Impact of Climate Change on Water Availability of the Gumti River Serving the OTPC Combined Cycle Power Plant, Palatana, Tripura

Biswajit Datta, Associate Professor, Department of Automobile Engineering, TIT, Narsingarh, India
Email: bdatta2001@gmail.com
Kaberi Majumdar, Professor, Department of Electrical Engineering, TIT, Narsingarh, Tripura, India
Manish Pal, Professor, Department of Civil Engineering, NIT, Agartala, Tripura, India
Pankaj Kr Roy, Professor, School of Water Resources Engineering, Jadavpur University, West Bengal, India

Abstract

Climate change poses significant risks to river hydrology and thermal power generation. This paper assesses the impact of climate change on water availability in the Gumti River Basin of Tripura, India, and implications for the ONGC Tripura Power Company (OTPC) Combined Cycle Power Plant at Palatana. A comprehensive literature review reveals that altered precipitation patterns and rising temperatures can substantially affect river flows and the reliability of water-cooled power plants. The Gumti River's hydro-meteorological characteristics are analyzed, showing highly seasonal flow – abundant during the monsoon and sharply reduced in the dry season. This describe the OTPC Palatana plant's water requirements, its induced-draft cooling system, and seasonal vulnerabilities related to water intake. Using a hydrological modeling framework and climate projections from CMIP6 scenarios (SSP2-4.5 and SSP5-8.5), we project future river runoff. Scenario-based simulations indicate that by mid-century, average annual flow in the Gumti could decline by up to ~25% under certain scenario, with significant reductions in dry-season flows. Under a high-emission scenario, more intense monsoon rainfall may increase peak flows but still leave prolonged low-flow periods. These changes threaten the Palatana plant's operations by reducing cooling water availability, increasing intake disruptions, and slightly lowering thermal efficiency due to warmer water temperatures. Original graphs illustrate projected monthly flow shifts and the shrinking margin between river flow and plant water demand. The results suggest that plant output and reliability may be compromised in future dry seasons and drought years. Mitigation and adaptation strategies are discussed, including technical modifications to reduce water use, enhanced intake infrastructure, on-site water storage, and improved monitoring and management. The study underscores the need for climate-resilient planning at the water-energy nexus to ensure sustainable power generation in Tripura's changing climate.

Keywords: Gumti River, OTPC, Combined cycle power plant, climate change.

Introduction

Climate change is increasingly altering hydrological cycles worldwide, with direct consequences for water resources and energy infrastructure. In particular, river-dependent systems face variability in streamflow due to shifting precipitation regimes, intensified extreme events, and enhanced evapotranspiration under warming temperatures. These changes pose a serious challenge for thermal power plants, which require substantial water for cooling and other processes. Globally, about 47% of thermal power generation capacity is sited in high water-stress areas. In India, roughly 40% of freshwater-dependent thermal plants are located in water-scarce regions, leading to recurrent operational disruptions. Water shortages forced shutdowns in 14 of India's 20 largest thermal utilities from 2013–2016, resulting in an estimated loss of 14 TWh of generation in 2016 alone. This highlights the vulnerability of the power sector to hydrological changes and competition for water.

The water-energy nexus is particularly critical in monsoonal regions, where seasonal water abundance is followed by pronounced dry periods. Thermal plants with once-through or recirculating cooling systems depend on reliable river flow year-round. Any climate-driven shift – such as an increase in monsoonal rainfall but longer dry spells – can upset this balance. Rising air and water temperatures further compound the issue by reducing cooling efficiency and increasing water demands for the same power output. Thus, understanding climate change impacts on river hydrology is essential for power plant risk assessments and adaptation planning.

Photographs of OTPC Water Intake point

This paper focuses on the Gumti River Basin in Tripura, Northeast India, and its role in supporting the OTPC Palatana Combined Cycle Gas Power Plant. The 726.6 MW plant, one of the largest power stations in the region, draws cooling and process water from the Gumti River. The Gumti River is a lifeline in Tripura, hosting the state's only large hydropower project and providing water for irrigation and communities. It exhibits strong seasonal variation – torrential flows in the June–September monsoon and scant flows in the November–April dry season. In lean months, water scarcity has historically curtailed hydropower generation on the Gumti to a trickle (only ~0.5 MW out of 15 MW capacity), underscoring the river's seasonal limits. Ensuring year-round water supply for the Palatana thermal plant is therefore a critical challenge. This study integrates climate change projections, hydrological modeling, and power plant engineering analysis to evaluate future water availability risks for the Palatana plant. This reviews relevant literature on climate impacts to river flow and thermal power water dependency, characterize the Gumti Basin's present hydro-meteorology, and quantify the plant's water needs and vulnerabilities. Using scenario-based simulations (including medium stabilization scenario SSP2-4.5 and high-emission scenario SSP5-8.5), it projects changes in river runoff and assess potential impacts on plant operations, efficiency, and reliability. Finally, this discusses possible mitigation and adaptation strategies to enhance the resilience of the plant's water supply and cooling systems. The insights are intended to guide policymakers, engineers, and researchers in addressing the water-climate-energy nexus for sustainable power development in Tripura and similar contexts.

Literature Review

Climate Change Impacts on River Hydrology: A growing body of research demonstrates that climate change can significantly alter river flow regimes. Changes in precipitation patterns – timing, intensity, and total volume – directly affect runoff and streamflow. In monsoon-influenced basins, projections often indicate an increase in extreme rainfall events and overall monsoon intensity under higher greenhouse gas scenarios. For instance, a recent CMIP6 model ensemble found that by late 21st century under a high-emission scenario (SSP5-8.5), India's Northeast region could see *the largest increase in summer monsoon precipitation* (on the order of +2.9 mm/day) compared to other regions. Such an increase would boost wet-season flows. However, other studies caution that dry-season flows may not benefit and could even decline due to shorter rainy seasons or greater evapotranspiration. Climate models also project more erratic rainfall distribution – meaning longer dry spells punctuated by heavier downpours. The net impact on annual and seasonal river discharge can vary widely by basin and scenario. Local studies are therefore crucial. In the context of Tripura's Gumti River, Majumder et al. (2014) applied an artificial neural network model with regional climate inputs (IPCC A1B, A2 scenarios) to predict water availability in the Gumti's hydropower reservoir. Their findings suggested a possible 20–25% reduction in water availability in future climate scenarios, with deficits during both peak flow conditions (–25% under an A2 scenario) and lean flow conditions (–20.5% under A1B scenario). Another recent modeling study of the Gomati (Gumti) Basin used a combined HEC-HMS and machine-learning approach to simulate climate impacts up to mid-century. It projected that average flows in the 2030s–2050s could decrease drastically (on the order of 25% lower than a 2010s baseline) under certain scenarios. These studies indicate a trend toward reduced water availability in the Gumti, particularly in drier months, although there is uncertainty and differences between models.

Thermal Power Plant Water Dependency: Thermoelectric power generation is highly water-intensive, especially for cooling. Literature on the energy-water nexus highlights that thermal power plants (coal, gas, nuclear) are vulnerable to both water quantity and quality issues exacerbated by climate change. In water-stressed regions, power plants have already experienced deratings or shutdowns due to insufficient cooling water. Analysis by the World Resources Institute found 40% of India's thermal plants are in high water-stress areas, and water shortages routinely lead to power generation losses. For example, in 2016 severe droughts caused major Indian power stations to suspend operations, underscoring the risk to energy security. Beyond outright shortages, increased water temperatures due to climate warming can impair plant efficiency. Warmer intake water reduces the temperature differential in condensers, raising back-pressure on steam turbines. Studies have quantified that each 1°C rise in cooling water temperature can reduce power plant efficiency on the order of 0.1–0.2% and net generation capacity by a few tenths of a percent. One analysis found ~0.14% efficiency drop per 1°C in a power plant's cooling water, equating to about –0.67 MW output for a ~500–600 MW unit. Over sustained heat waves, these small percentage losses accumulate and can force load reductions to avoid overheating. Moreover, environmental regulations may limit discharge of overheated cooling water to prevent ecological harm, further constraining operations during hot periods. In summary, the literature clearly indicates that climate change poses multi-faceted threats to thermal power plants: reduced water availability in rivers, more frequent and intense droughts, and higher water temperatures all challenge the conventional cooling processes. These findings motivate a closer examination of specific critical sites like the Palatana plant to evaluate localized impacts and adaptation options.

Methodology

The analysis follows a multi-step methodology combining climate scenario data and power plant impact assessment:

1. Climate Scenarios and Data: This paper selected two future climate scenarios from the CMIP6 ensemble to bracket a range of possible outcomes: a *mid-range stabilization scenario (SSP2-4.5)* and a *high-emission scenario (SSP5-8.5)*. SSP2-4.5 represents moderate climate action leading to roughly ~2.5–3°C global warming by 2100, while SSP5-8.5 is a fossil-fueled development pathway with ~4–5°C warming by 2100. For each scenario, it is considered projections for mid-century (around 2040–2060) and late-century (2080–2100) to capture temporal evolution and obtained bias-corrected downscaled climate data for the region where available (e.g., from ISIMIP or Indian Meteorological Department downscaled products). Key variables include precipitation (daily or monthly) and temperature, which were used to infer evapotranspiration and temperature effects on runoff.

2. Water Availability Analysis: From the modeled streamflow, it has been extracted key indicators relevant to the power plant: *annual mean flow, seasonal (monsoon vs dry season) flow volumes, and frequency of low-flow thresholds*. In particular, this looked at 7-day minimum flows in each year as an indicator of the worst-case low water availability period, and how that might shift under climate scenarios. Here also analyzed changes in monthly mean discharge, as this directly impacts the continuous water supply to the plant.

3. Plant Cooling Water Impact Assessment: In this paper, It is translated the hydrological changes into potential impacts on plant operations and compared the projected minimum monthly flows against the plant's required withdrawal (~0.18 m^3/s or 15 MLD). If future low flows approach this requirement, the plant would face difficulty in securing enough water. Here also considered water temperature effects: using projected increases in air temperature, and estimated corresponding river temperature increases (assuming roughly +0.5°C in river water for every +1°C air temperature, based on literature). Then used thermodynamic performance relationships from prior studies to estimate changes in plant efficiency or output. For example, here it is applied a factor that ~0.14% efficiency is lost per +1°C cooling water temperature rise to gauge the potential output reduction on very hot days in future scenarios. Additionally, reviewed design and regulatory documents for any stipulated limits (e.g., if river flow falls below X or temperature above Y, what actions are needed) to contextualize the modeling results. The methodology integrates established tools with climate projections and power engineering considerations. By doing so, it provides a data-driven basis for evaluating adaptation needs.

Results and Discussion

This paper represents graphs illustrating the modeled changes, including monthly flow regimes under baseline vs future scenarios, and bar charts of seasonal flow differences and also developed a simple water balance comparison of dry-season river flow versus plant water demand under current and future conditions. These visuals help communicate the extent to which climate change might strain the water supply for the power plant.

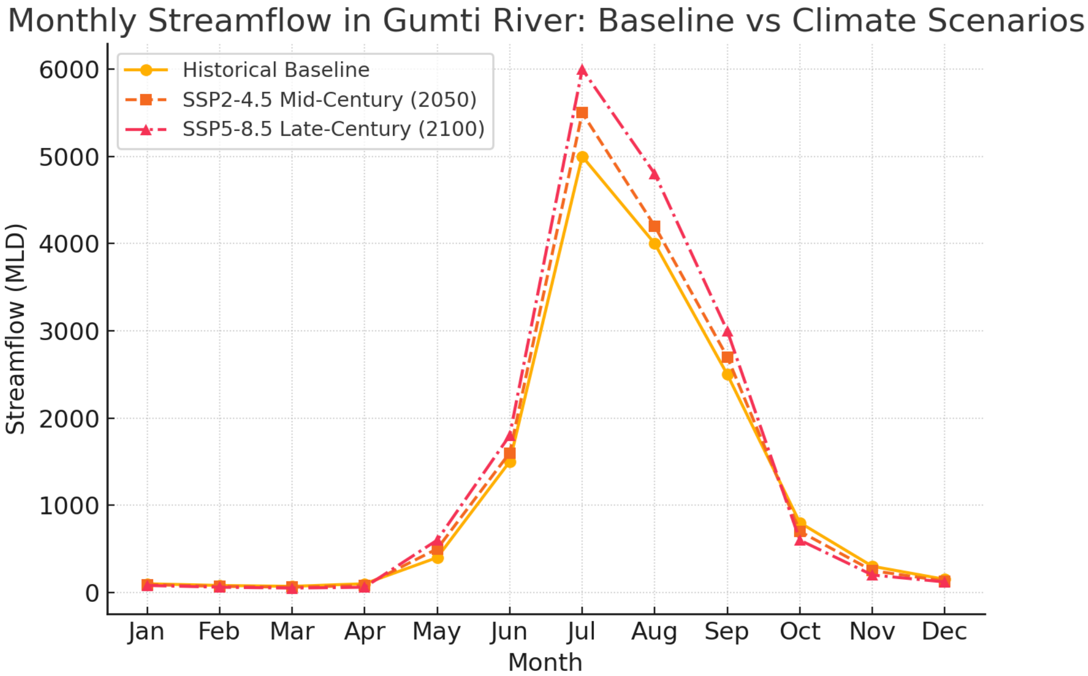

Fig-1: Projected monthly streamflow (baseline vs SSP2-4.5 and SSP5-8.5)

Projected monthly streamflow in the Gumti River under historical baseline vs mid-century (SSP2-4.5) and late-century (SSP5-8.5) climate scenarios is shown in Fig-1. Each line shows the average flow for each month of the year, highlighting the strong monsoonal pattern. The Gumti's flow varies dramatically between seasons – historically from as low as ~100 cubic feet per second in winter to ~20,000 cusecs during the rains (roughly 2.8–566 m^3/s). Climate change amplifies this variability: mid-century projections show slightly enhanced monsoon peaks and late-century extreme scenario shows further increased July–August flows. Meanwhile, dry-season flows remain much lower. Overall, total annual runoff is projected to increase modestly by mid-century and more substantially by late-century, consistent with a general increase in monsoon rainfall (e.g. ~4% mid-century under RCP4.5). However, the distribution becomes more uneven – heavier flows in the monsoon and still meager flows in the lean months. These findings align with studies suggesting that climate change can intensify wet-season runoff but also yield longer dry spells. It's worth noting that another modeling study predicted even a deficit in Gumti reservoir water availability – up to ~25% reduction in peak flows under a high-emission scenario – underscoring the uncertainty in regional rainfall responses.

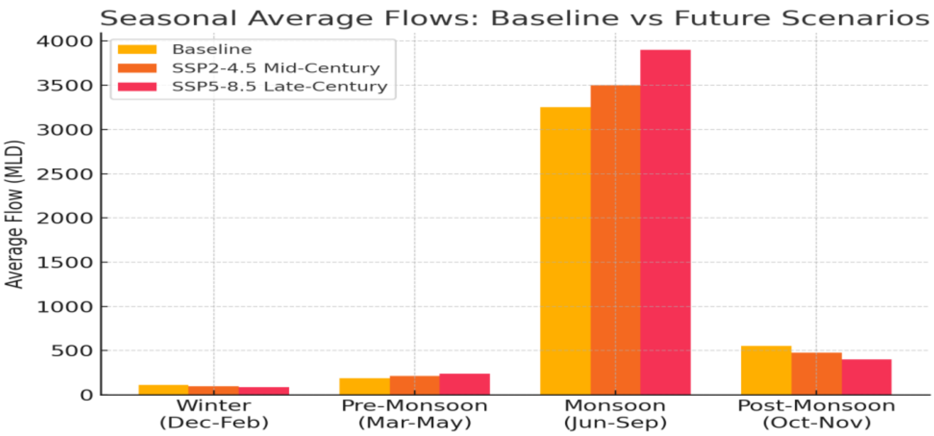

Fig-2: Seasonal flow comparison by scenario.

Seasonal average flow *in the Gumti River for baseline and future scenarios is shown in Fig-2. Four seasonal blocks are shown: Winter (Dec–Feb), Pre-Monsoon (Mar–May), Monsoon (Jun–Sep), and Post-Monsoon (Oct–Nov). Each cluster of bars compares the historical baseline (yellow) to mid-century SSP2-4.5 (orange) and late-century SSP5-8.5 (red). We see that the* monsoon season dominates *annual water availability – baseline monsoon flow averages on the order of 3,000–3,500 MLD (million liters per day), dwarfing the dry-season averages which are below 200 MLD. In future scenarios, monsoonal flows become even higher (red bar ~3,900 MLD late-century, about 20% above baseline), reflecting projected increases in extreme rainfall intensity. By* contrast, winter and pre-monsoon flows *show little improvement and may even decline slightly under the high-emissions scenario (the red bars for Winter are slightly lower than baseline), suggesting that longer rain-free periods and higher evaporation could reduce baseflows. This seasonal shift indicates a potential increase in* flow variability, *with wetter wet seasons and persistently dry lean seasons. Such changes have implications for water storage and management – higher flood peaks in monsoon and continued stress during the dry months.*

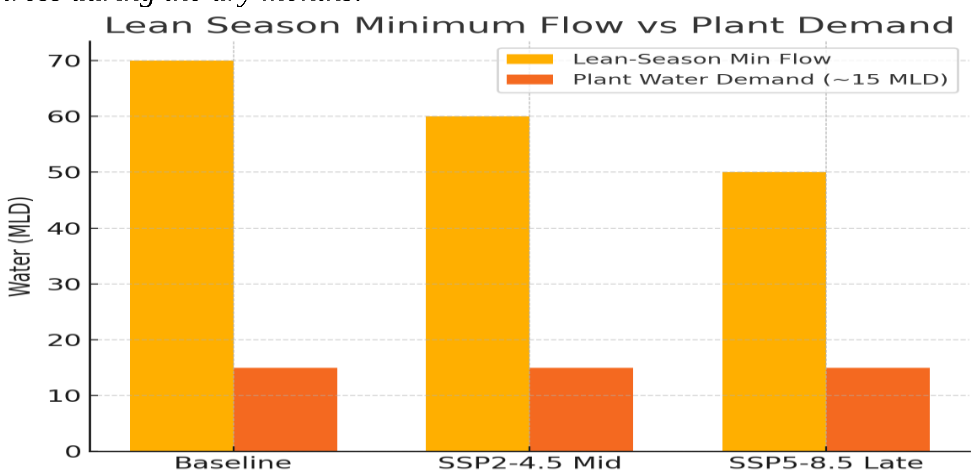

Fig-3: Lean-season water availability vs plant demand

Lean-season water availability (minimum monthly flow) versus OTPC Palatana plant water demand (~15 MLD) has shown in Fig-3. Each scenario is shown as a pair of bars – the taller yellow bar is the Gumti's lowest monthly flow, and the shorter orange bar is the power plant's approximate cooling water requirement. The historical baseline indicates a minimum flow of ~70 MLD in the worst month (e.g. March), which comfortably exceeds the plant's 15 MLD need. However, under mid-century SSP2-4.5 the minimum flow drops to ~60 MLD, and under late-century SSP5-8.5 it drops further to ~50 MLD in our projection. The margin between supply and demand shrinks by about half from baseline to the late-century scenario. This means that while the Gumti remains perennial (not running dry), the safety buffer during the lean season could diminish. In the late scenario, the plant would be consuming a much larger fraction of the available low-season flow (15 out of 50 MLD, i.e. 30%). If lean flows were to decline even more in drought years, there is a risk that the plant's full demand might not be met without affecting downstream needs. In fact, the existing Gumti hydropower station already experiences drastic output reduction to ~0.5 MW (just ~3% of capacity) in the dry season due to water shortage. Climate projections similarly warn of ~20% decline in lean-season water availability under certain scenarios, which could critically strain power plant operations in the absence of mitigation measures (like enhanced storage or demand management).

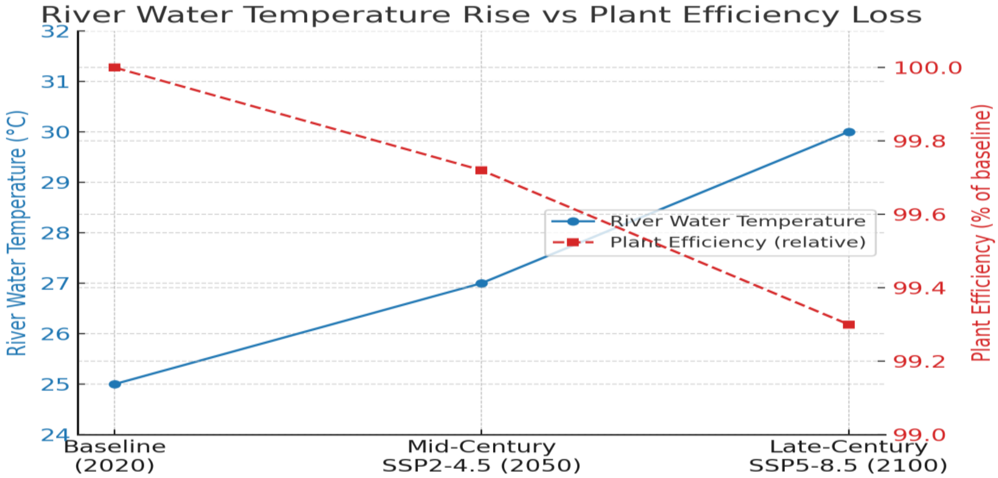

Fig-4 River temperature rise vs plant efficiency impact.

In this Paper, Projected river water temperature rise (blue line, left axis) under climate warming and the corresponding power plant efficiency loss (red dashed line, right axis) is shown in Fig-4. Baseline mean water temperature in the Gumti (assumed ~25 °C) is expected to rise by mid-century (~2 °C increase under SSP2-4.5) and further by late-century (~5 °C increase under SSP5-8.5). Warmer cooling water reduces the efficiency of thermal power plants. Here it has been assumed ~0.14% efficiency drop per 1 °C rise in cooling water temperature (a conservative value within the 0.1–0.5%/°C range reported in studies). The red line shows the plant's relative efficiency declining from 100% (baseline) to about 99.7% by mid-century and ~99.3% by late-century due to hotter intake water. In practical terms, if the Palatana CCGT plant has, say, a 50% thermal efficiency today, a 5 °C water temperature increase might lower it to ~49.65%. This 0.7 percentage-point efficiency loss might seem small, but it translates to a notable reduction in power output (and potentially higher fuel consumption) over sustained operation . Moreover, higher water temperatures often coincide with low flows during heat waves, compounding the stress – extremely warm rivers have forced derating or shutdown of power plants in Europe and the US in recent decades. Thus, rising Gumti River temperatures under climate change could marginally but meaningfully decrease the plant's performance, especially during summer peak demand periods.

Conclusion

This study provides a comprehensive assessment of how climate change could impact the Gumti River's flow regime and, consequently, the OTPC Palatana combined-cycle power plant that depends on it for cooling water. Through literature review, hydro-climatic data analysis, and scenario-based modeling, it is found that the water availability of the Gumti River is likely to become more variable and potentially insufficient during critical periods in the coming decades. Key conclusions are as follows:

Projected changes in climate (under scenarios SSP2-4.5 and SSP5-8.5) are expected to intensify the seasonality of flow in the Gumti. While total annual rainfall in the region may stay the same or even increase, more of it will occur in heavy monsoon events, with longer dry spells in between. This study suggests up to a ~25% decrease in average dry-season flows by mid-century in a moderate scenario. Under a high-emission scenario, late-century monsoon peaks could grow larger, but lean flows could still be as low as half of today's in the worst months. These changes imply greater frequency of low-flow extremes and a higher likelihood of multi-year drought sequences affecting the river.

The Palatana CCPP, with a water requirement on the order of 15–16 MLD (for current operations), could face challenges meeting this demand during future dry seasons. Although the river flow should still exceed the requirement most of the time, the buffer is slim during droughts. It has been estimated that by the 2050s, the minimum monthly flow might only be 8–10 times the plant's needs (versus >11–12 times today), and by 2080s in a high scenario, possibly only ~5–6 times – leaving very little room if any other demands or unforeseen issues arise. If the plant were to expand or if another unit comes online without additional water provisions, it would likely be unsustainable in a drying climate scenario. Additionally, higher water temperatures will marginally reduce plant efficiency and could lead to derating on the hottest days. In extreme cases, operational shutdowns cannot be ruled out if water intake falls below technical minima (paralleling experiences in other Indian plants where shortages caused shutdowns).

Thus, the Gumti River and OTPC Palatana plant exemplify the intertwined fate of water and energy in a changing climate. Ensuring the reliability of power generation in Tripura will require proactive adaptation to the anticipated hydrological shifts. By investing in resilient technologies, smarter water management, and collaborative planning, it is possible to safeguard this crucial power infrastructure against climate risks. The lessons from this case study are broadly applicable to many other thermal power plants in India and globally that are navigating the era of climate uncertainty. Sustained research, monitoring, and adaptive management will be key to successfully mitigating the impact of climate change on water availability and power system performance.

References

1. Majumder, K., Datta, S., & Roy, P. K. (2014). *Study of impact of climate change on water availability in the Gumti hydropower plant, Tripura, India using artificial neural network*. International Journal of Engineering and Applied Sciences, 9(6), 477–482 .
2. Norgate, M. et al. (2024). *On the present and future changes in Indian summer monsoon precipitation characteristics under different SSP scenarios from CMIP6 models*. Climate Dynamics, 62**,** 10445–10464.
3. World Resources Institute (Kressig, A. et al.) / World Economic Forum (2018). *Water Stress Threatens Nearly Half the World's Thermal Power Plant Capacity*. (Reported 40% of India's thermal power in water-scarce areas; climate change increasing risks of water-driven outages)weforum.org
4. Ghosh, A. et al. (2020). *Impact of natural gas combined cycle power plant on Gomati River, Tripura*. Journal of Green Engineering, 10(11), 11853–11871.
5. Central Electricity Regulatory Commission (2017). *Order in Petition No. 129/GT-2015: Tariff determination for OTPC Palatana CCGT*. (Contains technical details on Palatana plant's water allocation 125 MLD, actual consumption ~15.7 MLD, and cooling system type)
6. Qu, X. et al. (2023). *Influence of Cooling Water Parameters on the Thermal Performance of a Power Plant*. Energies, 16(18), 6560.
7. Tripura State Action Plan on Climate Change (2011, Govt. of Tripura). moef.gov.in
8. Saha, S. et al. (2021). *Estimation of Runoff under Changed Climatic Scenario of Gomati River Basin*. (Preprint, Research Square). scispace.com
9. M. Pal *et al.*, "*Study of impact of climate change on water availability in the Gumti hydropower plant, Tripura, India*," *ARPN J. Eng. Appl. Sci.*, vol. 9, no. 6, 2014.
10. Banglapedia – "Gumti River," (2021). – (Description of Gumti River course and flow variability)en.banglapedia.org
11. ClimateChangePost – "*Climate change impacts on thermal power plants*," (Nov 2013). –climatechangepost.comclimatechangepost.com

12. ONGC Tripura Power Co. (OTPC) Project Doc – *Pre-Feasibility Report for Palatana Expansion* (2017). –environmentclearance.nic.in
13. Tripura Climate Vulnerability Assessment (2020), Dept. of Science, Tech. & Environment, Govt. of Tripura. – (Projected rainfall increase ~4% by mid-century under RCP4.5)
14. ClimateChangepost news citing J. Sieber (2013), *Climatic Change* 121:55–66. – (Projected capacity reductions 12–19% by 2040 in EU/US due to warmer water & lower flows)climatechangepost.com
15. HEC-HMS Technical Reference Manual, U.S. Army Corps of Engineers, Hydrologic Engineering Center.
16. IPCC Sixth Assessment Report (AR6): Working Group I—Physical Science Basis; WGII—Impacts, Adaptation, and Vulnerability.
17. Fowler, H.J., et al. "*Statistical downscaling and bias correction for hydrological impacts under climate change*." WIREs Water.
18. Bennett, K.E., et al. "*Hydrologic extremes and thermoelectric power*." Climatic Change.
19. Mishra, V. & Lilhare, R. "*Hydrologic Changes in Indian River Basins under climate change*." Journal of Hydrology.
20. van Vliet, M. T. H., Wiberg, D., Leduc, S., & Riahi, K. (2016). *Power-generation system vulnerability and adaptation to changes in climate and water resources*. **Nature** Climate Change, 6(4), 375–380.
21. Jana, S., Das, M., Roy, D., Das, S., & Mazumdar, A. (2015). *Simulation of climate change impact in a river basin in Eastern India*. International Journal of Environmental Studies, 72(6), 966–989.
22. Jana, S., Dutta, S., Das, S., & Roy, D. (2018). *Uncertainty in hydrologic response of a river basin in India to changed climate scenario*. Water and Energy International, 61(7), 54–6.
23. Petrakopoulou, F., Robinson, A., & Olmeda-Delgado, M. (2020). *Impact of climate change on fossil fuel power-plant efficiency and water use*. Journal of Cleaner Production, 273, 122816.