June 2024

Charles Worringham || IEEFA Contributor

India Feels the Heat: Wet-bulb Temperature Closely Tracks Power Demand

- *Power demand increases substantially on hotter, humid days, reflecting the demand for air conditioning and fans, while also increasing (though much less) on colder, drier days when the demand for heaters is higher.*
- *The Northern Region showed a disproportionately high increase in demand in the last 12 months considered in this analysis, relative to the preceding year, on hot and humid and (to a lesser extent) cold and dry days, than on those with moderate temperatures.*
- *In the 12 months preceding 22 June 2024, Delhi's year-on-year peak demand growth was 3.8 times higher at 711 megawatts (MW) on the hottest and most humid days than on days with moderate temperatures (growth of 188MW). At the other end of the temperature scale, on cold and dry days, the increase was smaller but still significant at 506MW, or 2.7 times higher than the growth on moderate days.*

Executive Summary

India witnessed a sizeable jump in temperature-related electricity demand in the last 12 months (up to 22 June 2024). IEEFA's latest analysis uses an estimate of wet-bulb temperature. In simple words, wet-bulb temperature can be thought of as a combined measure of temperature and humidity, which is closely related to how well humans can tolerate the conditions. Wet-bulb temperatures above 35 degrees Celsius have been considered impossible to survive in for more than a few hours. Yet, studies increasingly predict temperatures exceeding this threshold in various parts of the world. One of the key takeaways from this analysis is that power demand is lowest on moderate days, but it increases substantially on hotter, humid days, reflecting the demand for air conditioning and fans, while also increasing (though much less) on colder, drier days when the demand for heaters is high. Moreover, wet-bulb temperature also strongly predicted the demand increase last year. In addition, the Northern Region showed a similar disproportionately high increase in demand in the last 12 months, relative to the preceding year, on hot and humid and (to a lesser extent) cold and dry days.

Given that heatwaves might well become the norm, the burden of power generation cannot be borne solely by thermal plants, which are already operating close to peak capacity. Scaling up utility-scale solar growth is the need of the hour and must be undertaken rapidly.

Introduction

As Delhi and north India reel from days of sweltering heat and emergency treatment of severe heat illness in India's capital draws the attention of the world media, the relentless growth in electricity demand for cooling becomes evident again.

A year ago, IEEFA's "The Heat of the Moment" analysis drew attention to the superior prediction of power demand for the Delhi (NCR) sub-division and the Northern Region by daily minimum temperatures (minima) rather than daily maximum temperatures. Speculating that high minima may interfere with sleep and, therefore, be closely related to cooling demand, the analysis also emphasised the shift to peak demand increasingly occurring in the afternoon hours, when solar's contribution to the grid is close to maximum.

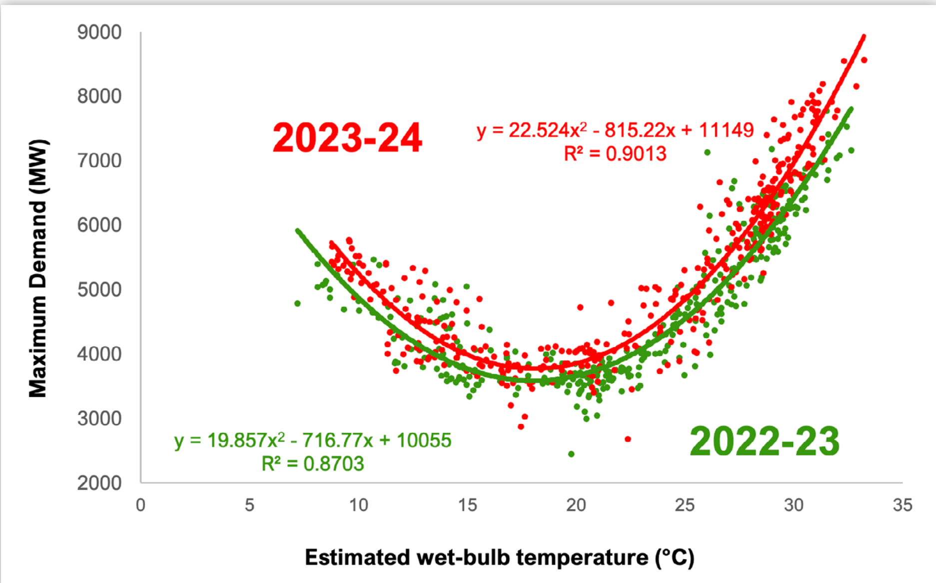
This year, our focus is on the sizeable jump in temperature-related electricity demand in the last 12 months (up to 22 June 2024), evident from the comparison of daily demand patterns with those for the corresponding period a year earlier.

Wet-Bulb Temperature Analysis

Unlike our earlier use of minimum and maximum temperatures, this new analysis uses an estimate of wet-bulb temperature (WBT) – the lowest temperature that can be reached through evaporation in the given conditions. By combining measures of temperature and humidity, it acts as an important index for human health – wet-bulb temperatures above 35 degrees Celsius (°C) have been considered impossible to survive in for more than a few hours. However, some recent studies put that threshold lower, at 31°C.

Power demand is even more closely related to this index than to the daily minimum temperature in both Delhi and India Grid's Northern Region. In the last 12 months, 90% of the variation in daily peak electricity demand for Delhi was accounted for by WBT temperature. In the corresponding period a year earlier, that igure was 87%.

Figure 1: Delhi's Electricity Demand in Relation to Wet-Bulb Temperatures



Source: Electricity data – Grid India Daily Reports. Meteorological data – Safdarjung Airport Station, New Delhi, The Weather Company. Estimated WBT = average temperature – average dewpoint depression/three for each day. Data are for all days between 23 June 2022 – 22 June 2023 (2022-23), and for 23 June 2023 – 22 June 2024 (2023-24), except for missing data on isolated days.

The chart plots power demand against WBT temperature, with cooler and less humid days to the left and hotter, more humid days to the right. Each dot represents a single day, and the solid curves represent each year's temperature-demand relationship (using the best-fitting second-order polynomial to describe each curve mathematically).

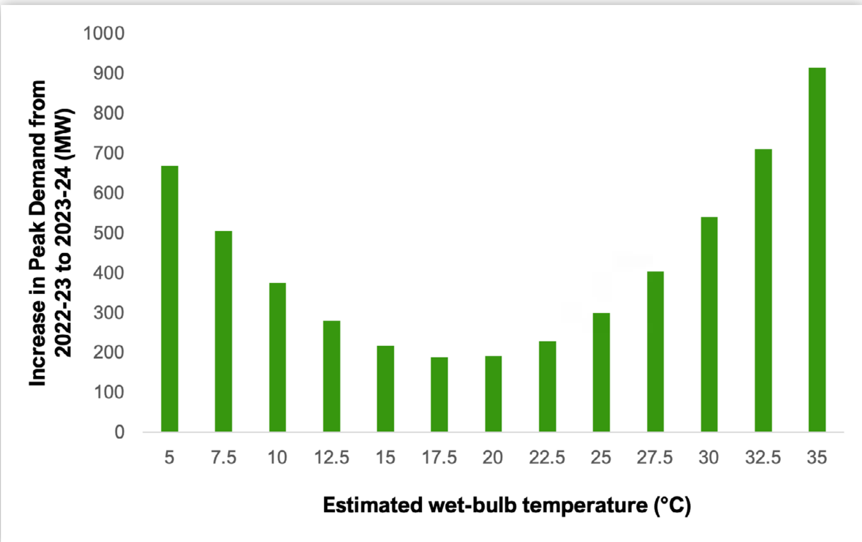
There are five key takeaways rom this comparison.

First, the J-shape shows that power demand is lowest on moderate days (e.g. 17.5°C WBT, but it increases substantially on hotter, humid days (e.g. above 30°C WBT), reflecting the demand for air conditioning and fans while also increasing (though much less) on colder, drier days when the demand for heaters is high.

Second, there has been a marked increase in the number of very hot and humid days (with 30°C or above WBT). In this analysis, there were 24 such hot and humid days in 2022-23, which jumped to 40 days in the 12-month period just completed. This increase may be just chance, and deeper analysis is needed to establish if the trend is robust. Nevertheless, the levels directly threatening human health have been surpassed far more often in this heatwave, leading one national newspaper to call for treating such prolonged summers as natural disasters. Cooling on such days is no luxury. It is life-saving and reliably meeting electricity demand becomes paramount.

Third, although power demand in the 12 months just ended is higher compared with the preceding 12 months overall, the growth in demand is itself closely related to WBT temperature. This is shown in the second chart, in which each bar shows the increase in demand from last year to this year (in other words, the difference between the curves for each year in the first chart. On moderate days (17.5°C WBT, Delhi's peak demand grew by a modest 188 megawatts (MW), but on the hottest and most humid (using 32.5°C WBT as a criterion), the annual increase was 3.8 times higher at 711MW. At the other end o the temperature scale, the increase was smaller on very cold and dry days (7.5°C WBT but still significant at 506MW, or 2.7 times higher than the increase on moderate days. These figures suggest that Delhi's recent power demand growth can largely be attributed to cooling and heating, with more year-round factors (such as those related to economic growth) playing a far smaller role.

Figure 2: Delhi's Peak Demand Increase at 13 Different WBTs



Source: Derived from curves in the preceding chart.

What holds true for peak demand (the highest rate of electricity consumption – in MW) applies just as much to the total amount of electrical energy supplied across the whole day – in megawatt-hours (MWh). In fact, for the last 12 months, WBT temperature also explained 90% of the daily variation in total "energy met" for Delhi, slightly higher than the 90% figure for peak demand. (The data patterns closely resemble those for peak demand, so separate charts are not included.)

Finally, because Delhi sits in a region of northern India where most areas tend to experience similar weather conditions, WBT estimated from just one site in New Delhi (Safdarjung) was only slightly less accurate as a predictor of peak demand (85% of daily variation) and total energy (89%) in the grid's entire Northern Region, encompassing seven states from Punjab to Uttar Pradesh, two Union Territories and the National Capital Region.

In addition, the Northern Region also showed a disproportionately high increase in demand in the last 12 months considered in this analysis, relative to the preceding year, on hot and humid and (to a lesser extent) cold and dry days than on those with moderate temperatures, albeit with smaller relative differences than for Delhi. For peak demand, the year-on-year increase at 32.5°C WBT was 2.8 times higher than that at 17.5°C WBT, and for 7.5°C WBT, it was about 1.8 times higher than for such moderate days. The increase in total "energy met" was 2.9 times higher than that for 17.5°C WBT, while for 7.5°C WBT the increase was about the same as that for 17.5°C WBT. Estimates using localised meteorological data across the region would be more sensitive to differences and more informative.

Conclusion

What do these trends say about India's energy transition? After all, the challenge of meeting demand created by cooling is widely known. But with the national capital and the northern region now in the eye of brutal heatwaves and heavily reliant on importing power at such times, it would be justified to accord priority to an effective and rapid transition.

The burden cannot realistically be borne only or even primarily by thermal plants. Now operating much closer to peak capacity than in recent years, they have much less headroom to boost generation further during heat emergencies. Scaling up utility-scale solar growth is essential and can be undertaken more rapidly than adding thermal capacity. Acceleration of the rooftop solar programme to increase generation close to loads may become not just desirable but a key component in a series of measures to supply additional power, especially in urban areas. In rural areas, there is still place for locally controlled distributed renewable energy (DRE) to ease the burden on grid power.

On the demand side, moderating the growth rate in power demand will be seen not just as a desirable long-term goal but also as an urgent one. This should include a higher priority for challenging yet vital projects such as the Centre's Building Energy Efficiency Programme and other state-level initiatives to improve energy efficiency, as well as encouragement of demand-side management initiatives through more flexible tariffs or other incentives. Load-shedding may sometimes be unavoidable, but it is the bluntest tool of all for managing demand.

Finally, this year's heatwave-driven power demand should remind us that electricity shortage at critical times can no longer be thought of as an inconvenience. Rather, it needs to be seen as a potential threat to life. In that light, redoubling efforts to finance and expedite the clean energy transition are more important than ever.

About IEEFA

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

About the Author

Charles Worringham

Dr Charles Worringham is closely tracking India's energy transition and is a guest contributor with IEEFA. Formerly an academic at QUT in Brisbane and the University of Michigan working on movement disorders and movement neuroscience, Dr Worringham taught multiple courses including research methods and statistics, and supervised several PhD students.