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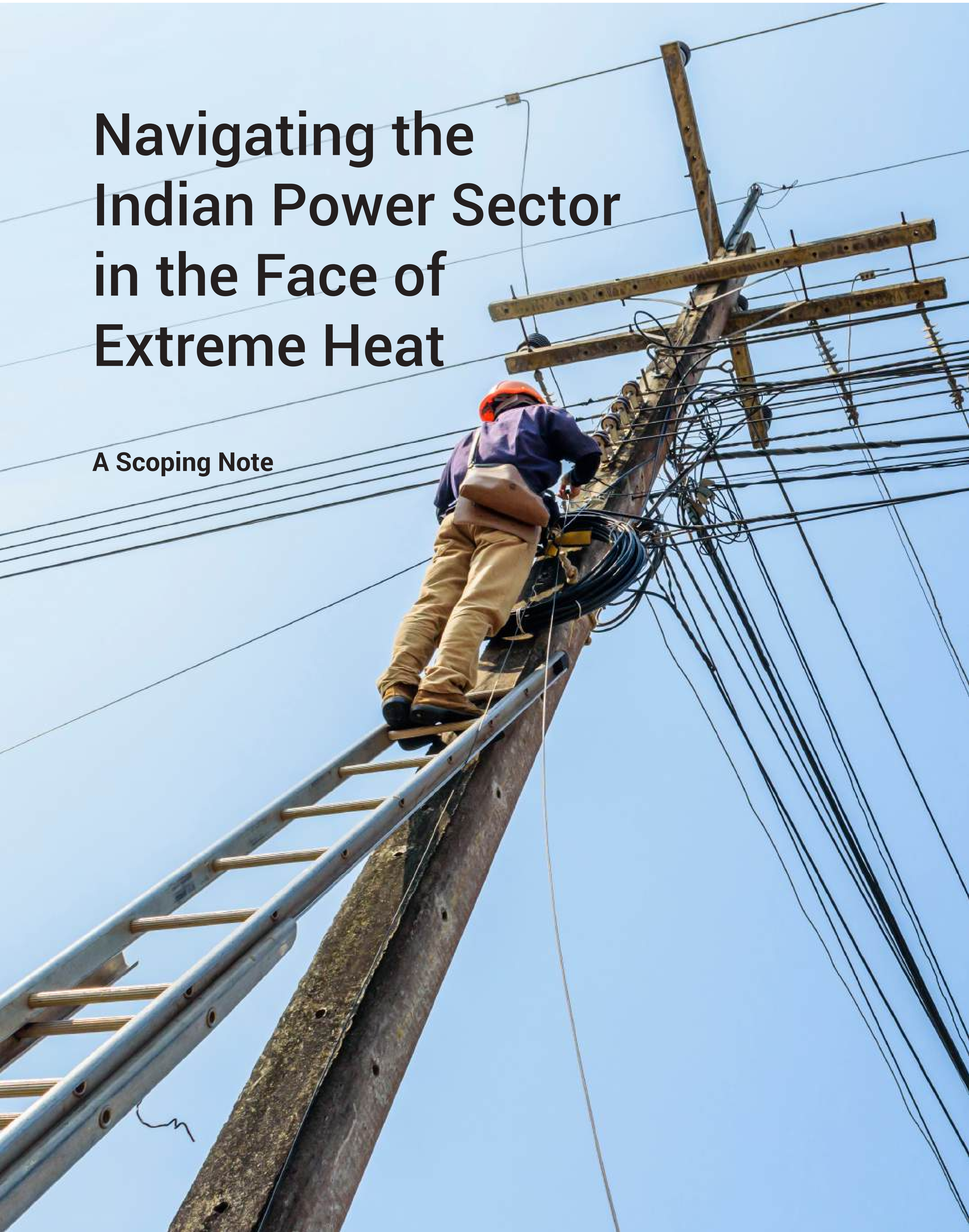

# Navigating the Indian Power Sector in the Face of Extreme Heat

## A Scoping Note

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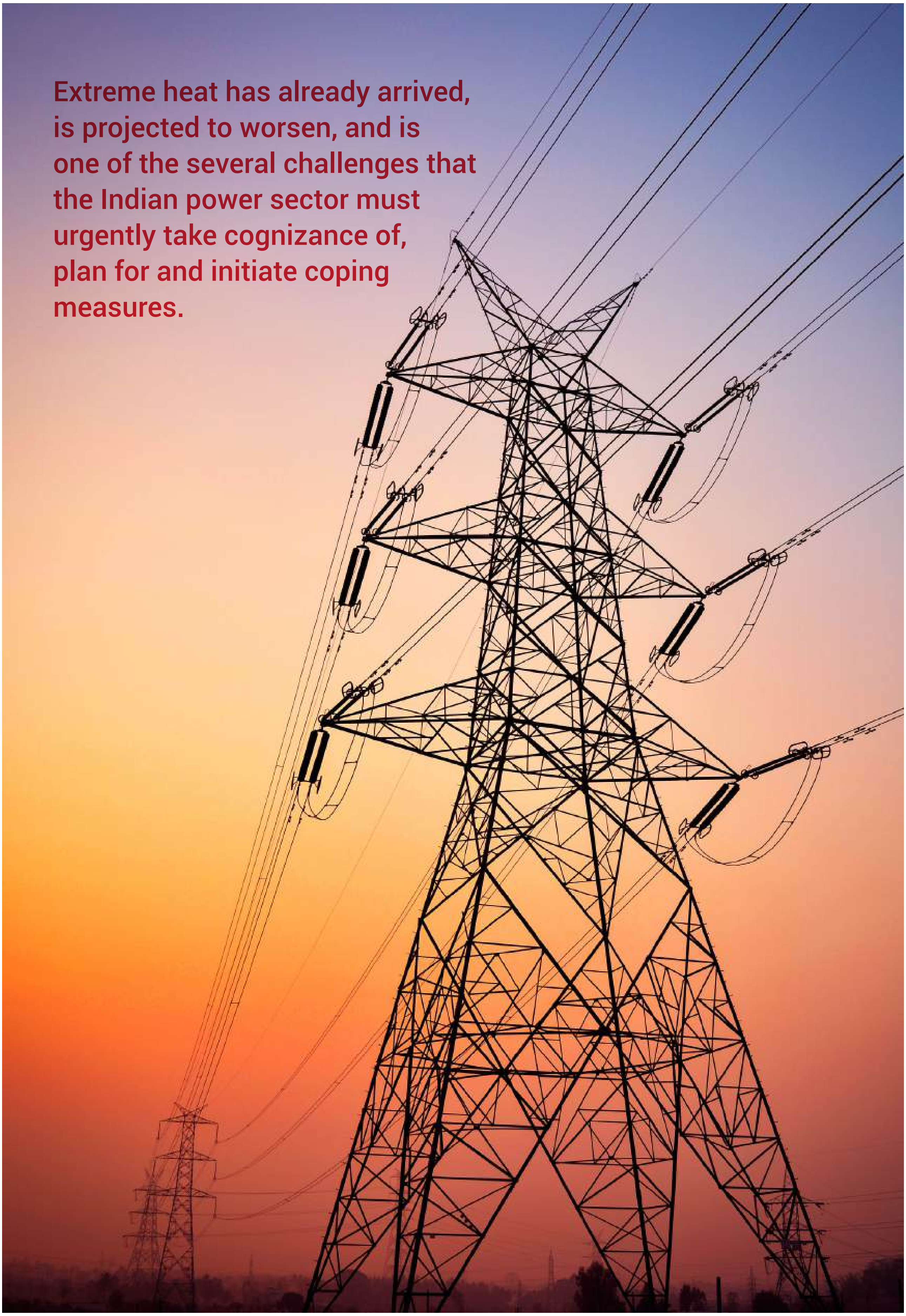
*April 2025*

# Contents

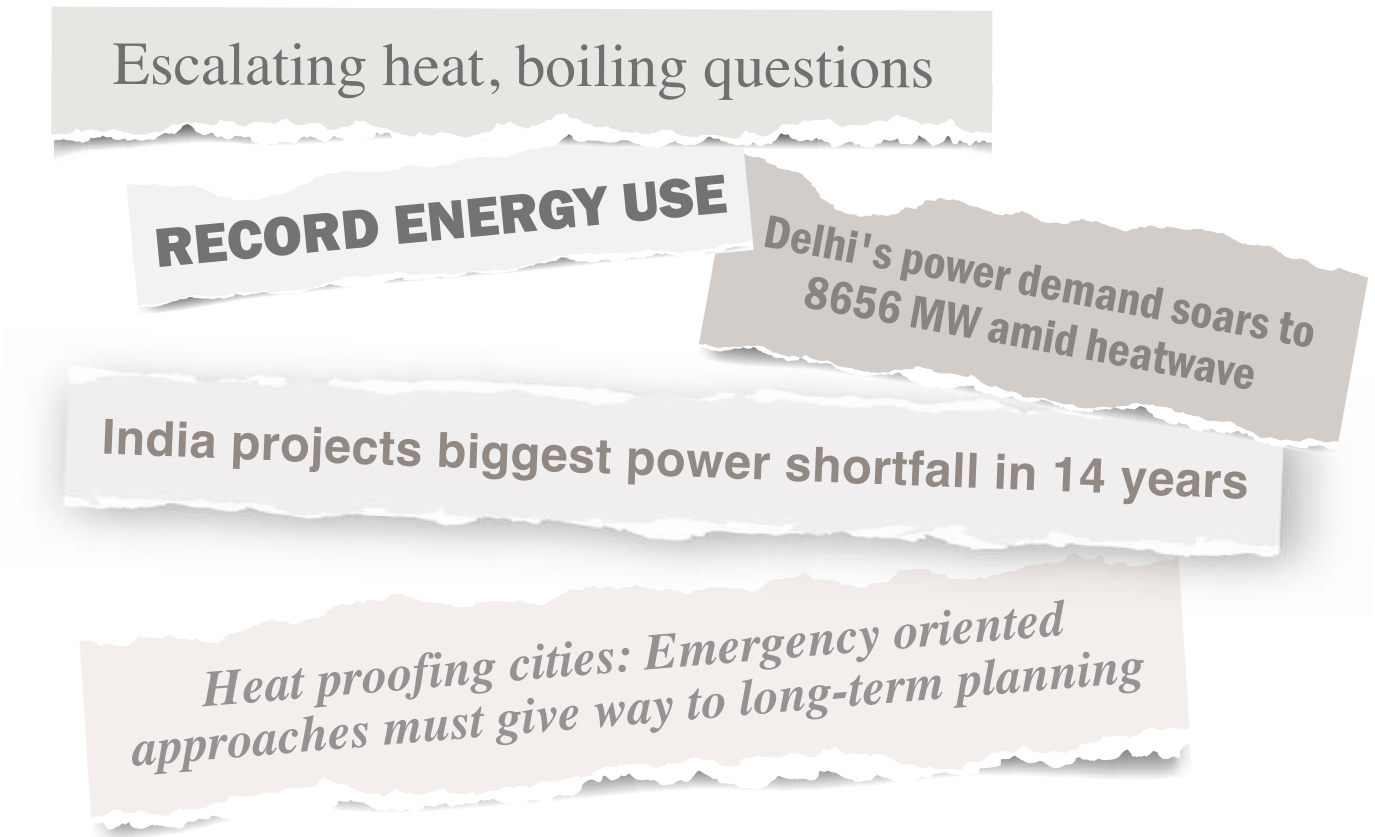


Extreme heat has already arrived, is projected to worsen, and is one of the several challenges that the Indian power sector must urgently take cognizance of, plan for and initiate coping measures.

# Context

Extreme heat has already arrived[1,2]. Scientific research clearly points to the increase in intensity, frequency and duration of heatwaves with these trends projected to worsen in the coming years due to enhanced global warming induced climate change[3,4,5]. The effect of such extreme heat is further exacerbated in urban and peri-urban areas due to the urban heat Island effect emanating from the way we plan, build and manage our cities[6]. Stark difference in nighttime land temperatures between urban and rural areas, up to 20°C can be seen in Northern India. Further, concurrent hot day and hot night (CHDHN) events are projected to increase manifold with increased global warming[7].

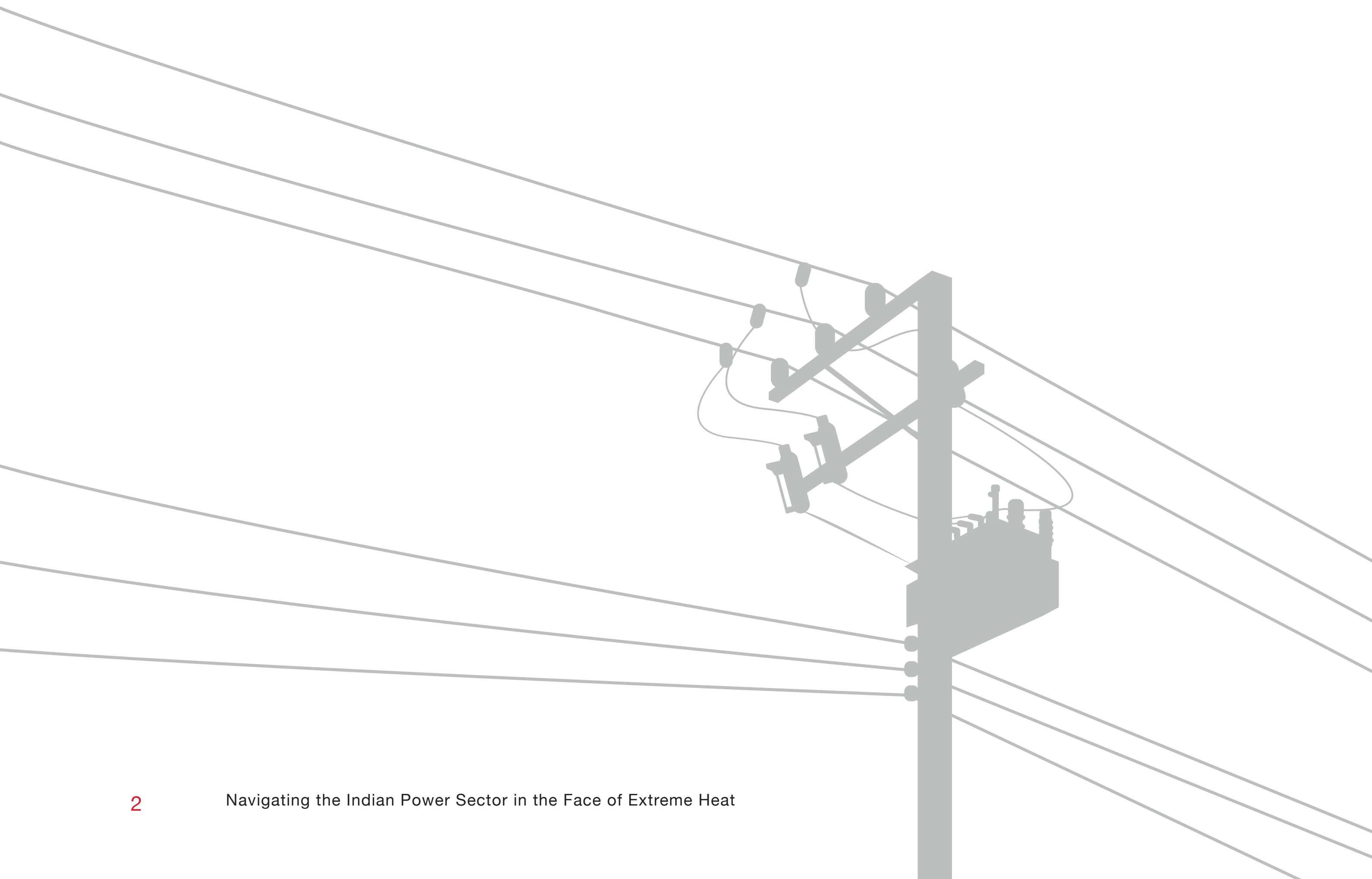
Extreme heat is one of the several challenges that the Indian power sector must urgently take cognizance of, plan for and initiate coping measures. While the reliability of electricity supply has been slowly but surely increasing[8] over the years through a variety of measures, planning for resilience, especially to various forms of extreme weather events is still only beginning. The weak financial status of the distribution sector[9] in India, with ₹ 6.48 lakh crore[10] of accumulated deficit (up to March 2023) exacerbates this challenge. News headlines such as '*Record Energy Use': Delhi's power demand soars to 8656 MW amid heatwave*'[11], '*India projects biggest power shortfall in 14 years in June*'[12], '*Heat proofing cities: Emergency oriented approaches must give way to long-term planning*'[13] and '*Escalating heat, boiling questions*'[14] are becoming increasingly common with each passing summer. One obvious and direct impact is reflected in the increase in cooling demand through increased sales and use of air conditioners (AC)[15] and fans. A related impact is the Distribution Companies (DISCOMs) resorting to short-term high-price power procurement[16] on the markets to meet such demand in summers.



However, there are many more direct and indirect impacts of extreme heat on the entire spectrum of the power sector (namely: demand, generation, transmission, distribution and system operation). Changing long-term climatic patterns and increasing uncertainties in short-term weather conditions[17] are clearly impacting consumption patterns, but these are also changing because of electrification of new end-uses (e.g., transport, cooking, industry, etc.), rising incomes, urbanization and self-generation options like rooftop solar. If not handled in a planned fashion, all these could result in reduced reliability/resilience and loss of load, all of which have direct and indirect economic and social impacts. The power sector is a key part of the broader economic infrastructure in the state enabling socio-economic development of citizens as well as the development of other sectors of the economy.

Hence, it is critical to study and understand the complex interaction of impacts of extreme heat across various components of the power sector and start working towards a framework which will identify effective technical, planning and governance solutions to navigate the power sector in the face of extreme heat.

**Approach:** Based on a literature review, complemented with short discussions with a few sectoral stakeholders, this note has identified the major impacts of extreme heat on the entire value chain (demand, generation, transmission, distribution and system operation) of the power sector. Secondly, based on this broad understanding, the note has also compiled possible action ideas, along with the current status and areas of improvement for existing and potential responses to such impacts of heat. However, the note has not looked at the technical design and operational aspects (related to heat and temperature) of various electrical equipment. Further, while the physical impacts of extreme heat on various elements within the power sector will be common across countries, the policy and regulatory framework referred to in the note is limited only to India. In India, action ideas would have to be fine-tuned across regions, states and districts.



# Impacts of extreme heat on the power sector, action ideas, current status and areas of improvement

The following sections 1-4 summarize the likely impacts, action ideas and current status of extreme heat on four components of the power sector, namely Electricity Demand, Transmission and Distribution, Generation and System Monitoring and Operation:

1. **Electricity Demand:** This covers the processes for estimating short-, medium- and long-term electricity demand, essential for planning power purchase and infrastructure of the sector. It also covers the specific demand surges arising due to cooling needs from sudden extreme heat events and strategies to mitigate and manage these fluctuations.

2. **Transmission and Distribution:** Transmission infrastructure covers overhead lines, cables and substations at voltage levels above 33 kV AC and HVDC. Transmission network is closely interconnected as a grid structure (not radial as in distribution), making its planning and operation relatively more complex. Distribution infrastructure covers overhead lines, cables and substations, typically at 33kV, 22 kV, 11 kV, 415 V and 240 V (single phase) voltage levels. Distribution network is mostly radial in nature, except in a few urban centres.

3. **Electricity Generation:** Generation covers conventional (coal, gas, large hydro and nuclear), renewable (wind, solar, biomass, etc.) and energy storage (pumped hydro, batteries, etc.) related infrastructure.

4. **System Monitoring and Operation:** This covers the real time operation of the grid to maintain supply-demand balance as done by the State, Regional and National load dispatch centres. It also covers distribution and generation monitoring and control centres.

Action ideas will have to be taken up by different sectoral actors noted below:

1. **Planners:** National – Ministry of Power (MoP), Ministry of New and Renewable Energy (MNRE), Ministry of Coal (MoC), Central Electricity Authority (CEA), Central Transmission Utility of India Limited (CTU), Grid India, Bureau of Energy Efficiency (BEE), State Energy Departments, State Nodal Agencies (SNAs), State Transmission Utilities (STUs) and Distribution Utilities

2. **Service providers:** National- and State-level utilities (generation, transmission and distribution)

3. **System operators and monitoring centres:** National, Regional and State Load Dispatch Centres, distribution monitoring and control centres and generation monitoring and control centres

4. **Regulators/standardization bodies:** CEA, Central and State Electricity Regulatory Commissions, BEE, Bureau of Indian Standards (BIS), Institute of Electrical and Electronics Engineers (IEEE) and International Electrotechnical Commission (IEC)

5. **Industry:** Component and equipment manufacturers, investors, financers, insurers, contractors, consultants, power exchanges, traders and ancillary service providers

6. **Research:** Public and private research and development and academic institutions

7. **Consumer groups:** Organizations of commercial, industrial, agriculture and domestic consumers

The following sections outline the impacts, possible action ideas, current status, and areas for improvement in existing and potential responses to the impacts of heat. These sections address each of the four components of the power sector - demand, transmission and distribution, generation and system operation. While these are not comprehensive, they are intended to initiate discussions on this topic and should be further refined and nuanced with additional evidence from the ground, based on consultations with a wide range of sector experts.

## 1. Electricity Demand

### Impacts

- Heat results in increased demand for electricity used for space cooling systems and appliances.
- Ceiling fans, air-conditioners and air-coolers are estimated to contribute to over 50 percent of the total residential electricity consumption and is projected to grow at 18 percent annually[18]. It also contributes to about 26 percent of the national peak load in summers *(ibid)*.
- Majority of the electricity consumed in commercial sector which accounts for 10 percent of the total electricity consumption is due to centralized cooling systems.
- Extreme heat waves can result in sudden increase in electricity demand. One study says *"On average, aggregate electricity demand in India increases by 11 percent or more at temperatures above 30 C from demand at temperatures of 21-24 C"*[19].
- Agriculture water pumping also has high correlation with extreme heat.
- Demand drop can be high when there is sudden reduction of temperature – due to pumping and cooling demand changes.

## Action Ideas

- Measures to improve building designs and increase adoption of passive cooling techniques[20] to reduce the need for cooling electricity demand and improve thermal comfort.
- Measures to improve energy efficiency of cooling appliances and agriculture pumping. These measures need to be mix of regulations and incentives.
- Adoption of better energy demand projections (especially for peak demand[21]) and load forecasting techniques by the DISCOMs which inform their long-term as well as short-term planning processes.
- Implement effective Time of Day (ToD) tariffs to send price signals to consumer to use their cooling appliances more judiciously during the stress (increasingly high net-peak load) periods.
- Implement targeted large scale Demand Response (DR) programmes to shift or reduce the loads at the stress (peak/net-peak) periods.

## Current Status and Areas of Improvement

- Bureau of Energy Efficiency has energy conservation building codes for both commercial and residential sector. Its adoption and implementation by the states has been limited.
- Bureau of Energy Efficiency runs a Standards and Labelling (S&L) Program which is mandatory for ceiling fans and air-conditioners and will soon be launched in voluntary form for air-coolers. It acts as both a regulatory measure as well as an awareness measure to improve energy efficiency[22]. While the programme has been successful, it can be further improved through increased consumer awareness, periodic revision of standards, and regular check-testing[23].
- Energy Efficiency Services Ltd. carried out a large-scale bulk procurement programme that resulted in transforming India's lighting market from CFL to more energy efficient LED bulbs. DISCOMs have been carrying out pilot scale rebate programmes in some states. However, programmes like these need to be scaled up for cooling appliances.
- High coincident demand (e.g., all ACs turning on during high heat periods) reduces the diversity factor. Most DTs/building have not been planned for such low diversity factor/ high peak-coincident demand and hence future planning need to specifically incorporate this.
- Almost all the DISCOMs have Time of Day (ToD) tariff for some consumer categories for some time now. However, these have not been effectively monitored and regularly improved to ensure whether the price signals are working. Over time, more consumer categories (especially residential) can come under ToD tariff regime. Regulators can consider increasing dynamic pricing, critical peak pricing, especially in seasonal stress periods.

- Few DISCOMs have been running pilot scale Demand Response (DR) programmes with the size limited to 15-25 MW. These need to be scaled up which requires adequate regulatory support and innovative business models (e.g., which seek to understand what level of monetary compensation would be needed for load shifts). This can be further enhanced with implementation of smart meters and easy access of real-time demand related information to consumers.

- The importance of circle-wise demand assessment has also been recognized in CEA's Network Planning Criteria. Recording spatially granular input data will further help in better overall demand forecasting. Demand projections need to include provisions of extreme heat events/ time periods along with humidity (including spatial temperature variation).

- Agriculture supply is highly subsidized and hence there is limited incentive for efficiency of water or electricity use. A comprehensive approach to enhancing efficiency in the water-food-energy nexus is lacking and needs to be taken up[24].

- Have a more comprehensive coverage of energy efficiency and demand side management measures possible by consumers and at the community/city level in Heat Action Plans (HAPs)[25].

## 2. Transmission and Distribution

### Impacts

- Impacts of catering to high demand: Increased demand results in higher loading of the system, which can reduce useful life, and increase stress especially at joints (more relevant in distribution).
- Lower load bearing capacity: High ambient temperature reduces load carrying capacity[26].
- Lines, towers/poles, insulators, Substation Transformers: Increased breakdowns and faults due to hot spots, sagging and over-heating, reduction of useful life. High loading and reduction of cooling due to high ambient temperatures is a known cause for DT failures.
- Cables: More frequent faults, reduction of life.
- Transformers: Faults and fires (more in oil filled), due to high oil or winding temperatures. Distribution Transformers are widely spread out and often located near habitations. Their failures and fires are a bigger challenge.
- Outdoor instrumentation: Malfunctioning, loss of accuracy (CT, PT, CB, AB switch, sensors, meters, control wiring, earthing).
- Forest fires[27]: Damage, especially to transmission infrastructure.
- O&M: Greater need and costs because of all the above. Online and offline maintenance tougher because of high ambient temperatures. Safety and impact on equipment and staff are concerns.

## Action Ideas

- Awareness: Building awareness of all stakeholders about extreme heat impacts.

- Extreme heat audit: Review the existing construction standards with respect to the expected extreme heat ambient temperature – maximum and sustained. Identify vulnerable areas – electrical and geographical. Identify requirements for heat measurement points in the network.

- Implement heat monitoring: At different monitoring areas - lines, substations, control centres, based on results of audit.

- Revise construction standards: Consolidate and revise the construction standards to address extreme heat, so that loading capability and reliability is improved. Similar changes should be incorporated in relevant CEA/IS/BIS standards for manufacturing and testing of equipment/ components.

- Revise General Network Access (GNA) requirements: States and users will have to revise GNA requirements to meet additional demand. States might have to opt for more Temporary-GNA to buy short-term power to meet sudden spike in demands.

- Reliability indicators: Revise calculation and reporting of reliability indicators: separately report force majeure periods; higher attention to key transmission lines, 11 kV feeders and DT loading and failures.

- Reliability approach: Different approach for areas which require and can afford high reliability (industry, critical loads etc) and which can tolerate occasional low reliability. In transmission, detailed contingency studies/simulations would be needed to understand the increase in infrastructure needed to maintain same levels of reliability considering scale, frequency and duration of high temperature events.

- Asset health Monitoring: DISCOMs and Transmission Companies (TRANSCOs) should carry out annual survey of their assets and identify which assets are more susceptible to extreme heat wave events. Data from Distribution transformers (DTs) and Substations should be analyzed by them for preparing preventive maintenance schedules. TRANSCOs can also install temperature measuring instruments on transmission lines for better understanding of asset response to extreme temperature such as hot spots. A recent initiative in Gujarat (Watchdog Transformer[28]) is a good example of this.

- Incentivize Feeder Level Performance Improvement in distribution: Monthly data on feeder-wise energy accounting as well as reliability indices should be available in the public domain to enhance the accountability of the DISCOMs. Monthly publishing of such information in the descending order of their Aggregate Technical and Commercial (AT&C)/ Distribution losses can have significant impact on operational performance.

- A cost-benefit analysis (CBA) framework for power sector investments to build resilience from various risks (including heatwaves) is very much needed. A starting point for such an analysis is given in Chapter 6, 'Climate Resilience for Energy Security'[29].

- Cost sharing: A mechanism to effectively share additional costs for enhanced reliability and resilience between state support and user contribution needs to be developed.

- Develop and pilot solutions for resilience - construction: to address cooling of DTs, reduction of hot spots, reduce line sagging, replace old conductors such as replacing Aluminium Conductors Steel Reinforced (ACSR) conductors with more temperature-resistant ACSS cables or HTLS conductors[30] have the potential to lessen climate-attributable reductions to transmission capacity[31], protecting outdoor instrumentation.

- Develop and pilot solutions for resilience – O&M: Regular and preventive O&M, speeding up location of line/cable faults, ToD /DSM measures to reduce peak loading of network.

- Convergence with responses to other extreme weather events: Coordination with urban and rural planning, disaster response, IMD, other utilities.

- District wise action plans (areas with high heat, high demand, relatively weak/old infrastructure).

## Current Status and Areas of Improvement

- Extreme weather impact: Impact of flood, rain, storm and wind are considered to some extent while planning and O&M. Preventive maintenance are carried out to address the impact of some of these factors. Examples are urban distribution companies and critical transmission lines. But extreme heat is presently not fully recognized as a major issue.

- Transmission planning: Planning for adequate transmission infrastructure (with enough spare to meet contingency events, N-1, N-1-1 etc.) to meet uninterrupted/reliable power supply is done. But these contingencies may not be factoring in extreme heat (as an event leading to higher-than-expected demand or an event impacting power flow).

- GNA in transmission: Transmission General Network Access (GNA) requirements of States do not factor in the possible additional demand requirements due to extreme heat.

- Grid India in collaboration with IMD (based on temperature etc. data) adjusts the Transmission Transfer Capability (TTC) in real time.

- Reliability calculation: Regulatory Commissions, utilities and REC report reliability trends covering some parameters. Calculation and reporting of reliability indices exclude force majeure conditions like extreme weather events. Therefore, reported reliability indicators do not reflect the impact of extreme weather events. CEA can formulate a data format which asks for system outage (separately for distribution and transmission network) due to various extreme weather events, including quantum of power outage, frequency, reason, duration of outage, etc.

- A quick review shows that ambient weather standards are typically 40/50/55 degree centigrade, humidity of 95/100 percent in some standards[32]. But a detailed study is needed to ensure that all standards specify at least 55 degrees ambient temperature, and that quality inspection is ensuring conformation with standards.

- Cost recovery: Cost of infrastructure and O&M are currently recovered from users of T&D infrastructure through a regulatory process. There are no clear processes for recovering costs incurred due to extreme weather events. Relevant changes in tariff regulations could be explored which could quantify costs arising from extreme events.

- Research work on extreme heat: Limited work towards equipping T&D infrastructure to function in extreme heat.

- Coordination with other agencies: Possibly limited in terms of collecting weather data for demand and generation forecasting. No formal mechanisms to plan for extreme heat.

## 3. Generation

### Impacts

- With rising ambient air temperatures, impacts are seen across:
  - Marginal reduction in efficiency of thermal power plants.
  - Increased boiler tube leakage related outages in thermal plants and derating effects, i.e., reduced capacity and efficiency of gas turbine (GT) and combine cycle gas turbines (CCGT).
  - Efficiency and thus the output of solar power reduces[33], resulting in revenue loss. Can cause increase wear and tear, micro-cracks and such physical damage.
  - Derating of MVA capacity of Wind Turbine Generators (WTGs), inverters and Battery Energy Storage System (BESS).
  - More than expected evaporation losses for Hydro and PSP plants.
  - Increased heat, droughts leading to lack of access of cooling water for thermal plants can reduce availability of such plants. Especially important for plants close to cities and drought prone areas.
  - Maintenance becomes an issue in Summers, planned maintenance is at time postponed leading to higher break-downs. Crew management is also an issue in high temperatures due to restrictions on outdoor work.
  - Increasing risk of abnormal/low performance of inverters due to high temperature[34,35].

## Action Ideas

- Improved generation planning (for fuel and planned maintenance) considering higher than expected demand periods.
- Temperature management for BESS is an important design and operational parameter given the tight operational range to avoid high level of drain, degradation and to maintain safety levels.
- Integrating energy storage with generation plants to enhance supply side flexibility.
- Effective design of HVAC systems for BESS, adequate monitoring of BESS, especially for high temperature to prevent fires/accidents.
- Need to have higher liquidity in the short-term markets Day-Ahead Market (DAM), Real Time Market (RTM), Green Day-Ahead Market (GDAM) to meet sudden changes in demand and demand in stress periods[36].
- Incentivising higher availability of thermal generators during peak seasonal (like summer) and diurnal (high net-peak time periods) demand.
- Adequately valuing hydro generation as a peaking supply option is important. Optimally managing the annual water budget across various needs and parameters in challenging.

## Current Status and Areas of Improvement

- Solar PV plant design already factors in 'normal summer' operating temperature to meet standard performance parameters like minimum CUF, availability etc. through various parameters including varying DC overloading, tracking systems etc. Precisely estimating drop in generation due to heatwaves with temperatures higher than normal may be needed going ahead.
- CEA has already issued a Procedure for assessment of the Design Temperature for RE Plants in compliance to CEA (Technical Standards for Connectivity to the Grid) Regulations.
- As per the *'Guidelines for Procurement and Utilization of Battery Energy Storage Systems as part of Generation, Transmission and Distribution assets, along with Ancillary Services'* dated 10th March, 2022, Appendix-2 specifies various *'Technical Parameters of BESS, BESS Characterization and Performance Parameters'*. These include various safety codes/standards including some specifically for *'Power Conditioning Unit Standards for BESS'* related to dry heat - IEC 60068-2-2:2007, change in temperature - IEC 60068-2-14:2009 and damp heat - IEC 60068-2-30:2005.
- Gradual removal / setting higher price caps (possibly with seasonal variation) to incentivise more availability of generation in peak periods.
- Amending MYT tariff regulations at Central and State Regulatory Commissions to give higher weightage to availability in peak season and hours for fixed cost recovery.

## 4. System Monitoring and Operation

### Impacts

- Sudden (over few hours/days) spike in peak demand/ net-demand due to rise in cooling services due to higher temperatures.
- Increase in short-term (likely higher price) electricity procurement through Exchanges.
- More demands for fault detection, isolation and restoration – in T&D and Generation.

### Action Ideas

- Assessment of reserves requirement considering extreme weather events is needed. Further ensuring adequate reserves of all types (primary, secondary and tertiary) in practice with strict penal regulatory provisions for non-compliance is needed.
- Incentivizing and institutionalizing Demand Response (DR) as a resilience measure to address peak demand, especially given the short duration (few days/weeks in a year) need to address the heat wave conditions.
- Enhancing system flexibility through stand alone or co-located energy storage takes care of intra-day forecast errors or sudden increases/decreases in demand to some extent. Starting with/ piloting some energy storage projects (BESS, PSP) will help gain experience in procurement and operation.

- Extending SCED to intra-state generators to further optimize supply.
- Strong inter-connected grid (including with neighbouring countries) and integrated dispatch increases resilience.
- Move towards 5-min dispatch over time to better manage ramp and deviation from schedule.
- Equip control and monitoring centres for faster fault detection, isolation and restoration.
- Higher demand flexibility (supply and demand side) will be needed with increasing share of variable renewables.
- More stringent Forecasting and Scheduling (F&S) regulatory requirements on wind and solar generators to prevent deviations from schedule and aid in generation-demand balancing.

## Current Status and Areas of Improvement

- CERC mandates primary, secondary and tertiary reserves as per the IEGC, 2023 and Ancillary services regulations, 2023. CERC's appointed expert Committee on Deviation Settlement Mechanism (DSM) regulations noted that, 'Generators' response through primary and secondary reserve participation was not adequate.' Primary reserves should be 4500 MW at a minimum, while 40 GW of conventional capacity are operating under AGC and are able to provide +/- 2000 MW of SRAS. NLDC has been placing up and down TRAS requirements up to 4000 MW in DAM-AS and RTM-AS. Newer concepts like *'Frequency Response Obligation (FRO), Frequency response characteristic (FRC) and Frequency Response Performance (FRP) and Rate of Change of Frequency (RoCoF)'* have been introduced in IEGC.
- The MoP notification (July 2022) recommends an Energy Storage Obligation, starting from 1% in FY 24 to 4% in FY 30. 12 SERCs have incorporated ESO in their RPO regulations[37]. Need to emphasize strong M&V and compliance implementation. The price discovery in the recent standalone BESS tender from GUVNL of ₹ 3.72 Lakhs/MW/month (~₹ 3.7/kWh as levelized cost of storage) is highly encouraging.
- In emergency situations, Government can issue orders under section 11, Electricity Act, 2003 to state embedded generators to supply energy to the state. (e.g., Karnataka in 2023).
- Pilots done on 5-min scheduling by POSOCO, Monitoring of SAMAST report recommendations and implementation.
- Preparing improved day-ahead schedules for demand as well as schedules for RE generators with storage (like in FDRE tenders) and modifying them in real-time based on actual conditions.
- Fault monitoring and restoration systems are not present to some extent in Transmission load dispatch centres, Generation and Transmission substation control centres, not at distribution level.
- As an extreme last resort measure, actively dropping the system frequency to reduce load, rather than risking system failure has been a practice used in the past.

# Key action items

The growth in electricity demand in India has historically been gradual and predictable. As a result, the application of rule of thumb approaches for some planning aspects has generally sufficed, albeit potentially sub-optimally from a financial perspective. However, with the heightened frequency and intensity of heat waves, a significant uptick in demand (especially peak) is anticipated, accompanied by sporadic surges. Under such circumstances, reliance on rule of thumb planning may prove inadequate and could potentially lead to infrastructure damage and cascading disruptions in grid operations. It is imperative for all sectoral institutions to recognize the gravity of this issue and integrate it appropriately into their operational practices.

Before considering suggested action items, it is important to take a bird's eye view of the Indian power sector to contextualize these action items. The role of the power sector in the Indian economy has been increasing over the years, with the growing electrification in existing uses and emerging new uses (such as transport, cooking and industry). Climate, environment and resource constraints, supported by technology developments, have been driving the increasing reliance on renewable energy and energy efficiency.

According to PFC's Report on Performance of Power Utilities, in FY 2023, the total revenue of the sector was ₹ 9.57 lakh crores[38], but the accumulated losses (as per balance sheet) were ₹ 6.47 lakh crores. As mentioned before, the quality of supply and service has improved over the years and so has the consumer expectations on quality supply. Supply to a large number of consumers – agriculture and small domestic are subsidized, mostly from budgetary support of state governments. In FY 2023, this subsidy amounted to ₹ 1.69 lakh Crores, equal to 17.7 percent of the total revenue. All these imply a financially weak sector and political economy of power supply. This also results in a crisis driven operation of the sector, with limited focus for long-term planning or strengthening resilience.

As per the Electricity Act (2003), the sector is regulated by Central and State Regulatory Commissions. Power generation and markets are lightly regulated, compared to transmission and distribution and power supply. Over the years, there has been significant private sector participation in generation, but limited (yet growing) participation in transmission and distribution. Distribution is managed by private companies in few urban centres (Mumbai, Delhi, Kolkata, Ahmedabad and Surat) and in the state of Odisha. There is a small but growing presence of electricity markets with traders and power exchanges playing an increasingly important role in operation of the sector. Unfortunately, there has been limited emphasis on demand side resources such as efficiency and demand response.

Within this existing policy and regulatory framework, there are several areas that can be enhanced and improved to effectively address the escalating threat posed by extreme heat. Based on this analysis, a few action items to navigate the power sector in the face of extreme heat are given in this section. Suggestions which are broad in nature, related to policy, planning and regulation and which are partly already underway and would address sector issues not only limited to extreme heat, are given first. This section concludes with a few suggestions which could be taken up in the immediate term – before the next summer.

**Planning and policy-related action items**

a. All sector institutions need to value and thus inculcate a mindset for planning for a reliable, robust and resilient power sector. There is a need to strengthen the planning cells in CEA, Utilities and Regulatory Commissions.

b. A cost-benefit analysis (CBA) and a cost sharing framework for power sector investments to build resilience from various risks (including heatwaves) must be developed and piloted in few areas.

c. Review, consolidate and revise various construction, operation and relevant IS/BIS standards for manufacturing and testing of equipment/components to address extreme heat, so that loading capability and reliability is improved.

d. Ensuring adequate system reserves for the Grid Operator in practice with strict penal regulatory provisions for non-compliance.

e. Incentivizing higher liquidity in the short-term markets (DAM, RTM, GDAM) to meet sudden changes in demand and demand in stress periods through gradual removal/ setting higher price caps (possibly with seasonal variation) amongst other measures.

f. Plan for adequate GNA requirements (both long-term and short-term T-GNA) to meet additional demand from out of state generation.

g. Constitute standing multi-ministerial review committees at national and state levels for climate resilience in the power sector which meets once in (approximately) six months to review the situation and recommend next steps.

h. The Disaster Management Plan[39] for power sector, prepared by CEA needs to be updated based on the current experiences of dealing with extreme heat.

**Medium-term regulatory action items**

a. Effective spatial and granular, bottom-up demand forecasting (especially in the short-term) and distribution network planning which is cognizant of extreme heat induced coincident demand rise/surges.

b. National policies and regulations to rapidly improve cooling appliance efficiency (especially ACs). State level policies for stricter implementation of ECBC codes in commercial and residential buildings.

c. State Regulations for effective seasonal and ToD consumer tariffs to incentivize shifting loads away from stress periods (peak or net-peak hours).

d. Effective programmes for Demand Response (DR) at scale to enhance demand side flexibility, especially given the relatively short time duration of the heat events.

e. Asset health monitoring (especially for DTs with remote metering) coupled with more effective heat audits and timely O&M practices specific to extreme heat.

f. Enhancing system flexibility through stand alone or co-located energy storage for managing intra-day forecast errors or sudden increases/decreases in demand due to heat.

**A few immediate action items with suggestions of the holders for the item**

a. Consolidate sector responses to extreme heat in 2024, and prepare action plan for summer of 2025 through experience sharing workshops (Holder: MoP/DISCOMs).

b. Organize regional experience sharing workshops to develop extreme heat audit process by utilities (Forum of Regulators, NDMA).

c. Prepare a study report on best international research trends in navigating extreme heat (CPRI/ Academic and Research institutes).

d. Develop protocols and contingency plans for heat emergencies in terms of spatial, temporal and consumer category/load specific load shedding/shifting (DISCOMs). Similarly develop public awareness campaigns for load reductions in stress hours (as was done recently in Kerala, May 2024).

e. Prepare Demand Side Management/ Demand Response plan for one state, with special focus on extreme heat (Specific State/BEE).

f. Include power sector impact and coping aspects in the city heat action plans (NDMA, Cities).

# References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28 *Watchdog Transformer: By Gujarat Power Research and Development Cell (GPRD) under Gujarat Urja Vikas Nigam Ltd (GUVNL).*
Limitations of the Current System: The existing power distribution system relies heavily on distribution transformers, critical for ensuring reliable power supply. However, there are significant limitations:
1. Lack of Monitoring: Once installed, there is no monitoring or controlling of distribution transformers' operational parameters. 2. Overloading Issues: Overloading by consumers, particularly in agricultural and industrial areas, is not monitored accurately. 3. Power Theft: Bypassing distribution transformers from LV bushings is a common practice for power theft, which is difficult to monitor. These limitations often lead to unexpected transformer failures, revenue loss, disrupting power supply and increasing maintenance costs.
Objectives of the Watchdog Transformer: The Watchdog Transformer (WDT) aims to address these issues by integrating advanced monitoring and controlling mechanisms directly into the distribution transformer system.
How the Watchdog Transformer Works: The WDT combines a traditional distribution transformer with a sophisticated Watchdog Device (WDD). The WDD is mounted on the transformer's LV terminals, preventing direct access and incorporating several advanced features:
• Data Acquisition and Monitoring: Uses IoT-based Data Control Units (DCU) for real-time data collection and monitoring of transformer parameters. • Energy Metering: Monitors energy export to consumers, comparing it with consumer tariff meters to detect discrepancies. • Protective Functions: Equipped Leakage current and overcurrent protection, and can disconnect consumer power if irregularities persist.
• Remote Control: Allows for remote ON/OFF control and scheduled power operations without visiting the transformer site. • Health Monitoring: Monitors transformer health parameters like oil and winding temperature, load, ampere, and voltage.
Benefits of the Watchdog Transformer: Implementing the WDT brings numerous benefits:
*1. Enhanced Reliability: Reduces the frequency of transformer failures by preventing overloading and monitoring operational health. 2. Operational Efficiency: Improves overall power distribution efficiency with better load management and energy auditing at the transformer level. 3.Cost Savings: Decreases operational costs by reducing human intervention and extending transformer operational life. 4.Theft Reduction: Minimizes power theft through accurate monitoring and immediate action on detected discrepancies. 5. User Convenience: Facilitates remote and scheduled control of power supply, enhancing user convenience and operational flexibility.*

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