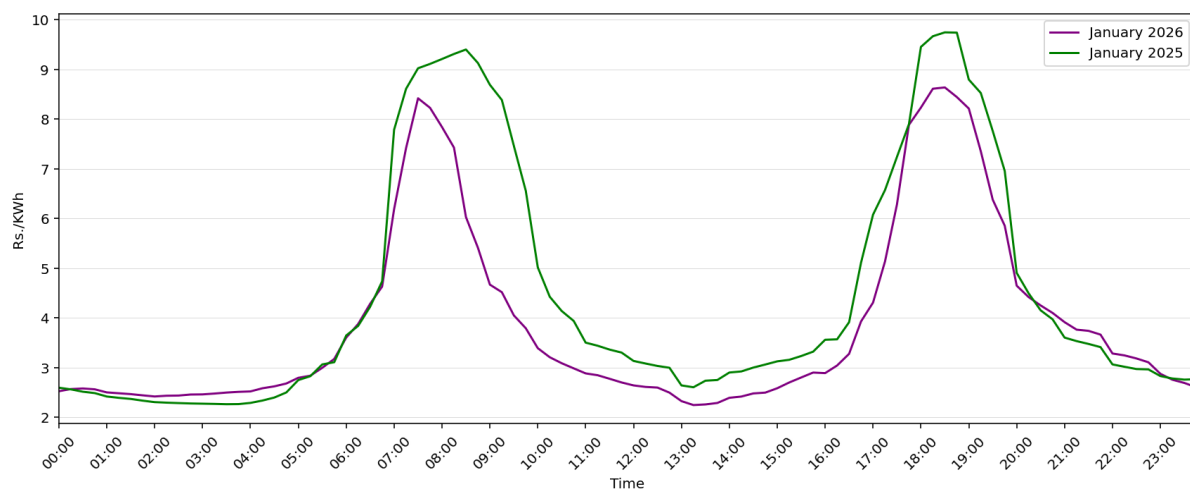
*Table 3: The average spread (max minus min) on the DAM-IEX for May*

Month	Minimum Price	Maximum Price	Spread	Max to Min Ratio
May-23	Rs 2.81 (at 13:00)	Rs 8.08 (at 22:45)	Rs 5.27	2.9
May-25	Rs 1.32 (at 10:00)	Rs 9.40 (at 22:45)	Rs 8.08	7.1
May-26	Rs 1.11 (at 13:00)	Rs 9.71 (at 23:15)	Rs 8.60	8.8

*Source: Day Ahead Market (DAM) data from the Indian Energy Exchange and authors' calculations*

A similar analysis was done for winter (January) for the years 2026 and 2025. 2023 is ignored because the price ceiling changed in April, 2023. 2024 is ignored to maintain consistency with the earlier analysis. The results are in **Figure 11** below.

*Figure 11: January Average DAM Price on the IEX – 2 year comparison*



*Source: Day Ahead Market (DAM) data from the Indian Energy Exchange and authors' calculations*

Where the summer price curve falls once after sunrise and climbs once into the evening, the January curve rises to a sharp morning peak (around 7:30–9:30 AM), dips through the middle of the day, and climbs again to an evening peak (around 6:30–7:00 PM). This is the price-market equivalent of the winter double humped Bactrian camel net-load curve. Just like the belly of the duck, the belly of the camel is also deepening year on year. The lowest average daytime price has fallen from ₹2.60 in January 2025 to ₹2.24 in January 2026. Solar is increasingly making its presence felt at midday even in winter. The net effect is that the winter intraday spread remains substantial, even if, unlike summer, it has not widened. Another point to notice is that in January 2025 the day's lowest price was still at night (₹2.26 at 03:30), a little below the midday low (₹2.60). By January 2026 the midday low (₹2.24) fell below the night low (₹2.42), so the cheapest power of the day is now at noon. This further establishes that solar is increasingly making its presence felt at midday, even in winter.

What the seasonal analysis in the above paragraphs means in practical terms is direct. The arbitrage value of moving a kilowatt-hour from the middle of the day to the evening has increased sharply and is widening for every season with every passing year. The duck and the camel have become the dominant feature of the wholesale price signal too, and this signal is hardening every year.

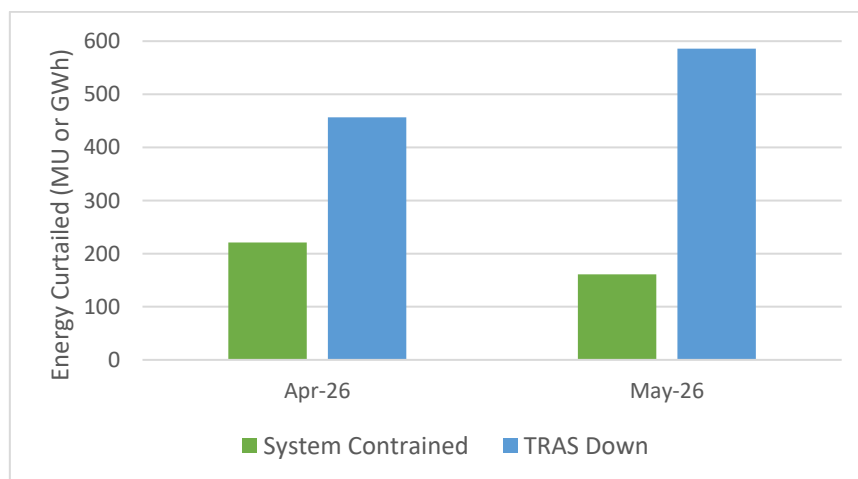
## B. The absurdity of solar curtailment

Solar and wind power in India is, by law, always requisitioned first followed by requisition from other sources. However, the instances of solar curtailment, i.e. an involuntary reduction of a generator's output, are on the rise. There are primarily two types of solar curtailment:

- a. **System-constrained curtailment:** A real-time instruction from a dispatch center telling a solar plant to back down immediately, because the network physically cannot take its output and allowing the solar output to come on to the grid would push the frequency to dangerously high levels. E.g. when midday demand is low relative to all the solar being generated.
- b. **Tertiary Reserve Ancillary Service (TRAS) - Down:** The same physical act of withholding solar energy, but routed through a formal bidding mechanism created under the CERC (Ancillary Services) Regulations, 2022. Here the system operator calls on plants that have opted in to reduce their output within fifteen minutes, and the plants are compensated as per the clearing price.

The quantum of both types of solar curtailment for April and May 2026 is shown in **Figure 12** below:

*Figure 12: Solar Curtailment in 2026 – System constrained and TRAS*



*Source: Grid-India NLDC Daily Renewable Energy Management Centre (REMC) / VRE Reports*

Combined monthly curtailment climbs from about 677 MUs (million units or Gigawatt hours) in April 2026 to 747 MUs in May. On an average May day, around 24 GW hours of solar energy were curtailed, under both mechanisms put together. To put this in

perspective, Delhi's total per day electricity consumption in 2023-24 was around 90 GW hours<sup>16</sup>. Therefore, the extent of solar curtailment in May amounted to throwing away electricity that could have powered more than a quarter of the nation's capital for a typical day in May. And the grid does this only hours before straining to meet its evening peak.

### C. Shortages in solar hours and non-solar hours

The third signal is shortage. Across the sixty-one days from 01 April 2026 to 31 May 2026, the pattern of solar-hour peak and non-solar hour peak shortages is strikingly asymmetric.

The grid fell short of meeting the solar-hours' peak demand only on 6 of 61 days (10%). The largest solar-hour peak shortage in the entire two-month window was 516 MW on 26 April 2026, roughly 0.2% of the load at that instant. Non-solar-hour shortages, by contrast, occurred on 36 of 61 days (59%), with much larger magnitudes, e.g. peak shortages of 5,405 MW on 24 April 2026 at 10:34 P.M. (2.25% of peak load) and 4,243 MW the following day at 10:39 P.M. (1.76% of peak load)<sup>17</sup>. This is also consistent with some recent coverage of India's power supply position in the mainstream media. E.g. Business Standard reported on 3 June 2026 that while India's solar has eased daytime demand, the night time shortages persist<sup>18</sup>.

## V. THE REGULATORY AND POLICY CONTEXT

The preceding sections diagnose a grid whose defining problem is the timing and flexibility of generation. That diagnosis arrives at a moment when the regulatory foundation of the sector is itself being re-laid. The draft Electricity (Amendment) Bill, 2025 proposes the most substantial changes to the Electricity Act, 2003 in over a decade. Reading them with the draft Electricity (Rights of Consumers) Amendment Rules 2026, this paper identifies six proposals which speak directly to the flexibility problem. This section sets out each in turn and identifies what the Bill says, what it means, and how it changes the position from the law as it stands.

### A. Enshrining energy storage in the law

The most direct response to the flexibility problem is to give legal standing to storage systems. At present, the Electricity Act does not mention storage at all. The Bill changes this in two steps. First, it inserts a definition. Proposed **clause 2(26a)** reads:

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<sup>16</sup> Delhi State Profile, India Climate and Energy Dashboard (<https://iced.niti.gov.in/state-report/delhi>) and authors' calculations.

<sup>17</sup> Grid Controller of India, Daily Power Supply Position Reports

<sup>18</sup> Business Standard, 03 June, 2026, [https://www.business-standard.com/industry/news/solar-power-india-grid-gaps-storage-evening-shortages-126060300625\\_1.html](https://www.business-standard.com/industry/news/solar-power-india-grid-gaps-storage-evening-shortages-126060300625_1.html)

*(26a) ‘Energy Storage System (ESS)’ means a system to store electrical energy in any form for a period of time and delivering it as electrical energy when required.*

Second, and more consequentially, it writes storage into the definition of ‘power system’ itself. Power systems are the set of facilities (e.g. generation, transmission, and distribution) the Act recognises as the working machinery of the grid. Proposed **clause 2(50)(k)** adds ‘energy storage system’ to the existing list of power systems in the Act. This is in line with the best international practices. E.g. the United Kingdom in 2023, amended its Electricity Act of 1989 to clarify that electricity storage is a distinct subset of generation, and defined storage as energy that was converted from electricity and stored for the purpose of its future reconversion into electricity. The stated purpose of the amendment was to remove ambiguities and provide long term clarity and certainty over the treatment of storage within the existing frameworks (e.g. planning and licensing) and possible future frameworks.<sup>19</sup>

The significance in the Indian context is that storage ceases to be a legal orphan. Once an energy storage system is part of ‘power system’ it can be planned, licensed, scheduled, regulated and remunerated as a normal element of the grid. The Bill’s own Comparative Statement lays down the importance of energy storage systems:

*Energy Storage Systems facilitate complete utilization of variable renewable energy from solar and wind sources by storing surplus energy for use during periods of low generation. They significantly enhance grid stability by balancing supply and demand, reduce peak deficits through peak shifting, and support essential ancillary services. Additionally, they allow utilities to optimize operations by capitalizing on price fluctuations in the electricity market. This leads to lower electricity costs, reduced carbon emissions, and plays a crucial role in meeting energy transition goals.*

## **B. Deepening the market for power – ‘Contracts for Difference’**

The bulk of India’s electricity is sold under long-term power purchase agreements at fixed schedules, outside the exchange. Only the residuary power is traded on the market. The Bill’s amendment to **Section 66** is aimed at widening the market’s reach, depth and the variety of instruments it supports. It substitutes the existing provision with the following:

*66. The Appropriate Commission shall promote the development of a market (including trading) in power and may introduce and regulate market platforms, intermediaries, market products including non-transferable specific delivery*

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<sup>19</sup> Energy Security Bill Factsheet, Defining electricity storage, <https://www.gov.uk/government/publications/energy-security-bill-factsheets/energy-security-bill-factsheet-defining-electricity-storage>

*contracts for difference, in such manner as may be specified and shall be guided by the National Electricity Policy referred to in section 3 in this regard.*

***(Proposed amendments in bold)***

The Explanatory Note accompanying the Bill sets out the reasoning. India is targeting 500 GW of non-fossil generating capacity by 2030 and around 2,000 GW by 2047, a build-out on a scale that distribution companies, signing long-term power purchase agreements one contract at a time, cannot realistically finance on their own. The Note points to the experience of the United Kingdom and the European Union, where renewable capacity has been expanded through market-based mechanisms rather than bilateral contracting alone. One such mechanism is a ‘*contract for difference*’. It is an arrangement in which a generator and a buyer agree a fixed reference price for power (the strike price); if the market price settles below, the buyer tops the generator up, and if it settles above the generator refunds the difference. The effect is to give the generator a predictable revenue, a structure widely used to finance renewable capacity in the United Kingdom<sup>20</sup>.

This paper makes the additional point that a richer market also incentivizes flexibility. Storage, demand response and fast-ramping are precisely the resources whose value lies in the intraday price spread the paper has measured. A market confined largely to long-term energy contracts gives them little to monetise. Empowering the regulator to design market products is one of the institutional preconditions for the storage build-out.

### **C. A statutory obligation to buy non-fossil power, and a penalty for default**

The third provision works on the demand side. The Bill recasts **Section 86(1)(e)**, under which the State Commissions set the share of a distribution company’s supply that must come from clean sources. The revised clause requires the State Commissions to:

*86(1)(e) promote co-generation and generation of electricity from **renewable non-fossil** sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution licensee, **which shall not be less than such percentage as may be prescribed by the Central Government.***

***(Proposed amendments in bold)***

Two shifts are embedded here. First, the obligation is widened from “renewable” to “non-fossil” sources, a broader category that takes in nuclear and other non-fossil sources. Second, and more importantly, it establishes a national floor. A state regulator may set a higher target but it can no longer set a target lower than the one that the Centre prescribes. The Explanatory Note explains that enforceable non-fossil consumption

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<sup>20</sup> <https://www.gov.uk/government/collections/contracts-for-difference>

obligations already exist under the Energy Conservation Act, 2001, but the Electricity Act “does not contain matching provisions”; the amendment aligns the two statutes so that “a national uniform mandate” drives all obligated entities toward the same goal.

The obligation is given teeth by a new penalty. **Section 142**, which presently provides no specific consequence for falling short of the purchase obligation, gains a sub-section (2):

*142(2). Notwithstanding anything contained in sub-section (1), where the Appropriate Commission is satisfied on a complaint filed before it or otherwise, that a person has not consumed power from non-fossil sources of energy as specified under clause (e) of sub-section (1) of section 86, the Commission shall after giving such person an opportunity of being heard, by order in writing, direct that, without prejudice to any other penalty to which he may be liable under this Act, such person shall be liable to pay a penalty of a sum calculated at a rate of not less than thirty-five paise per kilowatt-hour and not more than forty-five paise per kilowatt-hour for default.*

The Comparative Statement at the end of the bill notes that at present the Electricity Act does not provide for a specific penalty in cases of non-compliance with the Renewable Purchase Obligation (RPO). This has made enforcement difficult and has limited the effectiveness of the RPO framework. To address this gap, it is proposed to introduce a monetary penalty for shortfall in RPO compliance. This is aimed at ensuring stricter compliance, promoting genuine procurement of renewable energy, and reinforcing the integrity of the RPO mechanism.

This provision belongs in the paper’s narrative for a specific reason. A binding, nationally-floored non-fossil obligation will pull still more solar and wind onto the grid, which sharpens the flexibility problem. Each additional gigawatt of solar deepens the midday trough and steepens the evening ramp, unless it is accompanied by the storage and flexibility that allow its output to be used after dark. The law is hardening the duty to buy clean energy while signalling an intention to build the storage and the markets required to absorb it effectively on the grid. The two aspects will need careful calibration and oversight in the times to come.

#### **D. Demand response**

The Electricity (Rights of Consumers) Rules, 2020 contained no concept of demand response at all. The draft Amendment Rules of 2026 insert one. A new clause in the definitions, **Rule 2(1)(ga)**, reads:

*(ga) ‘Demand Response’ means managing electricity demand on the grid by encouraging consumers to shift their electricity usage to periods when supply is high or demand is low, using price signals or financial incentives;*

A new **Rule 17** requires regulators to build the machinery to implement demand response:

*17. Implementation of Demand Response.- The Commission shall specify a framework for the implementation of Demand Response. Such framework may include eligibility criteria for Demand Response Providers, incentives for participating consumers, software and system requirements, communication protocols, and procedures for measurement, verification and financial settlement.*

The Explanatory Note to the draft Amendment rules frames demand response squarely in the terms of the flexibility problem. It states that such programmes “*help consumers actively manage and optimize their electricity usage by shifting or reducing demand during peak hours in response to price signals or system conditions,*” which “*reduces the need for costly peak power procurement by DISCOMs*” and “*will also support better integration of renewable energy by balancing variability in generation.*” This is the demand-side counterpart to storage. The paper has shown that the grid’s sharpest stress is the evening climb on the conventional fleet and the after-dark shortage that follows it. Demand response attacks the same gap from the other end, by incentivizing consumers to move load out of the evening peak and into the solar hours. Where the 2020 Rules were silent, the draft gives the regulator both a definition to act on and an explicit mandate to design the eligibility, incentive, metering and settlement framework that a working demand-response market requires. Since the draft rules are yet to be notified, the framework is yet to be laid down.

#### **E. Time-of-day tariffs: a firmer deadline**

The clearest regulatory answer to this paper’s wholesale-price evidence is the time-of-day tariff, which charges the consumer different rates at different times so that the bill reflects the very different cost of power at noon and at night. The draft rules substitute the existing **Rule 8A**, setting a firmer deadline:

*(8A). Time of Day Tariff.- The Time of Day tariff for Commercial and Industrial consumers with a maximum demand exceeding ten Kilowatts shall be implemented no later than 1st April, 2027 and for all other consumers, excluding agricultural consumers, the Time of Day tariff shall be made effective from the date specified by the State Commission, but no later than 1st April, 2028.*

As the Explanatory Note records, time-of-day pricing already applies in principle to commercial and industrial consumers above 10 kW “*from 1st April, 2024, and for all other consumers (excluding agriculture) from 1st April, 2025*”, but its spread has been tied to the rollout of smart meters. Because “*nationwide installation is expected to be completed by April, 2028,*” the draft resets the deadlines to 1 April 2027 for commercial and industrial consumers and not later than 1 April 2028 for the rest.

## F. Getting prosumers to help solve the timing problem

The draft rules begin to turn the prosumer, a consumer who also generates (E.g. rooftop solar), into a grid participant that can help correct the timing problem. It substitutes **Rule 11(4)** and, for the first time, links the prosumer to time-of-day pricing and storage:

*11(4).....Provided also that in the case of Prosumers availing net-billing or net feed-in, the Commissions may introduce time-of-the-day tariffs whereby Prosumers are incentivised to install energy storage for utilization of stored solar energy by them or feeding into the grid during peak hours thus helping the grid by participating in demand response of the Discoms.*

The shift from earlier is substantial. The 2020 Rules simply provided net metering for loads up to a certain threshold and gross metering for loads above it. They did not ask the prosumer to do anything about when its solar reached the grid. The draft changes the objective. By tying net-billing and net-feed-in prosumers to a time-of-day tariff, it gives them a reason to hold their midday surplus in a battery and release it during the evening peak, which is precisely the shift from the overfull midday to the deficient evening that the rest of the paper argues for.

In fact, the draft rules go one step beyond incentives. A new **Rule 11(4A)** gives the regulator the power to mandate storage at the larger distributed installations:

*(4A) Energy Storage: The State Commission may mandate the installation of energy storage system of appropriate capacity by the Prosumer where installed capacity of renewable energy generation unit exceeds five hundred kilowatts.*

There was no equivalent power in the 2020 Rules. The Explanatory Note explains the reasoning and grounds it in cost:

*“Integrating energy storage can shift surplus solar power to evening hours, enhance grid stability, and reduce operational stress on DISCOMs....., with the declining cost of battery energy storage systems, integration of such systems with rooftop installations above 500 kW has become economically viable.”*

This is the distributed-scale version of the storage argument the paper makes at grid scale. A megawatt-class rooftop or campus solar plant paired with storage stops adding to the midday glut and instead delivers into the evening, the hours when the grid is genuinely short.

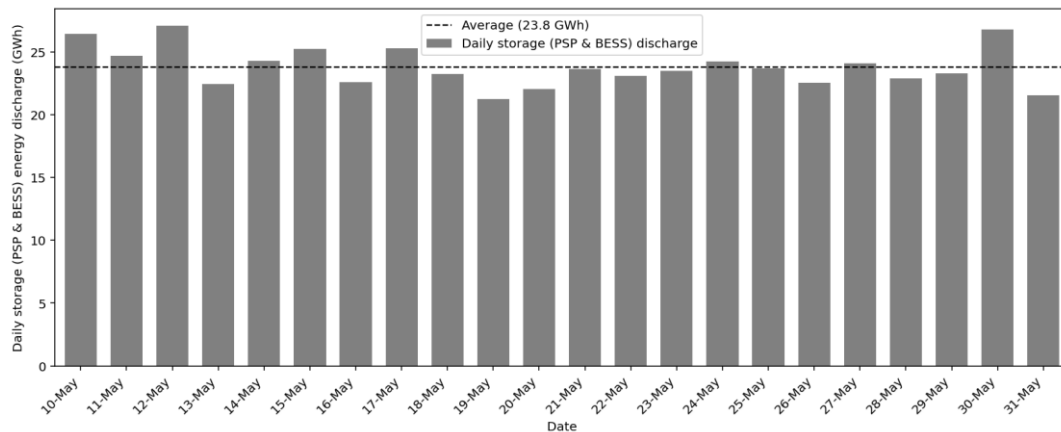
## VI. THE STORAGE CHALLENGE

As is evident, storage is the most direct response to the problem the data has identified. The arithmetic is clear. The summer evening ramp on the conventional fleet has grown from about 36 GW (May 2023) to 74 GW (May 2026), more than double in three years. Even at the conservative end, flattening only a single summer day’s evening ramp by

half would require storage discharge of **130 GWh** over the 1 pm to 8pm evening ramp (see **Annexure-II** for methodology).

To measure this against the current Indian storage output, we again rely upon Grid India’s SCADA data. From 10 May 2026 onwards, the data includes daily power output from storage (pumped storage and batteries), at the same 15-minute frequency. These numbers are converted from MW to GWh, summed across the day, and reported in **Figure 13** below:

*Figure 13: Daily storage (PSP & BESS) energy discharge from 10-May-26 to 31-May-26*



*Source: SCADA data from National Load Despatch Centre, Grid India, and authors’ calculations*

Across 10–31 May 2026, the combined pumped-storage and battery fleet discharged an average of about 23.8 GWh per day, within a narrow band of roughly 21 to 27 GWh, with little day-to-day trend. Set against the storage discharge (130 GWh) required merely to halve the evening ramp over the 13:00–20:00 window on an average day in May, the comparison is stark. Storage today operates at a scale that is useful at the margin but far short of the task of materially reshaping the net-load curve. Closing that gap would require a storage build-out many times larger than the fleet now in operation.

The large gap in storage is also corroborated by the Central Electricity Authority’s (CEA) reports. The CEA’s National Electricity Plan of 2022-23 envisioned a storage requirement of 16.13 GW (7.45 GW of pumped storage plants – PSPs, and 8.68 GW of batteries) in 2026-27. The target can be measured against recent performance. As per CEA’s Long-Term National Resource Adequacy Plan (2026-27 to 2035-36), the installed capacity of BESS was about 0.27 GW as on 31<sup>st</sup> January 2026, and the installed capacity of PSP was about 7.2 GW. Therefore, while pumped hydro has very nearly reached its mark, the gap in achieving the battery target remains large. However, significant additions in India’s BESS capacity have been reported during recent months,

increasing the capacity to 2.7GW<sup>21</sup>. A large gap still remains, and India's storage shortfall is, at this stage, primarily a battery shortfall.

Closing this gap need not depend only on new storage capacity. India's existing installed solar capacity, about 157 GW as of May 2026, is contracted largely through plain vanilla power purchase agreements under which generators supply power only as and when it is generated. As solar penetration rises, the midday curtailment grows, even as the evening peak remains unserved. There may be a case for an enabling framework under which willing generators and Discoms may convert existing solar contracts into contracts for storage-backed supply extending into evening hours. Such conversion could preserve the underlying contractual terms, with the incremental storage priced through transparent and competitive means. Co-locating batteries at existing plants carries natural advantages, since land, connectivity, and transmission infrastructure are already in place.

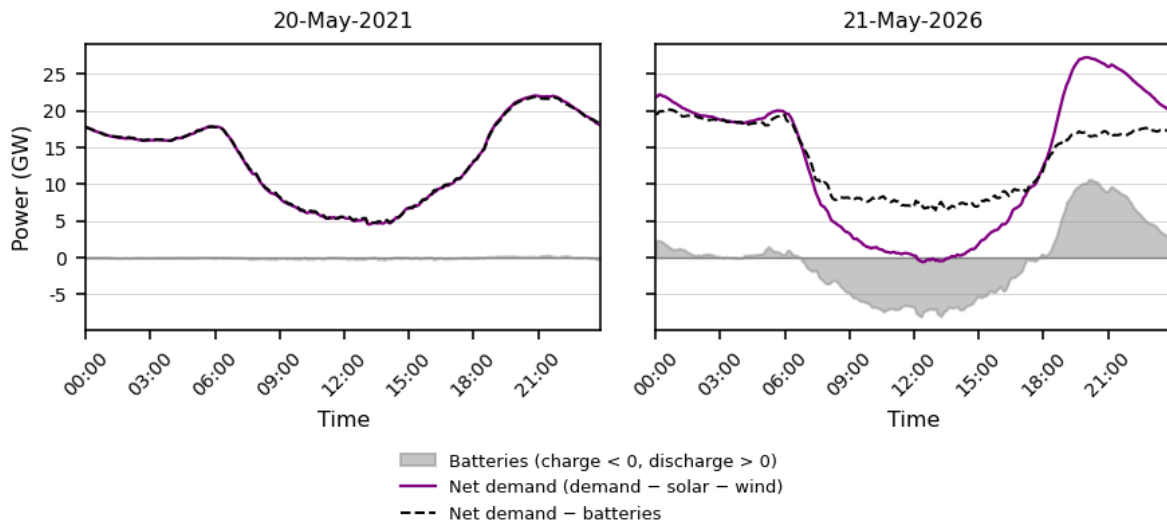
The impact of the storage shortfall, if it persists, on grid stress, will only worsen over time. The two forces driving the steepening of the ramp, evening peak load and daytime solar output, are both strengthening. More solar without more storage sharpens the evening problem. Each additional gigawatt of panels deepens the midday glut, pushing more clean power into curtailment at the peak solar hours, while doing nothing to serve the evening peak, which the conventional fleet must still cover by ramping up ever harder and faster. The morning and evening ramps will keep steepening, forcing thermal plants to cycle up and down more violently each year, a mode of operation that raises their running costs, accelerates wear, and increases the stress on the grid.

The grid from where the term 'duck curve' originated, i.e. the California ISO (CAISO), presents a live example of how battery storage has helped solve this problem. The two panels of **Figure 14** compare two days in May five years apart (20 May 2021 and 21 May 2026) each showing CAISO's net demand (system demand less solar and wind generation), net demand minus batteries (the same curve after netting out battery output), and the battery fleet's charging and discharging.

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<sup>21</sup> India's battery storage capacity gathers pace as power demand stays robust: HSBC, The Hindu Business Line, 30 June, 2026

Figure 14: The net load on the California grid – without storage (left panel) and with storage (right panel)



Source: California ISO

In 2021 the battery line scarcely departs from zero, the fleet neither charges nor discharges more than about 0.3 GW, and the two net-load curves (the normal net-load curve and the one after deducting battery discharge) lie on top of one another. By 2026 the battery fleet is large enough to charge at up to 8.0 GW and to discharge at up to 10.7 GW, and the two curves separate sharply.

The battery fleet is put to two distinct uses on the same day, and each reduces the steepness of the ramps. Through the middle of the day, when solar generation drives net demand down, the batteries charge and absorb the surplus. This lifts the trough of the load that the rest of the generation fleet must follow at midday from 0 GW to 6.8 GW, and it shallows the morning descent. The stored energy is then returned in the evening. As solar output fades and demand rises, the fleet discharges, cutting the evening peak that conventional generators must serve from 27.2 GW to 16.7 GW. Across the day the battery fleet stores 55 GWh during the midday hours and returns 45 GWh in the evening. Consequently, the evening up-ramp loses roughly a third of its original steepness.

It is worth mentioning that storage did not make the underlying net-demand curve itself less steep. Between 2021 and 2026 the growth of solar deepened the midday trough and steepened both ramps of net demand itself. What the battery fleet changes is the curve that conventional generators (thermal, hydro etc.) actually experience (net demand minus batteries). By charging into the midday solar glut and discharging into the evening peak, it converts an evening swing of nearly 28 GW in net demand into 10 GW, one that the conventional fleet can manage much more easily. This is the capability that India's grid will increasingly require as its own solar capacity expands.

## VII. CONCLUSION

This paper has argued, and the data has shown, that the defining problem of the Indian grid is no longer how much electricity the country can generate, but when it can generate it and how fast it can change what it generates. The binding constraint has shifted from capacity to flexibility. Three market signals confirm the diagnosis: (a) the intraday price spread between the solar hours and the non-solar hours has widened to a peak-to-trough ratio approaching nine, held back only by the market's price ceiling; (b) the grid's failures to meet demand rise overwhelmingly in the non-solar hours, relative to solar hours; and (c) solar energy is curtailed in volume because it cannot be used at the moment it is produced. The curtailment figures are striking: the average per day solar curtailment for May 2026 was equivalent to throwing away electricity that could have powered more than a quarter of Delhi for an entire day.

The most direct remedy is to store energy when it is abundant and release it when it is scarce, complemented on the demand side by time-of-day tariffs and demand response that move load toward the solar hours. The gap between need and provision of storage is the greatest, and it is overwhelmingly a battery gap. Grid-scale battery deployment remains well short of the national target, even as pumped hydro has very nearly reached its mark. The recent build-out in storage is significant, but a lot more is still required. That a large-scale battery build-out can effectively flatten net-loads is not merely conjecture. The California grid, with a battery fleet large enough to discharge over 10 GW, charges into the midday surplus and discharges into the evening, converting an evening net-load swing of nearly 28 GW into about 10 GW, adjusted for battery discharge. This is precisely the capability India will need as its solar fleet expands.

Encouragingly, the regulatory foundation is already being re-laid. The draft Electricity (Amendment) Bill, 2025, read with the draft Electricity (Rights of Consumers) Amendment Rules, 2026, write energy storage into the Act and into the definition of 'power system' itself. In addition, it directs the regulator to deepen the power market, including through contracts for difference; converts the renewable-purchase obligation into a nationally-floored non-fossil obligation backed by a monetary penalty; introduces demand response; sets firm deadlines for time-of-day tariffs; and begins to enlist the prosumer in demand response, with the power to mandate storage at larger renewable installations of prosumers.

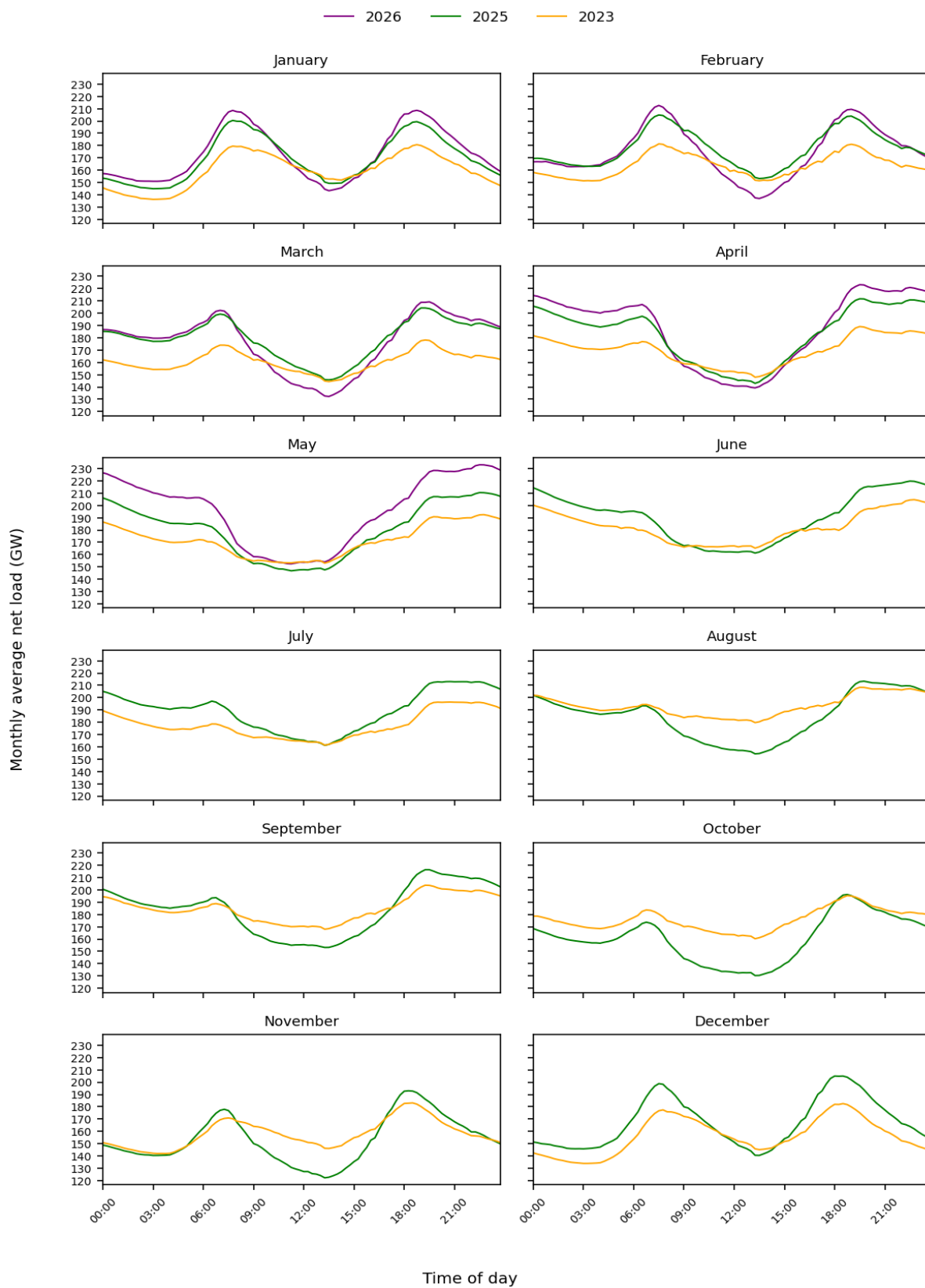
A caution remains. The provisions of the draft Electricity (Amendment) Bill, 2025, and the draft Electricity (Rights of Consumers) Amendment Rules, 2026 harden the support for renewables, especially solar. This is a good thing and the paper supports it. However, this paper tries to point out that growth in solar, without concomitant and adequate growth in storage and without implementation of other net load smoothing policies, will add to grid stress.

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## ANNEXURE-I

### Monthly average net load comparison plots for 2023, 2025 and 2026



Source: SCADA data from National Load Dispatch Centre, Grid India, and authors' calculations

## ANNEXURE-II

This note sets out the methodology used to estimate the storage capacity that would be required to halve the evening net-load ramp observed in the May 2026 monthly-average net-load curve. It is an approximation, not an exact estimate.

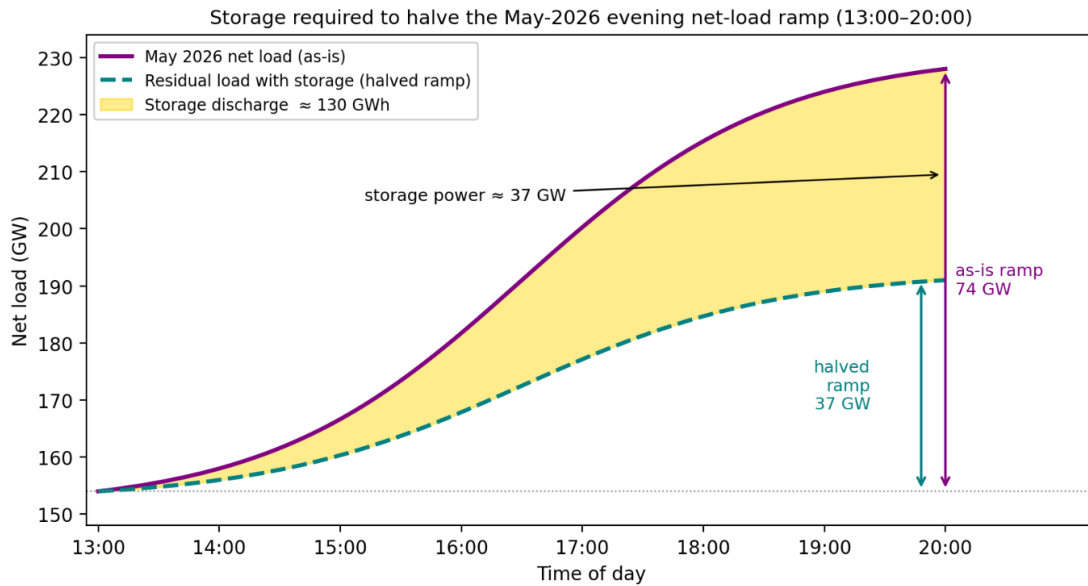
For the May 2026 average day, the ramp window is taken as **13:00 to 20:00 (seven hours)**, consistent with the window discussed in the main paper, with the net load rising from a midday trough of **154 GW** to an evening peak of **228 GW**, a ramp of:

$$\Delta P = 228 - 154 = 74 \text{ GW over } T = 7 \text{ hours.}$$

The objective is to reduce this ramp **by half**, so that the residual load seen by dispatchable generation rises by only **37 GW** over the same window (from 154 GW to 191 GW). The shortfall is met by discharging storage, which is charged earlier in the day from the midday solar surplus. It is assumed that storage is lossless.

Storage discharge is assumed to be zero at the start of the window (13:00) and to grow to its maximum (37 GW) at the end (20:00). This is illustrated in Figure A1 below. The slopes of the curves are illustrative, not actual.

*Figure A1*



The energy to be delivered by the desired storage system is the time-integral of the storage discharge over the window, which is the shaded area between the as-is and residual curves in Figure A1. Approximating the discharge as a linear rise from 0 to 37 GW over seven hours gives a triangle, whose area is:

$$\text{Energy} = \frac{1}{2} \times \text{Power} \times T = \frac{1}{2} \times 37 \text{ GW} \times 7 \text{ h} = 129.5 \text{ GWh} \approx \mathbf{130 \text{ GWh.}}$$

This is equivalent to a system able to deliver 37 GW for an effective duration of about three and a half hours ( $129.5 \text{ GWh} \div 37 \text{ GW} \approx 3.5 \text{ h}$ ).