

Analysis the Combined Impact of Climate Change and the NTPC Dadri Thermal Complex on Dadri Block, Gautam Buddha Nagar, UP

1. Sandeep Bhati

Research Scholar, Dept. of Geography, Meerut College Meerut-250001(U.P.) India,

2. Professor (Dr.) Naresh Kumar

Dept. of Geography, Meerut College Meerut-250001(U.P.) India, Email id - nareshkakran@gmail.com

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Abstract: Coal- and gas-fired power stations in rapidly urbanising peri-Delhi districts operate at the intersection of two pressures: they emit the pollutants and greenhouse gases that drive local and global environmental change, and they are themselves exposed to a warming, water-stressed climate. This paper examines that compound relationship for the National Capital Power Station (NTPC Dadri), a 2,669.78 MW coal-and-gas complex in Dadri Block, Gautam Buddha Nagar, Uttar Pradesh. Using a secondary-data, scenario-based design, we (i) reconstruct the station's annual emission and resource-use profile under three operating scenarios, (ii) quantify climate-induced derating and efficiency penalties through a temperature-sensitivity analysis ($\Delta T = 0-3^{\circ}\text{C}$), and (iii) integrate hazard, exposure, vulnerability and climate-amplification scores into a Composite Compound Impact Index (CCII). Under the base scenario the complex generates about 13.1 TWh and emits $11.5 \text{ Mt CO}_2 \text{ a}^{-1}$ ($0.88 \text{ tCO}_2 \text{ MWh}^{-1}$, about 23% above the 2024-25 all-India grid average of 0.710), consuming 7.0 Mt of coal and 46 million m^3 of water. A 2°C rise in ambient temperature reduces annual output by roughly 116 GWh (0.88%) and raises CO_2 by 46 kt, while groundwater extraction in Gautam Buddha Nagar already exceeds recharge (104.79%). The CCII ranks water resources (5.60), heat stress and health (5.48) and air quality (5.17) as the priority compound-risk domains. The findings support an integrated adaptation-mitigation strategy combining full emission-control compliance, treated-wastewater substitution, heat-health early warning and a managed transition of the fleet.

Keywords: Climate change; Thermal power; NTPC Dadri; Compound risk; Delhi-NCR; Greenhouse gas emissions; Water-energy nexus; Gautam Buddha Nagar

JEL classification: Q54, Q53, Q41, Q25, L94 | **Article type:** Research paper (secondary-data, scenario-based assessment)

1. Introduction

Global mean surface temperature during 2011–2020 was approximately 1.1°C above the 1850–1900 baseline, and every increment of warming intensifies heat extremes, hydrological stress and health risks (IPCC 2023). India, the world's third-largest emitter of greenhouse gases, meets roughly three-quarters of its electricity demand from coal and lignite, and its power sector is therefore simultaneously a central driver of, and a central casualty of, climate change (CEA 2025; Krishnan et al. 2020). The all-India weighted-average grid emission factor has fallen from $0.774 \text{ tCO}_2 \text{ MWh}^{-1}$ in FY 2013-14 to $0.710 \text{ tCO}_2 \text{ MWh}^{-1}$ in FY 2024-25 as renewables expanded, yet absolute emissions continue to rise with generation (CEA 2025).

The environmental debate around thermal power has traditionally been organised in two separate silos. One strand studies the plant as a **source** — of particulate matter, sulphur dioxide (SO_2), nitrogen oxides

(NO_x), fly ash, thermal discharge and CO₂ (Guttikunda and Jawahar 2014). A second strand studies the plant as a **receptor** — of heat, drought and water scarcity that derate output and threaten reliability (van Vliet et al. 2012, 2016). Very few studies examine the interaction of the two at the scale of a single administrative block, where the same population, aquifer and airshed absorb both the plant's emissions and the climate-driven stresses that amplify their consequences. This interaction is the essence of a **compound risk** (Zscheischler et al. 2020): the joint outcome is larger than the sum of separately assessed parts.

The NTPC Dadri complex is an ideal case. Situated about 48 km from Delhi in Gautam Buddha Nagar, it is one of the largest coal-and-gas complexes in the National Capital Region (NCR), draws cooling water from the Upper Ganga Canal, and sits in a district whose groundwater extraction exceeds 100% of the annually extractable resource (CGWB 2023, as reported by Down To Earth 2025). The surrounding Dadri Block has been classified as semi-critical in groundwater assessments cited in judicial proceedings (NGT 2022), and the wider airshed is among the most polluted in the world.

Research objectives. This study (1) profiles the station and its regulatory context; (2) estimates its annual emissions and resource footprint under alternative operating scenarios; (3) quantifies climate-induced operational and emission penalties; and (4) develops and applies a Composite Compound Impact Index to prioritise risk domains and adaptation actions. **Research questions:** RQ1 — What is the scale of the station's emission and resource footprint relative to national benchmarks? RQ2 — How sensitive is its output and emission intensity to regional warming? RQ3 — Which environmental domains exhibit the strongest compound (climate × plant) risk in Dadri Block?

2. Literature Review and Research Gap

Thermal power as an emission source. Guttikunda and Jawahar (2014) estimated that Indian coal-fired stations contributed substantial shares of national PM, SO₂ and NO_x emissions and projected rapid growth without stringent controls. Ambient PM_{2.5} exposure in India was linked to roughly 1.7 million deaths in 2019 in Global Burden of Disease assessments, with the loss of life expectancy concentrated in the Indo-Gangetic Plain (Balakrishnan et al. 2019). Conibear et al. (2018) showed that residential energy use dominates PM_{2.5} health impacts nationally, but that power generation is a significant secondary contributor in specific regions — a reminder that plant-attributable and regional burdens must be separated carefully.

Thermal power as a climate-exposed asset. Thermoelectric plants depend on cooling water and on favourable ambient conditions. van Vliet et al. (2012) projected that summer usable capacity of European and US plants could decline by several percentage points to double-digit percentages by mid-century because of warmer, scarcer cooling water; van Vliet et al. (2016) extended this to a global analysis showing significant power-generation vulnerability to climate and water-resource change. Gas turbines lose output as inlet air warms, and steam plants suffer higher condenser back-pressure and auxiliary loads. In South Asia, observed and projected increases in heat waves and moist-heat stress (Mishra et al. 2020) add a worker-health and reliability dimension.

Regional climate. The national assessment by the Ministry of Earth Sciences reports a rise of about 0.7 °C in India's average surface temperature between 1901 and 2018, with a marked increase in the frequency of heat waves and projections of substantially larger warming by the end of the century under high-emission pathways (Krishnan et al. 2020).

Compound events. Zscheischler et al. (2020) define compound events as combinations of drivers and hazards that contribute to societal or environmental risk; their typology (preconditioned, multivariate, temporally compounding, spatially compounding) provides the conceptual anchor for this study, in which pollution loading, heat and water scarcity precondition one another.

Table 1. *Synthesis of literature strands and the research gap*

Strand	Key evidence	Representative source	Gap addressed here
Plant as emitter	National thermal fleet is a major PM/SO ₂ /NO _x source; norms tightened in 2015	Guttikunda & Jawahar (2014); MoEFCC (2015)	Station-scale, block-level footprint under scenarios
Plant as receptor	Warmer air/water derates output; water constraints cut capacity	van Vliet et al. (2012, 2016)	Site-specific temperature sensitivity for a mixed coal–gas NCR complex
Health burden	PM _{2.5} deaths concentrated in Indo-Gangetic Plain	Balakrishnan et al. (2019); Conibear et al. (2018)	Attribution context for Dadri Block
Regional climate	+0.7 °C since 1901; rising heat waves	Krishnan et al. (2020); Mishra et al. (2020)	Linkage to plant operations and local vulnerability
Compound risk	Joint drivers amplify impacts	Zscheischler et al. (2020)	Operational index (CCII) for a single block

Source: Author's synthesis.

Research gap. Despite rich work on each strand, no study known to the author integrates plant-scale emission accounting, temperature-driven operational sensitivity and local water-stress indicators into a single, transparent framework for the Dadri–Gautam Buddha Nagar setting. This paper fills that gap.

3. Study Area and the NTPC Dadri Complex

Gautam Buddha Nagar (area about 1,442 km²) is an industrial district of Uttar Pradesh adjoining Delhi, comprising four development blocks — Birsakh, Dadri, Dankaur and Jewar (CGWB district brochure). Dadri Block (approximately 28.6° N, 77.6° E) hosts the National Capital Power Station, commonly called NTPC Dadri, operated by NTPC Ltd. The station's first coal unit was commissioned in October 1991, and the second stage (two supercritical units) began operating in 2010 (NS Energy 2019; Global Energy Monitor 2026).

The complex has three components: a coal-fired Stage I of four 210 MW subcritical units (840 MW); a coal-fired Stage II of two units, originally 490 MW each and shown in the April 2026 Central Electricity Authority installed-capacity report as uprated to 500 MW each (1,000 MW; Global Energy Monitor 2026); and a gas-based combined-cycle plant of 829.78 MW (four gas turbines of 130.19 MW and two steam turbines of 154.51 MW) supplied through the GAIL HBJ pipeline. Summing unit ratings gives 2,669.78 MW, slightly below the 2,674.78 MW quoted in some secondary sources, which appears to be an arithmetic discrepancy. Cooling water is drawn from the Upper Ganga Canal.

Table 2. *Configuration of the NTPC Dadri complex*

Component	Units	Rating (MW)	Commissioned	Fuel / technology
Stage I coal	4 × 210	840	1991–1994	Coal, subcritical
Stage II coal	2 × 500*	1,000	2010	Coal, supercritical
Gas plant (GT)	4 × 130.19	520.76	1992	Natural gas (HSD backup)
Gas plant (ST)	2 × 154.51	309.02	1993	Combined-cycle steam
Total	14 units	2,669.78	—	Coal 1,840 MW + Gas 829.78 MW

* Originally 490 MW each; uprated to 500 MW per CEA installed-capacity report (30 April 2026).
Sources: Wikipedia (NTPC Dadri); Global Energy Monitor (2026); NS Energy (2019); author's computation.

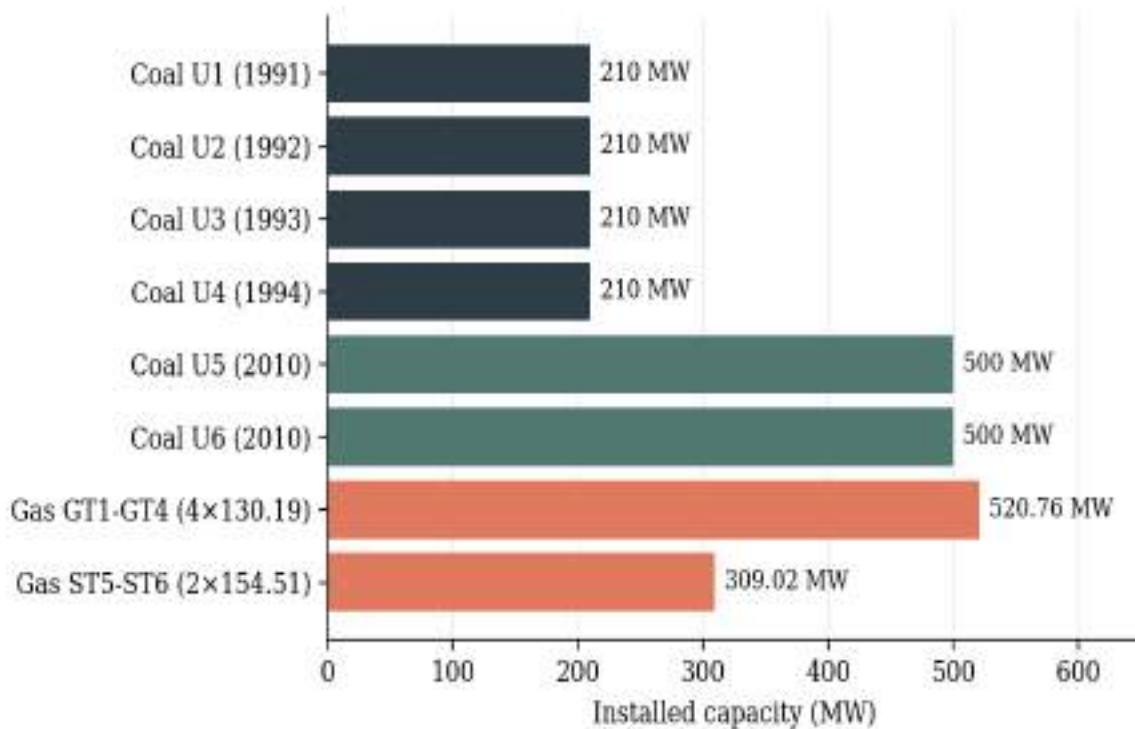


Fig. 1. Unit-wise installed capacity of NTPC Dadri. *Source: Table 2; author's compilation.*

Regulatory compliance is central to the station's environmental performance. NTPC has stated that the station monitors emissions online, transmits them to the Central Pollution Control Board (CPCB) in real time, and uses electrostatic precipitators on all coal units, dry sorbent injection on the 210 MW units and flue-gas desulphurisation (FGD) on the larger units (Business Standard 2020; NS Energy 2019). Because implementation status of retrofits has changed repeatedly since 2015, this paper treats control-technology performance as a scenario variable rather than an assumed fact.

4. Data and Methodology

4.1 Research design

The study uses a **secondary-data, scenario-based, mixed quantitative design**. It is deliberately an assessment framework rather than a claim of direct measurement: no primary stack or ambient sampling was conducted. Plant characteristics, grid emission factors, groundwater indicators and regulatory norms are drawn from published official and institutional sources (CEA, CGWB, MoEFCC, NTPC, Global Energy Monitor, tribunal records and investigative journalism); engineering coefficients are drawn from ranges typical of the literature and are declared explicitly in Table 3 so that every result is reproducible and can be re-run when plant-level CEA or CPCB data are inserted.

4.2 Emission and resource accounting

Annual generation for each unit class i is $G_i = C_i \times 8,760 \times \text{PLF}_i$, where C is installed capacity and PLF the plant load factor. CO_2 is $E_i = G_i \times \text{EF}_i$. Coal consumption is $G_i \times \text{SCC}_i$ (specific coal consumption); uncontrolled SO_2 (kt) is $\text{coal} \times S \times 2$ (assuming complete oxidation of fuel sulphur); fly ash is $\text{coal} \times \text{ash fraction}$; and water use is $G \times 3.5 \text{ m}^3 \text{ MWh}^{-1}$, which equals the norm prescribed for cooling-tower-based plants. Three scenarios bracket uncertainty in dispatch: Low (coal PLF 55%, gas 15%), Base (70%, 25%) and High (85%, 35%).

Table 3. Model parameters and assumptions

Parameter	Value	Basis
CO ₂ intensity, 210 MW subcritical coal	1.00 tCO ₂ MWh ⁻¹	Typical for older Indian subcritical units (assumed)
CO ₂ intensity, 500 MW supercritical coal	0.90 tCO ₂ MWh ⁻¹	Typical for supercritical units (assumed)
CO ₂ intensity, gas CCGT	0.45 tCO ₂ MWh ⁻¹	Typical for combined-cycle gas (assumed)
Specific coal consumption (210 / 500 MW)	0.65 / 0.60 kg kWh ⁻¹	Typical Indian domestic coal, GCV ~3,800–4,200 kcal kg ⁻¹ (assumed)
Coal sulphur / ash	0.45% / 35%	Typical Indian coal ranges (assumed)
Specific water consumption	3.5 m ³ MWh ⁻¹	MoEFCC (2015) norm, cooling-tower plants
Steam-unit output loss	0.4% per °C	Literature range for condenser/auxiliary penalties (assumed)
Gas-turbine output loss	0.7% per °C	Inlet-air derating range 0.5–1.0% per °C (assumed)
Heat-rate (emission) penalty	+0.2% per °C	Assumed
Evaporative water penalty	+2% per °C	Assumed
Grid benchmark	0.710 tCO ₂ MWh ⁻¹	CEA CO ₂ Baseline Database v21.0, FY 2024-25

Note: "assumed" parameters are modelling assumptions to be replaced by plant-specific CEA/CPCB/NTPC data in subsequent work.

4.3 Climate sensitivity analysis

Warming is represented by ambient temperature increments $\Delta T = 1, 1.5, 2$ and $3\text{ }^{\circ}\text{C}$, spanning the range from near-term to high-emission mid-to-late century conditions for northern India (Krishnan et al. 2020; IPCC 2023). For each ΔT , annual generation loss is computed for steam and gas units separately, together with additional CO₂ from the heat-rate penalty and additional evaporative water use. Impacts on non-thermal factors such as coal-supply disruption, floods or grid faults are outside this analysis.

4.4 Composite Compound Impact Index (CCII)

Six domains are screened: air quality, greenhouse gases, water resources, heat stress and health, fly ash and land, and operational/infrastructure integrity. Each is scored 1–5 for **Hazard (H)** from the plant, **Exposure (E)** of people and ecosystems, **Vulnerability (V)** of the receiving system, and **Climate amplification (A)** — the degree to which regional warming worsens the impact. The index is $CCII = (H \times E \times V)^{(1/3)} \times [1 + 0.1 \times (A - 1)]$. The geometric mean penalises domains in which any one dimension is low, while the amplification term explicitly encodes the climate $\times$ plant interaction. Scores were assigned by the author from the evidence base presented in Sections 3 and 5 and should be regarded as a structured screening judgement; a Delphi exercise with domain experts is recommended for validation.

5. Results

5.1 Emission and resource footprint

Under the base scenario the complex generates 13.10 TWh a⁻¹, of which 5.15 TWh comes from the 210 MW units, 6.13 TWh from the 500 MW units and 1.82 TWh from the gas plant (Table 4). Annual CO₂ emissions are 11.49 Mt, with the two coal stages contributing about 93%. The implied fleet-average intensity is 0.877 tCO₂ MWh⁻¹ — about 23% above the FY 2024-25 all-India grid average of 0.710 tCO₂ MWh⁻¹ (CEA 2025) and, for the coal units alone, 0.946 tCO₂ MWh⁻¹ (Fig. 2). Emissions range from 8.9 to 14.1 Mt CO₂ across the Low and High scenarios (Fig. 3).

Table 4. Modelled annual output, emissions and resource use under three scenarios

Indicator	Low	Base	High
Net generation (TWh)	9.96	13.10	16.24
CO ₂ emissions (Mt)	8.87	11.49	14.10
Coal consumption (Mt)	5.52	7.03	8.53
Uncontrolled SO ₂ (kt)	49.7	63.2	76.8
SO ₂ with 90%-efficient FGD (kt)	5.0	6.3	7.7
Fly ash generated (Mt)	1.93	2.46	2.99
Water consumption (million m ³)	34.8	45.9	56.9
Fleet CO ₂ intensity (tCO ₂ MWh ⁻¹)	0.891	0.877	0.868

Source: Author's model (parameters in Table 3). Values are estimates, not measured data.

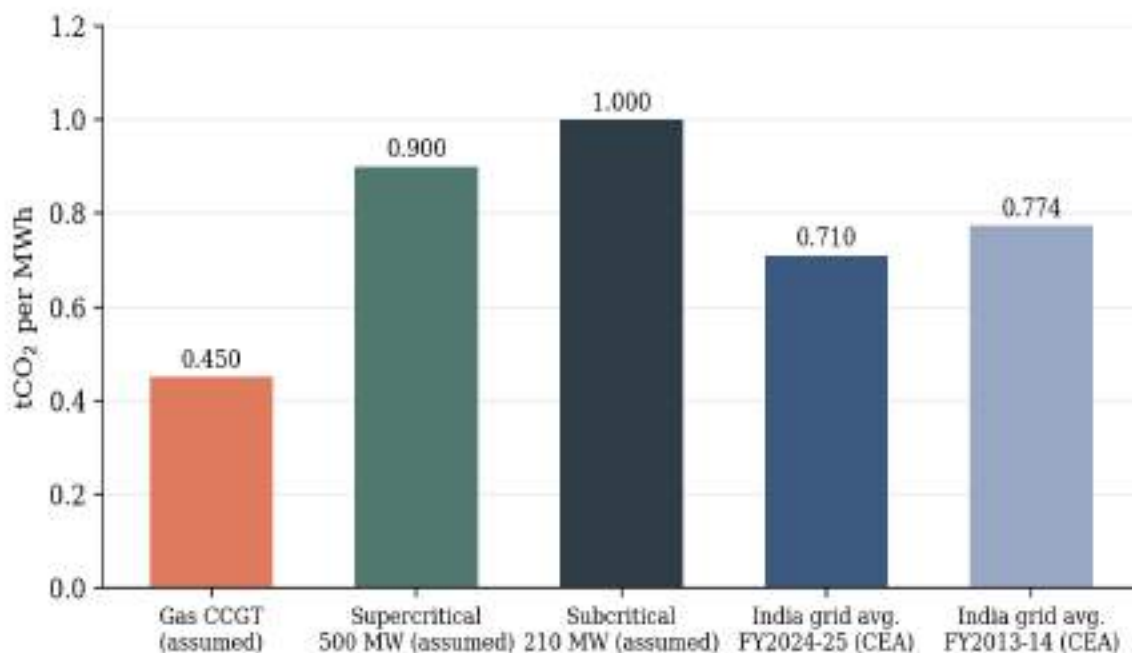


Fig. 2. CO₂ intensity of Dadri unit classes compared with the Indian grid average. Sources: CEA (2025) for grid values; author's assumptions for units.

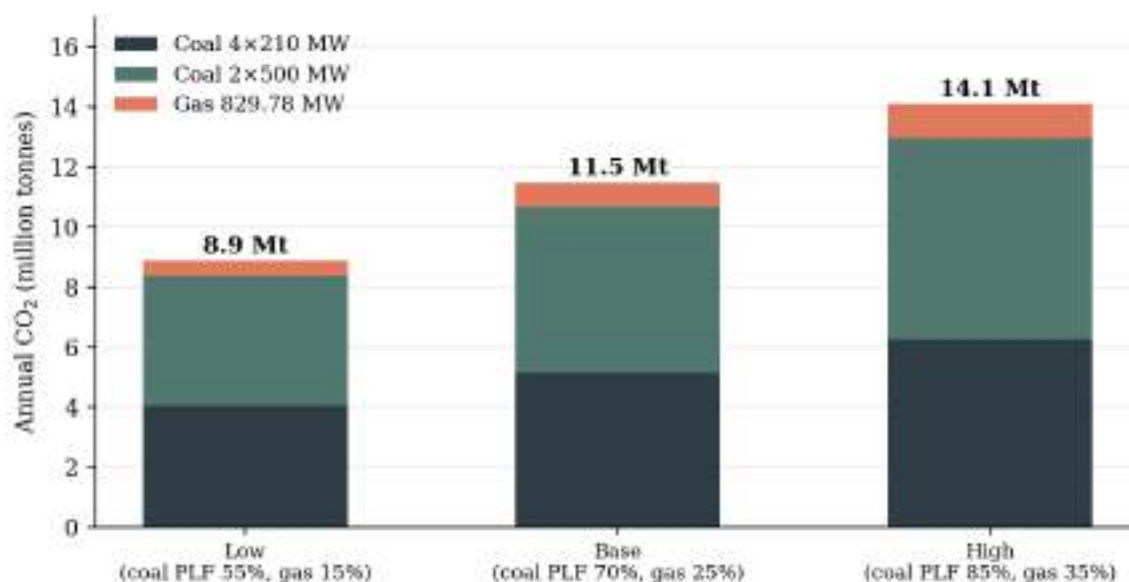


Fig. 3. Modelled annual CO₂ emissions by unit class under three operating scenarios. *Source: Author's model.*

Fly ash generation of about 2.5 Mt a⁻¹ in the base case implies a continuing land, dust and utilisation challenge in a district already facing intense land-use pressure. Uncontrolled SO₂ of 63 kt a⁻¹ would fall by roughly nine-tenths with efficient FGD, illustrating how much of the local air-quality benefit depends on retrofit performance rather than on dispatch.

5.2 Regulatory benchmarks

The MoEFCC emission standards notified in December 2015 differentiate by commissioning date and unit size. Stage I units (commissioned 1991–94) fall in the pre-2003 class, while Stage II units (2010) belong to the 2003–2016 class with tighter limits (Table 5). Subsequent amendments and category-based FGD deadlines — including the 2025 classification of plants by proximity to NCR and large cities — mean that the applicable compliance date for each unit should be verified against the latest notification and the CSE compliance tracker before policy conclusions are drawn.

Table 5. Indicative emission limits applicable to Dadri unit classes (mg Nm⁻³)

Unit class	PM	SO ₂	NO _x	Mercury
Units commissioned before 2003 (Stage I, 210 MW)	100	600	600	0.03
Units commissioned 2003–2016, < 500 MW	50	600	300	0.03
Units commissioned 2003–2016, ≥ 500 MW (Stage II)	50	200	300	0.03

Source: MoEFCC notification S.O. 3305(E), 7 December 2015 (as amended). Verify against the latest amendments.

5.3 Climate sensitivity

Warming reduces deliverable output and raises emission intensity (Table 6, Fig. 4). At ΔT = 2 °C, annual generation falls by 116 GWh (0.88% of base output), of which 90 GWh arises from steam units and 25 GWh from gas turbines; at ΔT = 3 °C the loss reaches 174 GWh (1.32%). Because the gas turbines are far more temperature-sensitive per MWh, they contribute disproportionately (about 22%) to derating despite producing only 14% of energy. The additional CO₂ from heat-rate penalties is

modest in relative terms (46–69 kt at 2–3 °C) but arises with no increase in useful output, i.e. it is a pure efficiency loss.

Table 6. Temperature sensitivity of the Dadri complex (Base scenario)

ΔT (°C)	Steam loss (GWh)	GT loss (GWh)	Total loss (GWh)	Loss (% of output)	Extra CO ₂ (kt)	Extra water (Mm ³)
1	45.1	12.7	57.9	0.44	23.0	0.92
1.5	67.7	19.1	86.8	0.66	34.5	1.38
2	90.3	25.4	115.7	0.88	45.9	1.83
3	135.4	38.2	173.6	1.32	68.9	2.75

Source: Author's model. Does not include water-availability curtailment, which could raise losses substantially (see Section 6).

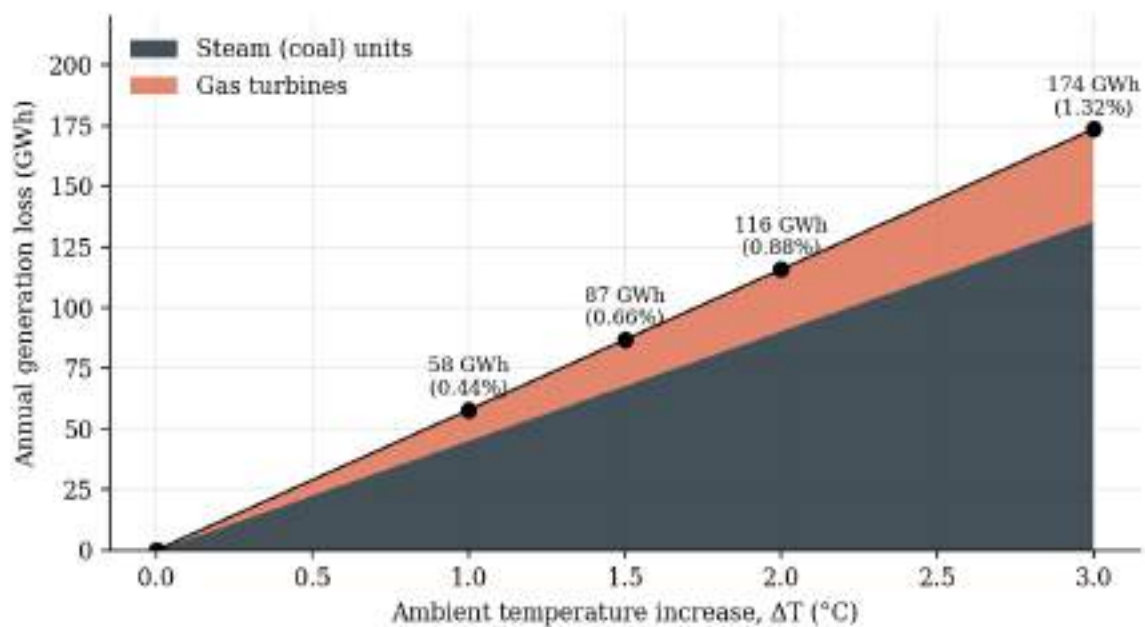


Fig. 4. Climate-induced derating of annual output by ΔT . Source: Author's model.

5.4 Water stress

Base-scenario water consumption is about 46 million m³ a⁻¹ (range 35–57). The plant depends on canal water rather than borewells, but the district context is one of severe hydrological stress: the Dynamic Ground Water Resources assessment for 2023 places Gautam Buddha Nagar's stage of extraction at 104.79% (Down To Earth 2025), and Fig. 5 shows that neighbouring NCR districts are in comparable or worse condition. Dadri Block has shown declining pre- and post-monsoon groundwater levels attributed to over-abstraction for domestic and irrigation needs (CGWB district brochure). Since canal allocations are shared with agriculture and urban supply, climate-driven variability in Ganga flows and evaporation directly affects both the plant's reliability and community access to water. Warming-linked evaporation (+2% per °C) adds only about 1.8 million m³ at $\Delta T = 2$ °C, but the marginal water is being drawn from a basin already in deficit.

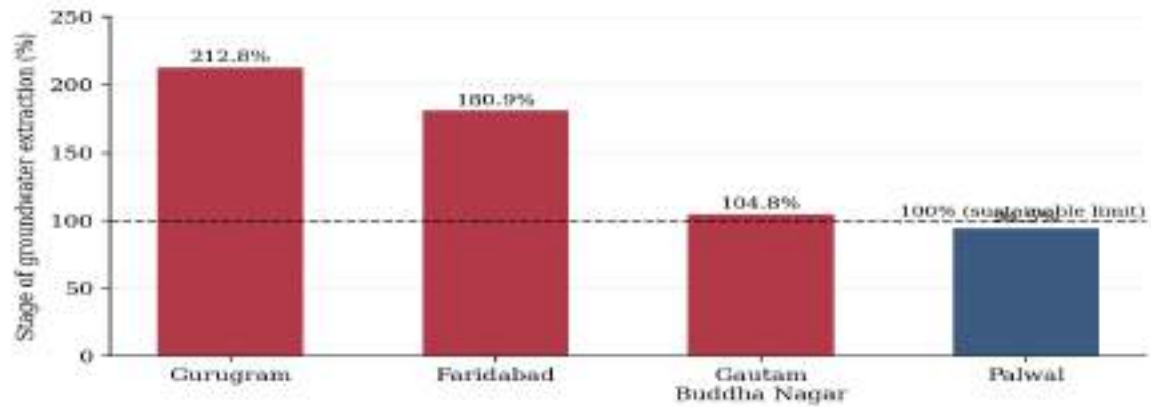


Fig. 5. Stage of groundwater extraction in Gautam Buddha Nagar and neighbouring NCR districts. Sources: CGWB reports as cited by Down To Earth (2025) and The Tribune; CGWB assessment years may differ between districts.

5.5 Composite Compound Impact Index

Table 7. CCII results and priority ranking

Domain	H	E	V	A	CCII	Priority
Water resources	4	4	5	4	5.60	Very high
Heat stress & health	3	5	4	5	5.48	Very high
Air quality (PM, SO ₂ , NO _x)	4	5	4	3	5.17	Very high
Greenhouse gases	5	3	3	2	3.91	Moderate
Operational / infrastructure	3	3	3	4	3.90	Moderate
Fly ash & land	3	3	3	2	3.30	Moderate

H = hazard; E = exposure; V = vulnerability; A = climate amplification (each 1–5). Priority: ≥ 5 very high; 4–5 high; < 4 moderate. Source: Author's assessment.

	Hazard	Exposure	Vulnerability	Climate amplification	CCII
Air quality (PM, SO ₂ , NO _x)	4	5	4	3	5.17
Greenhouse gases	5	3	3	2	3.91
Water resources	4	4	5	4	5.60
Heat stress & health	3	5	4	5	5.48
Fly ash & land	3	3	3	2	3.30
Operational / infrastructure	3	3	3	4	3.90

Fig. 6. Composite Compound Impact Index screening matrix. Source: Author's assessment (see Section 4.4).

Water resources (CCII = 5.60), heat stress and health (5.48) and air quality (5.17) emerge as very-high-priority domains. Water ranks first because vulnerability is maximal and amplification strong; heat stress ranks second because warming is the dominant amplifier and exposure of a large peri-urban workforce and neighbouring communities is high; air quality ranks third due to the plant's hazard in an already saturated airshed. Greenhouse gases receive the highest hazard score but a lower index because the receptor is global rather than local and climate amplification of the emission itself is limited.

6. Discussion

Two-way causation is the central finding. The station is both a cause and a casualty of climate change. Its base-case 11.5 Mt CO₂ a⁻¹ equals the annual emissions of a small industrial economy; at the same time, the very warming to which it contributes erodes its output and efficiency. Although a 1–2% derating appears small, it is paid for in additional fuel per unit of useful electricity, and it coincides with peak-demand summer months in which grid reliability is most valuable. Our sensitivity analysis is conservative because it excludes discrete events — extreme heat waves, canal shutdowns for maintenance, drought-driven allocation cuts — that van Vliet et al. (2016) identify as the principal drivers of forced capacity loss.

The local airshed is the binding constraint. Even if annual CO₂ is a global-scale problem, the immediate human cost is local. NCR winters are marked by temperature inversions and stagnant air, conditions that climate variability may worsen. Full and reliably operated SO₂ and NO_x controls are therefore not merely a regulatory duty but a precondition for keeping plant-attributable exposure low when meteorology is adverse. The gap between an installed control device and a continuously operated one is what matters; independent verification of continuous emission monitoring data remains a policy priority.

Water is the hidden multiplier. Discussions of coal plants and climate often focus on carbon. In Dadri Block, however, the most severe compound risk arises from water: a stressed aquifer, competing canal demand and rising evaporation. Reported arrangements to use treated sewage water from the Noida area for the station point in the right direction, because they decouple cooling demand from freshwater sources and improve resilience (as reported in secondary sources; details should be verified with NTPC).

Equity and vulnerability. Outdoor labourers, brick-kiln and construction workers, and low-income households in Dadri's villages and adjoining urban resettlements have the least adaptive capacity to heat and pollution, yet contribute least to the emissions. Adaptation planning that treats the plant's fence line as the boundary of concern will miss the largest share of the population at risk.

Comparison with the grid. The fleet's intensity is about 23% above the national grid average, but this comparison should be interpreted with care: Dadri serves NCR peak and base demand where alternatives are limited. What it does show is that the marginal pathway to lower emissions in the region lies less in dispatching Dadri differently than in accelerating renewables, storage and demand management around it, and in efficiency upgrades of the older 210 MW units.

7. Policy Implications and Mitigation–Adaptation Roadmap

Based on the CCII ranking, we propose a phased roadmap that couples mitigation (reducing the plant's contribution) with adaptation (reducing exposure and vulnerability) (Table 8).

Table 8. *Integrated mitigation–adaptation roadmap for Dadri Block*

Horizon	Water	Air & health	Climate & energy
Near term (0–2 yrs)	Publish plant water balance; maximise treated-wastewater use; canal-flow risk monitoring	Verify FGD/NO _x retrofit operation for every unit; public real-time CEMS dashboard; heat–health early warning for villages	Plant-level CO ₂ and heat-rate audit; index dispatch to ambient-temperature derating forecasts
Medium term (3–7 yrs)	Zero freshwater-drawing policy for cooling; aquifer recharge in Dadri Block	Health surveillance in fence-line communities; fly-ash utilisation ≥100%; green belt and cool-roof programmes	Efficiency upgrades of 210 MW units or phased retirement; co-firing biomass/torrefied pellets; solar + storage on plant land
Long term (8–20 yrs)	Basin-scale allocation with climate-adjusted flows	Airshed-level governance with UP, Haryana and Delhi	Managed transition of the coal units; repurposing of gas plant as flexible reserve; just-transition plan for workers

Source: Author's synthesis. Co-firing reference: NTPC pilots reported by Economic Times (2024).

Three institutional levers deserve emphasis. First, **climate-adjusted planning standards** — NTPC and the CEA should incorporate site-specific temperature and water-availability projections into capacity-declaration and outage planning. Second, **transparent compliance** — continuous emission monitoring data, retrofit commissioning dates and third-party audits should be public so that communities can hold operators and regulators accountable. Third, **integrated block-level governance** — the District Administration, Uttar Pradesh Pollution Control Board, CGWB and NTPC should co-develop a Dadri Block Climate-Resilience Plan that treats air, water, heat and energy together.

8. Limitations and Directions for Future Research

This study has several limitations. First, emissions and resource flows are modelled from typical coefficients, not measured stack data; actual results depend on coal quality, unit-specific heat rates, outages and dispatch. Second, temperature-sensitivity coefficients are drawn from literature ranges rather than manufacturer curves for Dadri's specific equipment. Third, the CCII scores are expert-judgement based and should be validated through a Delphi or multi-criteria decision process. Fourth, health impacts are treated qualitatively; a dispersion-model and concentration–response study (e.g., CALPUFF/WRF-Chem with GBD functions) would allow attributable-mortality estimates. Fifth, the analysis excludes upstream coal mining and transport, and Scope 3 effects. Future research should (i) use CPCB CEMS and CEA plant-level fuel data, (ii) downscale CMIP6 projections for Dadri, (iii) conduct household surveys of heat and water vulnerability in the Block, and (iv) evaluate the economics of repowering, co-firing and renewable substitution.

9. Conclusion

The NTPC Dadri complex illustrates the dual position of India's thermal fleet. As a source, it emits an estimated 8.9–14.1 Mt CO₂ a⁻¹ and consumes 35–57 million m³ of water; as a receptor, it loses output and efficiency as temperatures climb, in a district whose groundwater is already over-extracted. The Composite Compound Impact Index identifies water resources, heat stress and air quality as the priority

domains in Dadri Block, with climate change acting as an amplifier rather than a separate hazard. Addressing these risks requires an integrated agenda: verified emission-control performance, a shift to treated-wastewater cooling, heat-health preparedness for vulnerable communities, and a planned, just transition of ageing units. The framework developed here is transparent, replicable and adaptable, and can be extended to other thermal clusters in the NCR and the wider Indo-Gangetic Plain once plant-level monitoring data are incorporated.

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