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THERMAL POWER PLANT BENCHMARKING REPORT 2026

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FOREWORD



India's energy landscape is undergoing a profound transformation. As the nation pursues sustained economic growth and rising electricity demand, the need for reliable, affordable and sustainable power has never been greater. Energy security has become the new challenge in present senerio. While renewable energy is expanding rapidly, thermal power continues to play a critical role in ensuring grid stability, reliability and energy security.

The imperative before the sector is to strengthen this role through higher efficiency, operational excellence, responsible resource utilization and giving reliable power at an affordable cost.

In this evolving landscape, energy benchmarking is more than a measure of performance—it is a catalyst for improvement. It enables power plants to assess their performance against industry peers, identify performance gaps, learn from best practices and establish pathways towards sustained operational excellence.

The Thermal Power Plant Benchmarking Report 2026 for Indian Thermal Power Plants, developed by the CII–Sohrabji Godrej Green Business Centre (CII-GBC), is intended to serve as a credible and practical reference for the Indian thermal power sector. The benchmarks presented in this report are based on operational and performance data submitted by participating thermal power plants under the 27th CII National Awards for Excellence in Energy Management – 2026, complemented by technical insights from domain experts.

The true value of benchmarking lies not merely in knowing where a plant stands, but in understanding how far it can progress. The insights presented in this report can help utilities optimize auxiliary power consumption, improve equipment and system performance, strengthen operating practices, reduce energy losses and accelerate the adoption of proven best practices.

I sincerely acknowledge the valuable contributions of all participating power plants, energy professionals, engineers and domain experts whose collective efforts have made this initiative possible.

May this report serve not only as a benchmark of where we stand today, but as a catalyst for the excellence we aspire to achieve tomorrow.

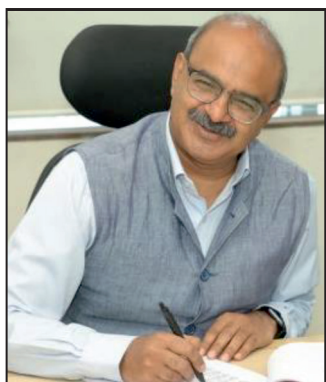
(Ajay Sharma)

Executive Director- (Operations Services)

NTPC Limited

Chairman- Power Plant Summit 2026

MESSAGE FROM THE CO-CHAIR



India's power sector is witnessing a rapid transformation driven by the need for reliable electricity, enhanced energy efficiency, and sustainable growth. While the energy mix continues to diversify, thermal power plants remain essential for ensuring grid stability and supporting the nation's energy security objectives. In this evolving landscape, energy benchmarking has emerged as a valuable tool for assessing performance, identifying opportunities for improvement, and fostering a culture of operational excellence.

This publication, Thermal Power Plant Benchmarking Report- 2026 for Indian thermal power plants, has been developed by the CII-Sohrabji Godrej Green Business Centre (CII-GBC) to provide thermal power utilities with a practical reference for evaluating their energy performance. The benchmark values presented in this report are based on industry data and expert inputs and are intended to serve as indicative reference points for performance comparison and continuous improvement.

I sincerely acknowledge the contributions of the participating thermal power plants and experts whose support has been instrumental in the development of this publication. I trust that this report will serve as a useful resource for plant managers, engineers, energy professionals, and policymakers in their efforts to enhance energy performance and build a more efficient and sustainable thermal power sector in India.

Dr. Dharmendra Shrivastava

Chief Executive & Whole Time Director

L&T- MHI Power Turbine Generators Pvt. Ltd.

Task Force Leader- L&T- MHI Power Boilers Pvt. Ltd.

Co-Chair- Power Plant Summit 2026

ACKNOWLEDGEMENT

The Confederation of Indian Industry – Sohrabji Godrej Green Business Centre (CII- GBC) extends its sincere gratitude to all the organisations and individuals whose valuable contributions have made the publication of **Thermal Power Plant Benchmarking Report 2026** possible.

We are especially grateful to the thermal power plants that participated in the CII National Awards for Excellence in Energy Management and generously shared their operational and performance data. Their commitment to energy efficiency, transparency, and continuous improvement has provided the foundation for developing meaningful benchmark values that will benefit the thermal power sector.

We also express our appreciation to the distinguished jury members and domain experts associated with the CII National Awards for Excellence in Energy Management. Their rigorous evaluation process and technical expertise have played an important role in promoting excellence in energy management and encouraging the adoption of best-in-class practices across the thermal power industry.

Finally, we express our sincere appreciation to all the stakeholders of the thermal power sector. The collaborative effort reflects a shared vision to foster cleaner, smarter, and more flexible energy sector practices, supporting India's ambitious climate and clean energy goals.

The list of domain experts in alphabetical order is as follows:

- **Mr. Amitava Roy**, Former Executive Director, NTPC Ltd.
- **Mr. C. V. Prasad Rao**, MD & CEO, Adeptus Consulting, Former Sr. Vice President & Project Director- Reliance Infra
- **Mr. D. K. Agrawal**, Director- Efficient Powertech Solutions (P) Ltd., Former Executive Director, NTPC Ltd.
- **Mr. Pankaj Bhartiya**, Director- Efficient Powertech Solutions (P) Ltd., Former General Manager and Head of CenPEEP, NTPC Ltd.
- **Dr. Pradip Chanda**, Professor (Adjunct), NTPC School of Business, Former Head, Operations & Efficiency, NTPC Ltd.

An aerial photograph of a nuclear power plant at dusk. Two large, white, hourglass-shaped cooling towers are the central focus, each emitting a thick plume of white steam that rises into the darkening sky. The plant's various buildings and piping are illuminated by warm yellow lights, contrasting with the cool blue tones of the twilight. In the background, a range of mountains is visible under a deep blue sky. The foreground shows a dark, silty river or reservoir, a road with streetlights, and some industrial buildings. The overall scene conveys a sense of industrial activity and energy production.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

India's power sector is undergoing a significant transformation driven by rapid growth in electricity demand, increasing renewable energy integration, decarbonisation commitments, and the need for reliable and affordable power. While renewable energy capacity continues to expand rapidly, coal-based thermal power plants remain the backbone of the Indian electricity system, contributing the majority of annual generation and providing critical grid-balancing support. In this evolving energy landscape, improving efficiency, flexibility, and environmental performance of thermal power plants has become increasingly important.

This report presents an energy benchmarking study of Indian coal-based thermal power plants based on operational and performance data submitted by participating organisations under the CII's National Awards for Excellence in Energy Management 2026. The study covers key performance indicators including Station Net Heat Rate (SNHR), Station Gross Heat Rate (SGHR), Design Station Gross Heat Rate (D-SGHR), Auxiliary Power Consumption (APC), Boiler Efficiency, Flexibility Readiness, Water Consumption, Ash Utilisation, and Carbon Dioxide (CO₂) Emission Intensity (Scope-1).

Plants have been categorised into three groups based on installed capacity: 300 MW (average station capacity between 150 and 350 MW), 600 MW (average station capacity between 500 and 600 MW), and 660 MW (average station capacity above 600 MW).

The benchmarking results clearly demonstrate that larger supercritical units consistently outperform smaller and older subcritical units across most performance indicators. These results highlight the benefits of advanced steam-cycle technology, higher operating parameters, improved turbine efficiency, lower auxiliary consumption, and modern process control systems.

Key Findings (Best performing top 3 plants for each KPI)

1. Station Net Heat Rate- SNHR (kcal/kWh)

1.1 SNHR: 300 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest SNHR Value	kcal/kWh	2450	2482	2542
Year of Establishment		2010	2013	2000
Turbine Heat Rate (THR)	kcal/kWh	1975	2012	2042
Auxiliary Power Consumption (APC)	%	7.6	6.76	7.58
Boiler Efficiency	%	87.3	86.9	86.9
Coal Type	-	Indian	Indian	Indian
Coal GCV	kcal/kg	3400-3600	3100-3300	3800-4000

1.2 SNHR: 600 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest SNHR Value	kcal/kWh	2377	2408	2434
Year of Establishment		2015	2014	2007
Turbine Heat Rate (THR)	kcal/kWh	1953	1977	1975
Auxiliary Power Consumption (APC)	%	5.11	5.15	6.46
Boiler Efficiency	%	86.6	87.4	86.7
Coal Type	-	Indian	Indian	Indian
Coal GCV	kcal/kg	3100-3300	3100-3300	2900-3100

1.3 SNHR: 660 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest SNHR Value	kcal/kWh	2232	2251	2275
Year of Establishment		2020	2023	2008
Turbine Heat Rate (THR)	kcal/kWh	1782	1819	1867
Auxiliary Power Consumption (APC)	%	7.15	6.94	4.70
Boiler Efficiency	%	86.0	86.8	86.1
Coal Type	-	Indian	Blended	Indian
Coal GCV	kcal/kg	2800-3000	3300-3500	3600-3800

2. Deviation in Design vs Operating Station Gross Heat Rate

2.1 Deviation in SGHR for 300 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Turbine Heat Rate	kcal/kWh	1964	1975	2062
Boiler Efficiency	%	85.0	87.0	86.0
Station Gross Heat Rate	kcal/kWh	2309	2264	2387
Design Turbine Heat Rate	kcal/kWh	1944	1944	2049
Design Boiler Efficiency	%	85.0	87.0	87.0
Design Station Gross Heat Rate	kcal/kWh	2288	2238	2342
Deviation	%	0.90	1.13	1.93
Year of Establishment	-	2019	2010	1982
Coal GCV	kcal/kg	3600-3900	3400-3600	3700-3900

2.2 Deviation in SGHR for 600 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Turbine Heat Rate	kcal/kWh	1953	1997	1975
Boiler Efficiency	%	86.58	87.43	86.73
Station Gross Heat Rate	kcal/kWh	2256	2284	2277
Design Turbine Heat Rate	kcal/kWh	1927	1944	1946
Design Boiler Efficiency	%	86.8	86.37	86.91
Design Station Gross Heat Rate	kcal/kWh	2225	2251	2239
Deviation	%	1.37	1.48	1.70
Year of Establishment	-	2015	2014	2007
Coal GCV	kcal/kg	3100-3300	3100-3300	2900-3100

2.3 Deviation in SGHR for 660 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Turbine Heat Rate	kcal/kWh	1782	1949	1869
Boiler Efficiency	%	85.98	85.96	85.48
Station Gross Heat Rate	kcal/kWh	2072	2268	2186
Design Turbine Heat Rate	kcal/kWh	1781	1917	1816
Design Boiler Efficiency	%	86.19	85.82	85.01
Design Station Gross Heat Rate	kcal/kWh	2066	2234	2136
Deviation	%	0.30	1.50	2.35
Year of Establishment	-	2020	2008	2021
Coal GCV	kcal/kg	2800-3000	3400-3600	2700-2900

3. Auxiliary Power Consumption- APC (%)

3.1 APC: 300 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest APC	%	6.76	7.58	7.60
Year of Establishment	-	2013	2000	2010
Coal Type	Indian/Imported	Indian	Imported	Indian
Type of BFP	TDBFP/MDBFP	TDBFP	MDBFP	MDBFP
Type of Cooling Tower (CT)	IDCT/NDCT	IDCT	IDCT	IDCT
Condenser Type	-	Water Cooled	Water Cooled	Water Cooled
Coal GCV	kcal/kg	3000-3200	5600-5800	3400-3600

3.2 APC: 600 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest APC	%	5.11	5.15	5.59
Year of Establishment	-	2015	2014	2011
Coal Type	Indian/Imported	Indian	Indian	Indian
Type of BFP	TDBFP/MDBFP	TDBFP	TDBFP	TDBFP
Type of Cooling Tower (CT)	IDCT/NDCT	IDCT	NDCT	IDCT
Condenser Type	-	Water Cooled	Water Cooled	Water Cooled
Coal GCV	kcal/kg	3100-3300	3100-3300	3600-3800

3.3 APC: 660 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest APC	%	4.45	4.70	5.67
Year of Establishment	-	2007	2008	2019
Coal Type	Indian/Imported	Indian	Indian	Blended
Type of BFP	TDBFP/MDBFP	TDBFP	TDBFP	TDBFP
Type of Cooling Tower (CT)	IDCT/NDCT	NDCT	NDCT	IDCT
Condenser Type	-	Water Cooled	Water Cooled	Water Cooled
Coal GCV	kcal/kg	3600-3800	3600-3800	3600-3800

4. Boiler Efficiency (%)

4.1 Boiler Efficiency: 300 MW

Parameter	Unit	Plant-1	Plant-2	Plant-3
Highest Boiler Efficiency	%	87.25	86.93	86.89
Year of Establishment		2010	2013	2000
Fuel Type	Indian/Imported	Indian	Indian	Imported
GCV of Fuel	kcal/kg	3500-3600	3100-3200	5700-5800
O ₂ Level	%	2.80	3.36	4.22
Exit Flue Gas Temperature	°C	146	130	140

4.2 Boiler Efficiency: 600 MW

Parameter	Unit	Plant-1	Plant-2	Plant-3
Highest Boiler Efficiency	%	87.43	86.85	86.83
Year of Establishment		2014	2008	2011
Fuel Type	Indian/Imported	Indian	Indian	Indian
GCV of Fuel	kcal/kg	3200-3400	3800-4000	3700-3900
O ₂ Level	%	3.0	3.50	2.72
Exit Flue Gas Temperature	°C	142	140	133

4.3 Boiler Efficiency: 660 MW

Parameter	Unit	Plant-1	Plant-2	Plant-3
Highest Boiler Efficiency	%	88.0	87.68	86.12
Year of Establishment		2014	2007	2023
Fuel Type	Indian/Imported	Imported	Indian	Indian
GCV of Fuel	kcal/kg	5200-5400	3700-3800	3600-3800
O ₂ Level	%	4.25	2.7	3.2
Exit Flue Gas Temperature	°C	145	131	130

5. Flexible Operation Readiness

5.1 Subcritical Plant

Parameter	Unit	Plant-1	Plant-2	Plant-3
Highest Flexibility Readiness	%	65.1	64.2	63.8
Year of Establishment		2010	1993	2013
Mode of Operation	-	Sliding Pressure	Sliding Pressure	Sliding Pressure
Modified SOP	Y/N	Yes	Yes	Yes
Extended MTM	Y/N	Yes	Yes	Yes
SCAPH Installed	Y/N	Yes	Yes	Yes
Regulating R/C for BFP	Y/N	Yes	Yes	Yes
Improved Flame Scanners	Y/N	No	Yes	No
Type of Coal		Indian	Indian	Blended
GCV of Coal	kcal/kg	3600-3800	3500-3700	3600-3800

5.2 Supercritical Plant

Parameter	Unit	Plant-1	Plant-2	Plant-3
Highest Flexibility Readiness	%	69.03	66.7	62.5
Year of Establishment		2008	2019	2023
Mode of Operation	-	Sliding Pressure	Sliding Pressure	Sliding Pressure
Modified SOP	Y/N	Yes	Yes	Yes
Extended MTM	Y/N	Yes	Yes	Yes
SCAPH Installed	Y/N	Yes	Yes	Yes
Regulating R/C for BFP	Y/N	Yes	Yes	Yes
Improved Flame Scanners	Y/N	No	Yes	No
Type of Coal		Indian	Indian	Blended
GCV of Coal	kcal/kg	3600-3800	3500-3700	3600-3800

6. Emission Intensity (kg CO₂/kWh):

6.1 Emission Intensity: 300 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest Emission Intensity	kg CO₂/kWh	0.901	0.913	0.935
Year of Establishment		2010	2013	2019
Boiler Efficiency	%	87.25	86.93	85.09
Turbine Heat Rate	kcal/kWh	1975	2012	1964
APC	%	7.6	6.76	9.18
Type of Fuel	Indian/ Imported	Indian	Indian	Indian
Coal GCV	kcal/kg	3500-3600	3100-3300	3700-3900

6.2 Emission Intensity: 600 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest Emission Intensity	kg CO₂/kWh	0.874	0.885	0.895
Year of Establishment		2015	2014	2007
Boiler Efficiency	%	86.58	87.43	86.73
Turbine Heat Rate	kcal/kWh	1953	1997	1975
APC	%	5.11	5.15	6.46
Type of Fuel	Indian/ Imported	Indian	Indian	Indian
Coal GCV	kcal/kg	3200-3300	3200-3400	3000-3200

6.3 Emission Intensity: 660 MW category

Parameter	Unit	Plant-1	Plant-2	Plant-3
Lowest Emission Intensity	kg CO₂/kWh	0.821	0.828	0.836
Year of Establishment	-	2020	2023	2008
Boiler Efficiency	%	85.98	86.82	86.12
Turbine Heat Rate	kcal/kWh	1782	1819	1867
APC	%	7.15	6.94	4.7
Type of Fuel	Indian/ Imported	Indian	Blended	Indian
Coal GCV	kcal/kg	2800-3000	3600-3800	3600-3800

Strategic Insight:

- The benchmark results establish that plant performance is strongly influenced by a combination of technology, operating practices, equipment condition, maintenance excellence, and process optimisation.
- Performance is not necessarily determined by the plant's vintage or age. In many cases, a well-maintained and effectively operated plant can outperform a newly commissioned facility.
- Sustainable high performance is primarily driven by robust operational and maintenance strategies, disciplined execution, and continuous improvement practices rather than the relative age of the assets.

Looking ahead, thermal power plants will increasingly be required to operate under variable loading conditions to complement renewable energy generation. Consequently, future competitiveness will depend not only on efficiency but also on operational flexibility, faster ramping capability, lower technical minimum load, reduced emissions, and improved resource utilisation.

Conclusion:

- A key finding of this benchmarking study is the need to reduce the gap between design parameters and actual operating performance. Improving heat rate, steam cycle efficiency, auxiliary power consumption, and equipment reliability through sustained performance monitoring and optimisation can deliver significant efficiency gains and emissions reductions.
- Biomass co-firing has emerged as an important pathway for reducing the carbon intensity of coal-based power generation. Wider adoption of biomass, along with improved fuel quality management and combustion optimisation, can support decarbonisation while maintaining grid reliability.
- Further opportunities for improving cycle efficiency and sustainability lie in condenser performance enhancement, waste heat recovery, reduction of auxiliary power consumption, advanced water management, and modernisation of aging equipment. These measures can collectively improve plant competitiveness and environmental performance.
- The increasing adoption of Artificial Intelligence (AI) and advanced analytics offers significant potential for thermal power plants. AI-enabled predictive maintenance, real-time performance optimisation, anomaly detection, and intelligent decision support can enhance efficiency, reliability, and operational excellence.

The findings reaffirm that efficiency improvement and decarbonisation are mutually reinforcing objectives. By narrowing the design-to-operation performance gap, expanding biomass utilisation, and leveraging AI-driven solutions, thermal power plants can accelerate their transition toward cleaner, more efficient, and sustainable operations.

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ABBREVIATIONS

Abbreviation	Full Form
AFBC	Atmospheric Fluidized Bed Combustion
AHP	Ash Handling Plant
AI	Artificial Intelligence
APC	Auxiliary Power Consumption
APFC	Automatic Power Factor Correction
APH	Air Preheater
AT	Air Temperature
BEE	Bureau of Energy Efficiency
BESS	Battery Energy Storage System
BFP	Boiler Feed Pump
BMCR	Boiler Maximum Continuous Rating
BTG	Boiler Turbine Generator
BU	Billion Units
CBAM	Carbon Border Adjustment Mechanism
CBD	Continuous Blowdown
CEA	Central Electricity Authority
CEMS	Continuous Emission Monitoring System
CEP	Condensate Extraction Pump
CERC	Central Electricity Regulatory Commission
CCUS	Carbon Capture, Utilisation and Storage
CFBC	Circulating Fluidised Bed Combustion
CMD	Contract Maximum Demand
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
COP	Coefficient of Performance
CPP	Captive Power Plant
CT	Cooling Tower
CW	Cooling Water

Abbreviation	Full Form
CWP	Cooling Water Pump
D-SGHR	Design Station Gross Heat Rate
DCA	Drain Cooler Approach
DCS	Distributed Control System
DM	Demineralised Water
EC	Economiser
EMS	Energy Management System
ECR	Energy Consumption Ratio
ESP	Electrostatic Precipitator
FD Fan	Forced Draft Fan
FGD	Flue Gas Desulphurisation
FG	Flue Gas
GCV	Gross Calorific Value
GEF	Grid Emission Factor
GENCO	Generation Company
GHG	Greenhouse Gas
GT	Gross Generation
GWh	Gigawatt-hour
HP	High Pressure
HPH	High Pressure Heater
HRSG	Heat Recovery Steam Generator
ID Fan	Induced Draft Fan
IDCT	Induced Draught Cooling Tower
IEA	International Energy Agency
IE3	International Efficiency Class 3 Motor
IE4	International Efficiency Class 4 Motor
IP	Intermediate Pressure
IPP	Independent Power Producer
kcal	Kilocalorie
kg	Kilogram

Abbreviation	Full Form
KPI	Key Performance Indicator
kWh	Kilowatt-hour
LDO	Light Diesel Oil
LP	Low Pressure
LPH	Low Pressure Heater
MCR	Maximum Continuous Rating
MDBFP	Motor Driven Boiler Feed Pump
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoP	Ministry of Power
MS	Main Steam
MTM	Metal Temperature Monitoring
MU	Million Units
MW	Megawatt
MWh	Megawatt-hour
NCR	National Capital Region
NCV	Net Calorific Value
NDC	Nationally Determined Contribution
NDCT	Natural Draught Cooling Tower
NITI Aayog	National Institution for Transforming India
NO _x	Nitrogen Oxides
NTPC	National Thermal Power Corporation
O&M	Operation and Maintenance
O-SGHR	Operating Station Gross Heat Rate
OEM	Original Equipment Manufacturer
O ₂	Oxygen
PA	Primary Air
PA Fan	Primary Air Fan
PAT	Perform, Achieve and Trade
PC	Pulverised Coal

Abbreviation	Full Form
PF	Pulverised Fuel
PLF	Plant Load Factor
PSP	Pumped Storage Project
RE	Renewable Energy
RH	Reheater
R&M	Renovation and Modernisation
SA	Secondary Air
SA Fan	Secondary Air Fan
SCAPH	Steam Coil Air Preheater
SCR	Selective Catalytic Reduction
SEC	Specific Energy Consumption
SFC	Specific Fuel Consumption
SGHR	Station Gross Heat Rate
SH	Superheater
SHR	Station Heat Rate
SNHR	Station Net Heat Rate
SO ₂	Sulphur Dioxide
SOP	Standard Operating Procedure
TDBFP	Turbine Driven Boiler Feed Pump
TG	Turbo Generator
THR	Turbine Heat Rate
TTD	Terminal Temperature Difference
TWh	Terawatt-hour
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery
ZLD	Zero Liquid Discharge

OVERVIEW OF THE INDIAN POWER SECTOR

1. OVERVIEW OF THE INDIAN POWER SECTOR

1.1 Introduction

The Indian power sector is one of the largest and fastest-growing electricity systems globally and plays a pivotal role in supporting the country's economic growth, industrial development, urbanisation, and improving quality of life. Over the past two decades, India has significantly expanded its generation capacity while simultaneously improving transmission infrastructure, grid reliability, and universal electricity access. The sector has undergone a major transformation with increasing private sector participation, integration of renewable energy, implementation of competitive electricity markets, and adoption of advanced operational practices.

India's per capita electricity consumption has risen steadily over the past decade, reflecting increasing electrification, industrialisation, urbanisation, and improved access to reliable power. Per capita consumption reached 1,460 kWh in FY 2024-25, up from 957 kWh in FY 2013-14, representing a growth of nearly 52.6% in the last decade.¹ The rise in demand reflects the country's economic growth, rising electrification levels, and increasing energy consumption across sectors. A major milestone was achieved on 01 May 2026 when India successfully met its highest-ever peak electricity demand of 270.8 GW. The demand was met through a diversified generation mix comprising thermal, hydro, nuclear and renewable energy resources.

India's power sector development strategy is closely aligned with its commitments under the Paris Agreement through its Nationally Determined Contributions (NDCs). Under its NDC for the 2031-35 period, India has committed to reducing the emissions intensity of its GDP by 47% from 2005 levels by 2035. The country has also set ambitious targets to achieve 60% of its cumulative installed electricity generation capacity from non-fossil fuel-based energy sources and to create an additional carbon sink of 3.5-4.0 billion tonnes of CO₂ equivalent through enhanced forest and tree cover by 2035². India has consistently demonstrated strong progress toward its climate objectives, notably achieving the milestone of 50% installed power capacity from non-fossil fuel sources in 2025, five years ahead of its original 2030 target. These achievements reflect the country's commitment to pursuing sustainable economic growth while accelerating the transition toward a low-carbon energy system.³

Despite the rapid deployment of renewable energy, coal-based thermal power plants continue to form the backbone of India's electricity generation system because of their capability to provide reliable base-load generation and grid balancing services. According to the Central Electricity Authority (CEA), thermal generation contributes the largest share of annual electricity generation due to its higher plant utilisation compared to renewable energy sources. Consequently, improving the operational efficiency of existing thermal power plants remains one of the most cost-effective strategies for reducing fuel consumption, lowering greenhouse gas emissions, and minimizing the cost of electricity generation.⁴

The Government of India has adopted a dual approach of expanding renewable energy while simultaneously improving the efficiency, flexibility, and environmental performance of the existing thermal fleet. This approach is reflected in the National Electricity Plan, National Electricity Policy, Perform, Achieve and Trade (PAT) scheme, Renovation and Modernisation (R&M) programs, biomass co-firing initiatives, and flexible operation guidelines issued for coal-fired generating stations.⁵

¹ <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2215187®=48&lang=2>

² <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2245209®=3&lang=1>

³ <https://www.pib.gov.in/FactsheetDetails.aspx?Id=149232®=48&lang=2>

⁴ CEA - Monthly Reports

⁵ Scenarios-Towards-Viksit-Bharat-and-Net-Zero-Sectoral-Insights-Power.pdf

1.2 Installed Capacity

India's installed power generation capacity has undergone a significant transformation over the last decade, driven largely by the rapid expansion of renewable energy (RE). Renewable energy capacity increased from 89 GW in 2016 to 291 GW in 2026, registering a robust CAGR of approximately 11.9%, reflecting the country's strong policy focus on clean energy adoption and energy transition. In contrast, thermal power capacity grew more gradually, from 211 GW to 251 GW during the same period, resulting in a CAGR of approximately 1.7%. While thermal power continues to play a critical role in ensuring grid stability and meeting baseload demand, the substantially higher growth rate of renewables highlights India's strategic shift towards a cleaner and more diversified energy mix. As a result, renewables have emerged as the primary driver of capacity additions, significantly increasing their share in the country's overall installed capacity.⁶

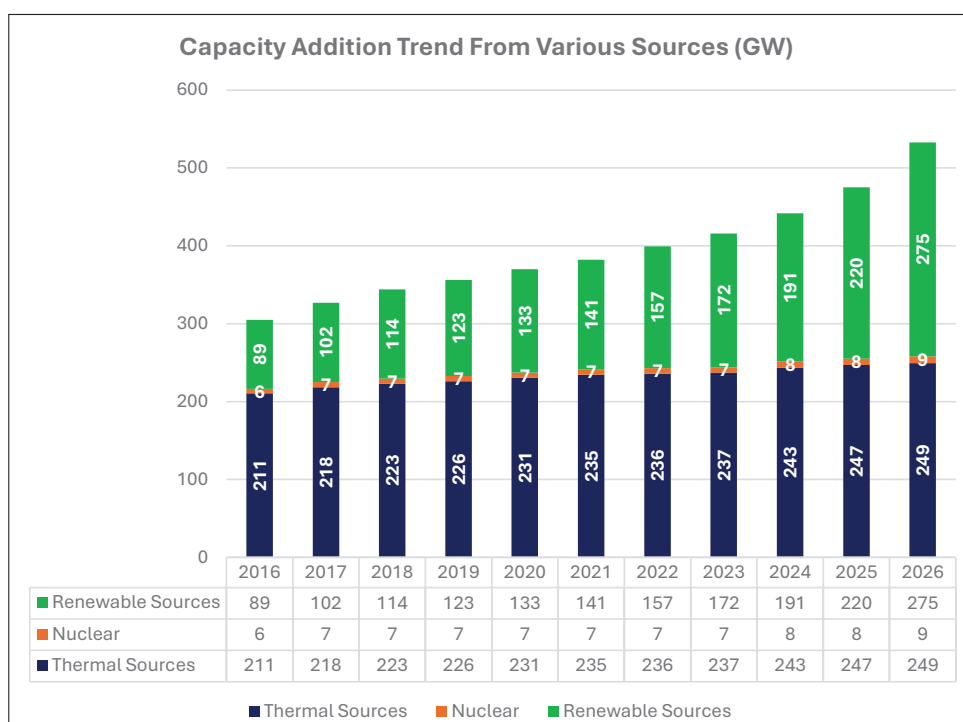


Figure 1: Capacity addition trend from various sources (GW)

As of 31st July 2026, India's total installed power generation capacity stood at 552 GW. Non-fossil fuel sources accounted for 54.4% (301 GW) of the total installed capacity, surpassing fossil fuel-based generation at 45.6% (251 GW). Renewable energy sources, including large hydro, represented 52.8% of the country's installed capacity, underscoring India's sustained focus on energy transition. Among renewable sources, solar power emerged as the largest contributor with 164.5 GW of installed capacity, accounting for 29.8% of total capacity and nearly 56% of wind, solar and other renewable energy installations. The rapid growth of solar energy has been driven by a sharp decline in solar photovoltaic module costs, improvements in technology efficiency, competitive tariff discoveries through auctions, supportive government policies, large-scale solar parks, and increasing private sector investments. Wind power contributed 58.1 GW (10.5%), while hydro power, including pumped storage projects, accounted for 52.1 GW (9.5%).⁷

On the fossil fuel side, coal remained the dominant source of conventional generation, with 224.2 GW of installed capacity and a 40.6% share, highlighting its continued importance in ensuring reliable baseload power supply even as renewable energy increasingly drives capacity additions in the country.

⁶ CEA monthly installed capacity report

⁷ CEA monthly installed capacity report

Table 1: All-India installed capacity as on 31.07.2026

Source of Generation		Total Installed Capacity (MW)	% Share in Total (as on 31.07.2026)
Fossil Fuel	Coal	2,24,158	40.6%
	Lignite	6,620	1.2%
	Gas	20,122	3.6%
	Diesel	589	0.1%
	Total Fossil Fuel	2,51,490	45.6%
Non-Fossil Fuel	Solar	1,64,595	29.8%
	Wind	58,137	10.5%
	Large Hydro	52,065	9.4%
	Small Hydro (<25 MW)	5,182	0.9%
	Other	11,747	2.1%
	Total Non-Fossil Fuel	3,00,505	54.4%
Total Installed Capacity		5,51,995	100.0%

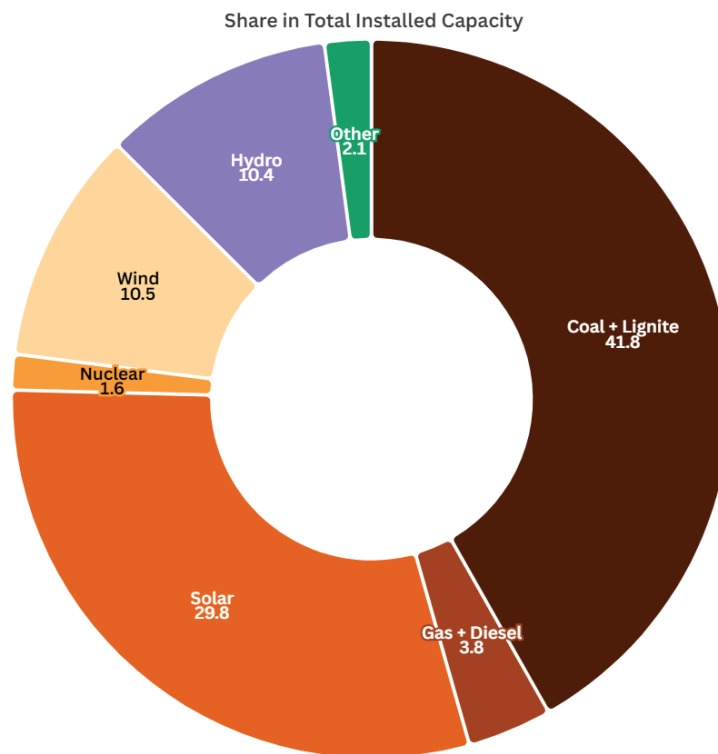


Figure 2: All-India installed capacity as on 31.07.2026

Although non-fossil-based electricity generation sources contribute nearly 54.4% of installed capacity, coal-fired power stations continue to generate most of the electricity because of their higher availability and capacity utilisation. This difference between installed capacity and actual generation highlights the continued importance of thermal power plants in ensuring grid reliability and meeting peak demand. Therefore, benchmarking and improving the performance of thermal power stations remain essential for achieving both economic and environmental objectives.

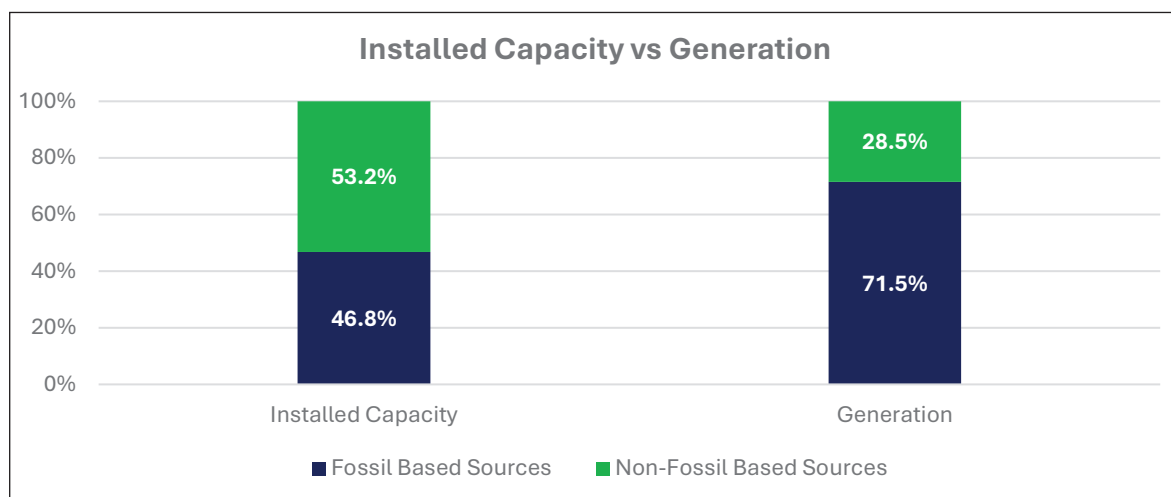


Figure 3: Installed Capacity vs Annual Electricity Generation (FY 2025-26)

The chart compares India's installed power capacity with its actual annual electricity generation for FY 2025-26. For comparison, the installed capacity at the end of FY 25-26 is considered along with the total generation in the same year. India had 533 GW of installed capacity (as on 31.03.2026), of which 53.2% was non-fossil-based while the remaining 46.8% was thermal.

However, in actual generation, thermal power contributed 1,307 BU (71.5%), while non-fossil-based sources contributed 521 BU (28.5%). This shows that thermal power still plays a major role in electricity generation despite renewables having a larger share of installed capacity.⁸

1.3 Grid Emission Factor

Grid Emission Factor (GEF) represents the amount of carbon dioxide (CO₂) emitted by the power grid to generate one unit of electricity and is typically expressed in kg CO₂/kWh. It is a key indicator of the carbon intensity of a country's electricity sector and is widely used for calculating Scope-2 emissions, assessing decarbonisation progress, and evaluating the environmental performance of industries and commercial establishments.

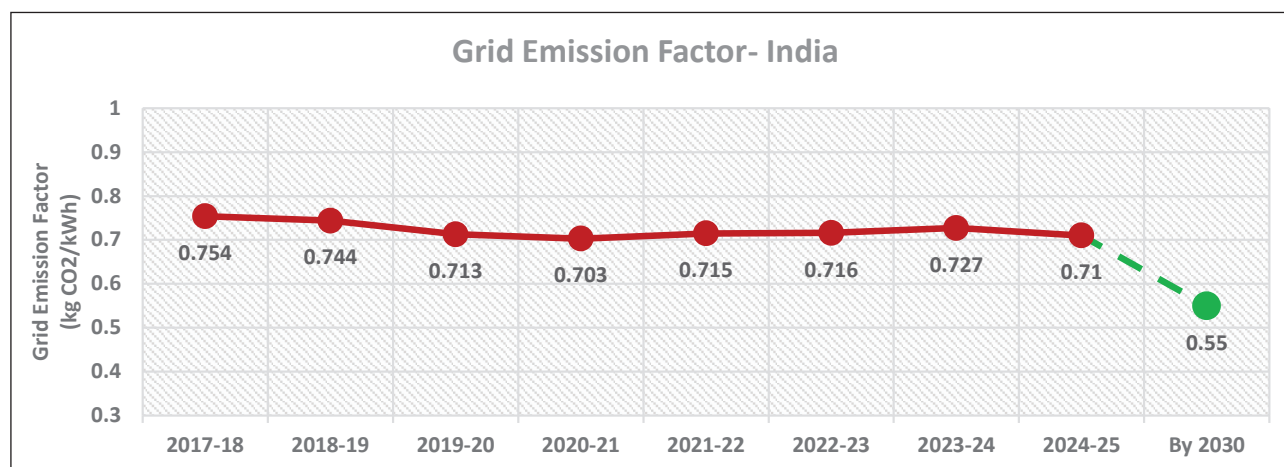


Figure 4: Grid emission factor trend for India

⁸ <https://iced.niti.gov.in/energy/electricity/generation/power-generation>

As shown in the figure, India's grid emission factor has declined from 0.754 kg CO₂/kWh in FY 2017-18 to about 0.710 kg CO₂/kWh in FY 2024-25, reflecting gradual improvements in the generation mix.⁹ A lower grid emission factor directly benefits the economy by reducing the carbon footprint of electricity-intensive sectors such as steel, cement, aluminium, chemicals, data centres, and manufacturing. In an increasingly carbon-conscious global market, regulations such as the European Union's Carbon Border Adjustment Mechanism (CBAM) make the carbon intensity of electricity a critical competitiveness factor. A lower GEF reduces embedded emissions in exported products, thereby lowering potential carbon costs, improving market access, and enhancing the global competitiveness of Indian industry.

The long-term reduction in India's grid emission factor is being driven by rapid growth in renewable energy, expansion of solar and wind capacity, improvements in coal plant efficiency, greater adoption of supercritical and ultra-supercritical technologies, expansion of nuclear and hydro generation, and investments in transmission infrastructure that enable higher renewable integration. Considering the share of fossil-based electricity in India's grid, it becomes imperative that the Indian Power Industry should focus on improving energy efficiency and adoption of emission reduction technologies in thermal power assets alongside working on building RE capacities.

Going forward, India's ambitious clean energy targets, including 500 GW of non-fossil fuel capacity by 2030, large-scale battery energy storage systems, green hydrogen initiatives, offshore wind projects, pumped storage schemes, and modernisation of the national grid are expected to further reduce the emission factor. Based on current policy and investment trajectories, India's grid emission factor is expected to fall in the range of 0.55 to 0.60 kg CO₂/kWh by 2030. Such a transition will not only support national climate commitments but also lower production emissions across sectors, reduce exposure to carbon-related trade barriers, attract green investment, and strengthen India's position as a competitive manufacturing hub in a low-carbon global economy.

1.4 Future Capacity Projections

India's power sector is expected to undergo a significant transformation by 2032, driven by sustained growth in electricity demand and the rapid expansion of renewable energy. As per the CEA's National Electricity Plan (NEP) 2022-32, the peak demand is expected to reach 366 GW in FY 2031-32 compared to the projected 277 GW in FY 2026-27, reflecting an increase of 32%.

Table 2: Projected electrical requirement and peak demand

Year	Electrical Energy Requirement (MU)	Peak Electricity Demand (MW)
2026-27	19,07,835	2,77,201
2031-32	24,73,776	3,66,393
Rise	29.7%	32.2%

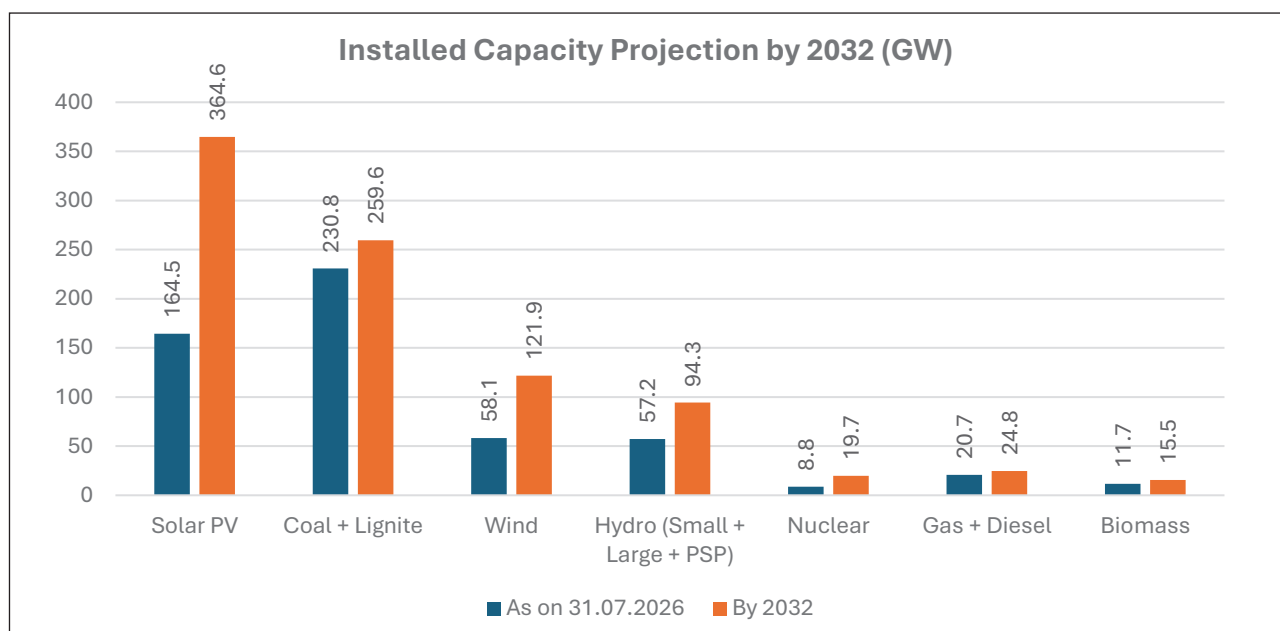
The report projects a substantial increase in solar and wind capacity, supported by energy storage systems, while coal and lignite-based generation will continue to play a critical role in ensuring grid reliability and energy security. As per the National Electricity Plan for 2022-32, the projected capacities from various sources are shown below.¹⁰

⁹ Scenarios-Towards-Viksit-Bharat-and-Net-Zero-Sectoral-Insights-Power

¹⁰<https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/09/202309011256071349.pdf>

Table 3: Comparison of present installed capacity with projected capacity by 2032

Sources	By the end of 2032 (GW)	As on 31.07.2026 (GW)	Capacity Addition (GW)	Rise in installed capacity (%)	Share in installed capacity by 2032
	(A)	(B)	(A - B)		
Hydro (Small + Large + PSP)	94.3	57.2	37.1	65%	10%
Solar PV	364.6	164.6	202.4	125%	30%
Wind	121.9	58.1	63.8	112%	10%
Biomass	15.5	11.7	3.8	32%	2%
Nuclear	19.7	8.8	10.9	124%	2%
Coal + Lignite	259.6	230.8	28.9	13%	42%
Gas + Diesel	24.8	20.7	4.1	20%	4%
Total	900.4	551.9	351.6	64%	100%

**Figure 5: Increase in installed capacities from various sources**

India's installed power generation capacity is projected to increase from 551 GW in 2026 to 900.4 GW by 2032, representing a growth of nearly 64%. While solar and wind power are expected to drive most new capacity additions, with solar capacity increasing by 202.4 GW (125%) and wind capacity by 64.5 GW (112%), coal and lignite-based generation will continue to play a central role in the electricity system. By 2032, coal and lignite capacity is expected to reach 259.6 GW, accounting for the largest share of installed capacity at 42%, compared to 30% for solar and 10% each for hydro and wind. This clearly indicates that India's energy transition will be supported by a substantial thermal generation base even as renewable energy expands rapidly.

The growing share of renewable energy will further enhance the importance of flexible, efficient, and reliable coal-based power plants. Solar and wind generation are inherently variable and dependent on weather conditions, creating challenges in maintaining grid stability and meeting demand at all times. Coal-based plants will therefore be required to provide firm and dispatchable power, support grid balancing, manage peak demand, and compensate for sudden fluctuations in renewable generation.

Moreover, the planned addition of nearly 29 GW of new coal capacity underscores the continued need for thermal power to ensure energy security and reliability. As India moves towards a renewable-rich power system, modern coal plants capable of flexible operation, faster ramping, and efficient performance at lower load levels will become critical enablers of higher renewable energy integration while ensuring uninterrupted and affordable electricity supply to consumers.

Overall, India's 2032 power-sector outlook represents a transition towards a diversified generation system where thermal power is going to play a critical role. Renewable energy is expected to provide an increasing share of low-cost electricity, storage will provide flexibility and time-shifting capability, while thermal generation will continue to provide firm capacity and reliability. This changing operating environment makes efficiency improvement and flexible operation increasingly important for the long-term performance of India's thermal power fleet.

1.5 Energy Storage and Emerging Power Systems

India's renewable energy sector has evolved from a policy-supported alternative into a major and increasingly cost-competitive source of electricity. The decline in renewable generation costs has been one of the key drivers of this transition. Solar tariffs, for example, have declined from around ₹10.95/kWh in 2010–11 to approximately ₹2.15/kWh in recent years, driven by technological improvements, economies of scale, competitive procurement and reductions in project costs. The increasing competitiveness of renewable electricity is changing the economics of power generation and is expected to place greater pressure on relatively high-cost and inefficient conventional generating units.

The growth of solar and wind, however, introduces variability into electricity generation and creates a requirement for flexible and dispatchable resources. Energy storage technologies are therefore becoming an important component of India's future power system. Battery Energy Storage System (BESS) can store surplus renewable electricity during periods of high solar or wind generation and discharge it during peak-demand periods, while Pumped Storage Plants (PSPs) can provide longer-duration storage. The Government is supporting BESS deployment through viability gap funding, with the capacity supported under the initial programme increasing from 4,000 MWh to 13,200 MWh. A further 30 GWh BESS programme with ₹5,400 crores of financial support was approved in 2025 to accelerate large-scale storage deployment.¹¹

The economics of BESS are also improving as technology costs decline and deployment scales up. Under the Government's initial Viability Gap Funding (VGF) programme, the support requirement for BESS was reduced from ₹96 lakh/MWh to ₹46 lakh/MWh or 30% of capital cost, whichever is lower.¹² Competitive procurement has also demonstrated increasing cost competitiveness, with Power Line reporting two-hour BESS tariffs as low as approximately ₹1.48 lakh/MW/month during 2025–26.¹³ These developments indicate that storage is gradually moving from an emerging technology towards an important component of commercially viable renewable-energy projects.

The transition is also reflected in the procurement strategies of major utilities. NTPC and its renewable-energy subsidiaries have issued multiple utility-scale BESS tenders, including projects associated with major renewable-energy locations such as Khavda, Bikaner and Fatehgarh.¹⁴ The increasing participation of large utilities in BESS procurement indicates a shift towards integrated renewable-plus-storage projects, where renewable generation and storage are planned together to provide more reliable and dispatchable electricity.

¹¹ Press Release Page | Press Information Bureau

¹² Press Release Page | Press Information Bureau

¹³ Green Energy Future: Emerging opportunities in the renewables sector - Power Line Magazine

¹⁴ NTPC: Home

Pumped Storage Projects (PSPs) will complement BESS by providing longer-duration energy storage and supporting the grid during extended periods of low renewable generation. India has identified approximately 181,350 MW of pumped-storage potential, while several PSPs are under construction. Unlike BESS, PSPs generally have project-specific land requirements depending on reservoir configuration, hydraulic head, storage duration, geology and topography. Therefore, a single land requirement per MW should not be considered a national benchmark. Government initiatives are increasingly supporting PSP development through policy facilitation, transmission incentives and integration of storage into the electricity system.

These developments will have a direct impact on the operation and economics of thermal power plants. During periods of high renewable generation, low-cost solar and wind power, supported by BESS and PSPs, can reduce the need for thermal generation. During periods of low renewable output, however, thermal power plants will continue to provide firm capacity and system reliability. Consequently, the future competitiveness of thermal plants will increasingly depend on their ability to operate efficiently and flexibly. Lower heat rate, reduced auxiliary power consumption, improved part-load efficiency, faster ramping, lower technical minimum load, shorter start-up times and improved availability will become increasingly important.

The emerging power system is therefore expected to operate through a complementary combination of technologies: renewable energy will provide an increasing share of low-cost electricity, BESS and PSPs will provide flexibility and energy-shifting capability, green hydrogen will create additional renewable-energy demand, and efficient thermal power plants will continue to provide firm capacity and reliability. For the existing thermal fleet, this transition reinforces the need for performance benchmarking, efficiency improvement, flexible-operation capability, and continuous technological modernisation.

1.6 Key Takeaways

- India's development and climate goals increasingly hinge on the Power Sector. As India moves toward Viksit Bharat 2047 and Net Zero 2070, the power sector's growth will determine whether growth can be both inclusive and sustainable. Reliable, affordable, and progressively cleaner electricity is essential to improve living standards, raise productivity, and unlock a low-carbon transition across transport, buildings, and industry.
- As projected, coal-based capacity addition of 29 GW is required to meet the demand requirement in FY 2031-32. In total, the capacity of coal & lignite sources is projected to be 260 GW by 2032. These assets are expected to play a critical role in meeting the electricity demand during the non-solar hours and filling the gaps during the day occurring due to the variable nature of RE.
- India has emerged as the world's 4th largest renewable energy market, reflecting the scale and momentum of its clean energy expansion. The next phase, however, is more complex. Demand will rise sharply with urbanisation, cooling, digitalisation, electric mobility, and green hydrogen, and the system is required to absorb much higher shares of variable renewables.¹⁵
- As renewable energy generation increases, thermal plants must be capable of rapid ramping, low-load operation, and fast response to demand fluctuations, making flexibility a critical requirement for a reliable and resilient power system.
- The role of thermal power is expected to shift from predominantly baseload generation towards flexible and balancing operation as renewable energy penetration increases.
- The energy storage capacity required for 2029-30 is likely to be 60.63 GW, including 18.89 GW PSP and 41.65 GW BESS. The storage required is 336.4 GWh (128.15 GWh from PSP and 208.25 GWh from BESS). As per CEA's Optimal Generation Capacity Mix for 2029-30, the northern region is best suited for investment in BESS since evening peaks in the northern region are found to be more prominent compared to other regions.¹⁶
- Artificial Intelligence will play a vital role in the future power system by enabling smarter, more efficient, and data-driven decision-making across the entire electricity value chain. AI can improve generation planning and plant performance through predictive maintenance, optimise renewable and conventional power scheduling, and enhance demand and renewable energy forecasting with greater accuracy. In transmission and distribution networks, AI can help detect faults, reduce technical losses, optimise power flows, and improve asset utilisation. By forecasting demand patterns and identifying system constraints in advance, AI can reduce stress on existing infrastructure, defer costly capacity additions, and support a more reliable, flexible, and resilient power system capable of integrating large shares of renewable energy.
- Overall, India's future power system is expected to follow a complementary model, where renewable energy provides low-cost electricity, storage provides flexibility, and efficient thermal power provides reliability and firm capacity.

¹⁵Scenarios-Towards-Viksit-Bharat-and-Net-Zero-Sectoral-Insights-Power

¹⁶ REPORT ON OPTIMAL GENERATION CAPACITY MIX FOR 2029-30 Version 2.0

BENCHMARKING FRAMEWORK



2. BENCHMARKING FRAMEWORK

2.1 Objective of Benchmarking

Benchmarking is a powerful performance improvement tool that enables coal-based power plants to evaluate their operational, energy, and environmental performance against industry peers and best-in-class standards. As the Indian power sector continues to play a critical role in supporting economic growth while addressing the challenges of energy efficiency, environmental compliance, and decarbonisation, benchmarking provides a structured framework for identifying performance gaps and driving continuous improvement.

The objective of this document is to provide a common platform for coal-based thermal power plants to assess their performance relative to comparable stations and identify opportunities for enhancing operational excellence. By comparing key performance indicators (KPIs) such as Station Heat Rate (SHR), Auxiliary Power Consumption (APC), Boiler Efficiency, Flexibility, and Emissions Performance, participating plants can gain valuable insights into their strengths and areas requiring improvement. This process supports better decision-making, resource optimisation, and performance enhancement across the sector.

Benchmarking also promotes a culture of continuous improvement by encouraging utilities to adopt superior operating practices, innovative technologies, and advanced management systems. It facilitates knowledge sharing among power plants, enabling wider dissemination of successful initiatives related to efficiency improvement, emissions reduction, reliability enhancement, and flexible operation. As coal-based power plants continue to serve as a cornerstone of India's energy mix, benchmarking can play a significant role in supporting energy security while contributing to national sustainability goals through improved efficiency, reduced fuel consumption, optimised resource utilisation, and lower environmental impact.

2.2 Approach & Methodology

The benchmarking study adopts a comprehensive, data-driven approach to evaluate the performance of coal-based power plants across key operational and environmental parameters.

Data for this benchmarking study has been derived from questionnaire responses submitted by participating thermal power plants for the 27th National Awards for Excellence in Energy Management 2026. While the source data is available in the public domain, all analyses and results have been presented in an anonymised manner, and every effort has been made to ensure that the identity of individual plants cannot be determined from this report.

The benchmarking analysis covers IPPs operating PF-fired boilers across different capacity ranges. CPPs and plants employing AFBC or CFBC boiler technologies have been excluded from the study to ensure meaningful and consistent performance comparisons among similar plant configurations. Additionally, IPPs with more than 150 MW unit size are considered for the performance benchmarking.

The study focuses on key performance parameters that have a direct influence on plant efficiency, operating costs, reliability, environmental compliance, and overall competitiveness. Emphasis has been given to Station Heat Rate, Auxiliary Power Consumption, Boiler Efficiency, operational Flexibility, and Emissions Performance, which are widely recognised as the most important indicators of thermal power plant performance.

Since power plants in India differ in size, capacity, and technology, they have been categorised into three groups for this document: 300 MW, 600 MW, and 660 MW. The classification criteria are outlined below.

Table 4: Details of plant categorisation

Category	300 MW	600 MW	660 MW*
Criteria	The average station installed capacity is between 150 and 350 MW	The average station installed capacity is between 500 MW and 600 MW	The average station installed capacity is more than 600 MW

**Note: For stations with a mix of subcritical and supercritical units, if the total installed capacity of the supercritical units is more than the subcritical units, the plant is considered under the 660 MW category.*

As per CEA guidelines, performance has been normalised to the 85-100% PLF range for all plants. Since most critical performance parameters, including SGHR, APC, and heat-rate-related indicators, are highly dependent on unit loading, this normalisation minimises the impact of varying operating loads and enables a fair, like-for-like comparison across plants.¹⁷

In addition to evaluating performance levels, the benchmarking exercise seeks to understand the underlying factors influencing these indicators. Variations in technology, unit size, operating practices, fuel quality, equipment condition, load patterns, and environmental systems can significantly impact plant performance. Therefore, the study not only establishes benchmark values but also provides insights into the key drivers affecting performance outcomes.

A unique aspect of the study is the inclusion of best practices adopted by leading power plants. By documenting successful initiatives in areas such as heat rate improvement, APC reduction, boiler performance enhancement, flexible operation, digitalisation, emissions control, maintenance excellence, and water conservation, the study creates a valuable knowledge-sharing platform for the sector. This integrated approach ensures that benchmarking serves not merely as a measurement exercise but as a catalyst for performance improvement and operational excellence.

¹⁷https://cercind.gov.in/2024/draft_reg/TTF2024/Revised%20Recommendation%20on%20Operation%20Norms%20of%20Thermal%20Power%20Stations%20%282%29.pdf

BENCHMARKING OF THERMAL POWER PLANTS



3. BENCHMARKING OF THERMAL POWER PLANTS

3.1 Station Net Heat Rate

Station Net Heat Rate (SNHR) is one of the most important indicators of overall power plant efficiency, as it reflects the amount of fuel energy required to generate one unit of net electrical energy exported from the station. Lower SNHR indicates superior overall performance resulting from efficient boiler operation, optimised turbine cycle performance, and lower auxiliary power consumption.

Key parameters that affect SNHR include boiler efficiency, turbine heat rate (THR), auxiliary power consumption (APC) and steam parameters. The category-wise benchmarking numbers for SNHR are as follows:

3.1.1 Benchmarking of Station Net Heat Rate - 300 MW

Figure 6: Station Net Heat Rate for 300 MW category

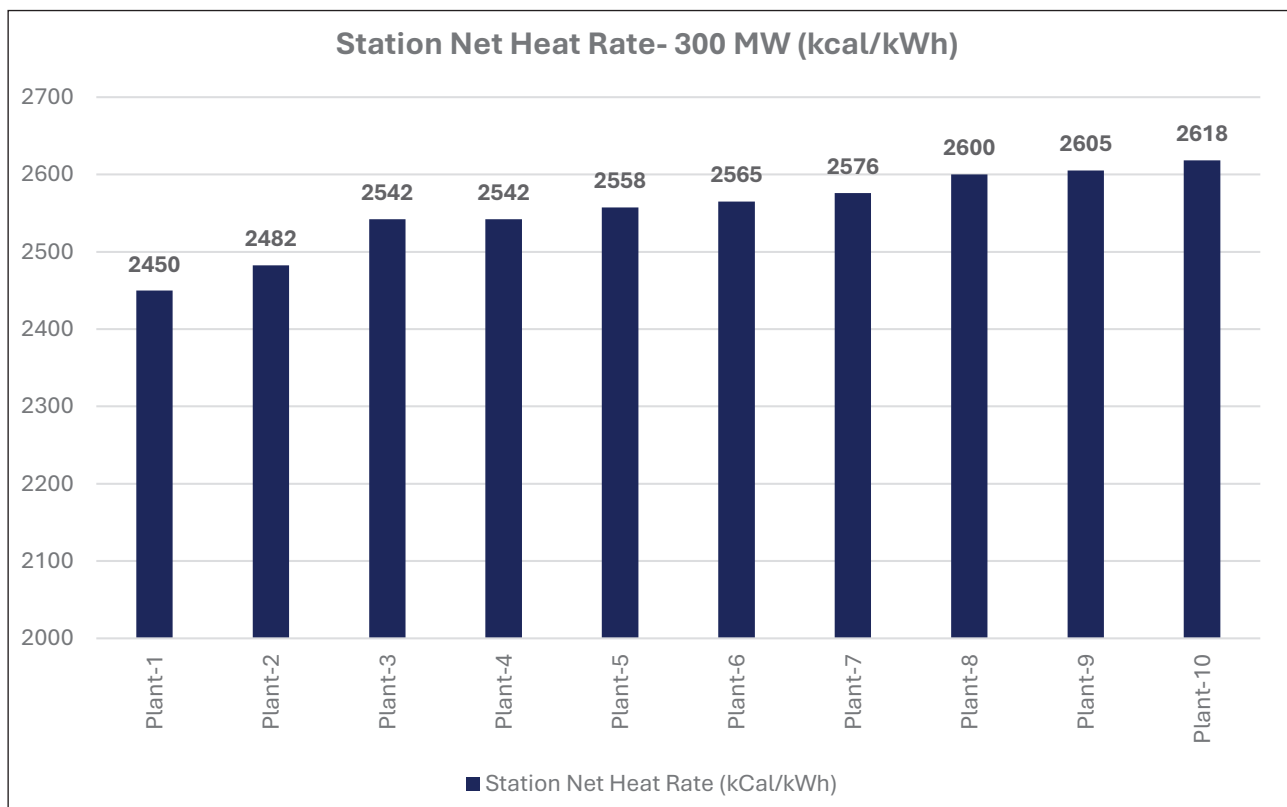


Table 5: Key parameters affecting SNHR of 300 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
Station Net Heat Rate	kcal/kWh	2450	2482	2542	2542	2558	2565	2576	2600	2605	2618
Average station capacity	MW	300	350	250	215	270	300	250	306	286	300
MS Temp (Actual)	°C	540	540	538	539	541	540	537	537	540	541
RH Temp (Actual)	°C	540	535	538	539	541	540	537	560	540	540
Turbine Heat Rate	kcal/kWh	1975	2012	1964	2041	2032	2003	2178	2046	2062	2046
Boiler efficiency	%	87.25	86.93	85.09	86.89	86.70	84.80	84.55	85.92	86.38	85.90
APC	%	7.60	6.76	9.18	7.58	8.36	7.92	8.58	8.42	8.37	9.03
Condenser vacuum	Kg/cm ² (g)	-0.890	-0.891	-0.910	-0.900	-0.909	-0.887	-0.909	-0.890	-0.900	-0.900
Fuel type	Indian/ Imported	Indian	Indian	Indian	Imported	Indian	Imported	Indian	Indian	Indian	Indian
Coal GCV	Kcal/kg	3400-3600	3100-3300	3800-4000	5700-5800	3400-3600	5300-5500	3500-3600	3700-3900	3200-3400	3700-3900

3.1.2 Benchmarking of Station Net Heat Rate - 600 MW

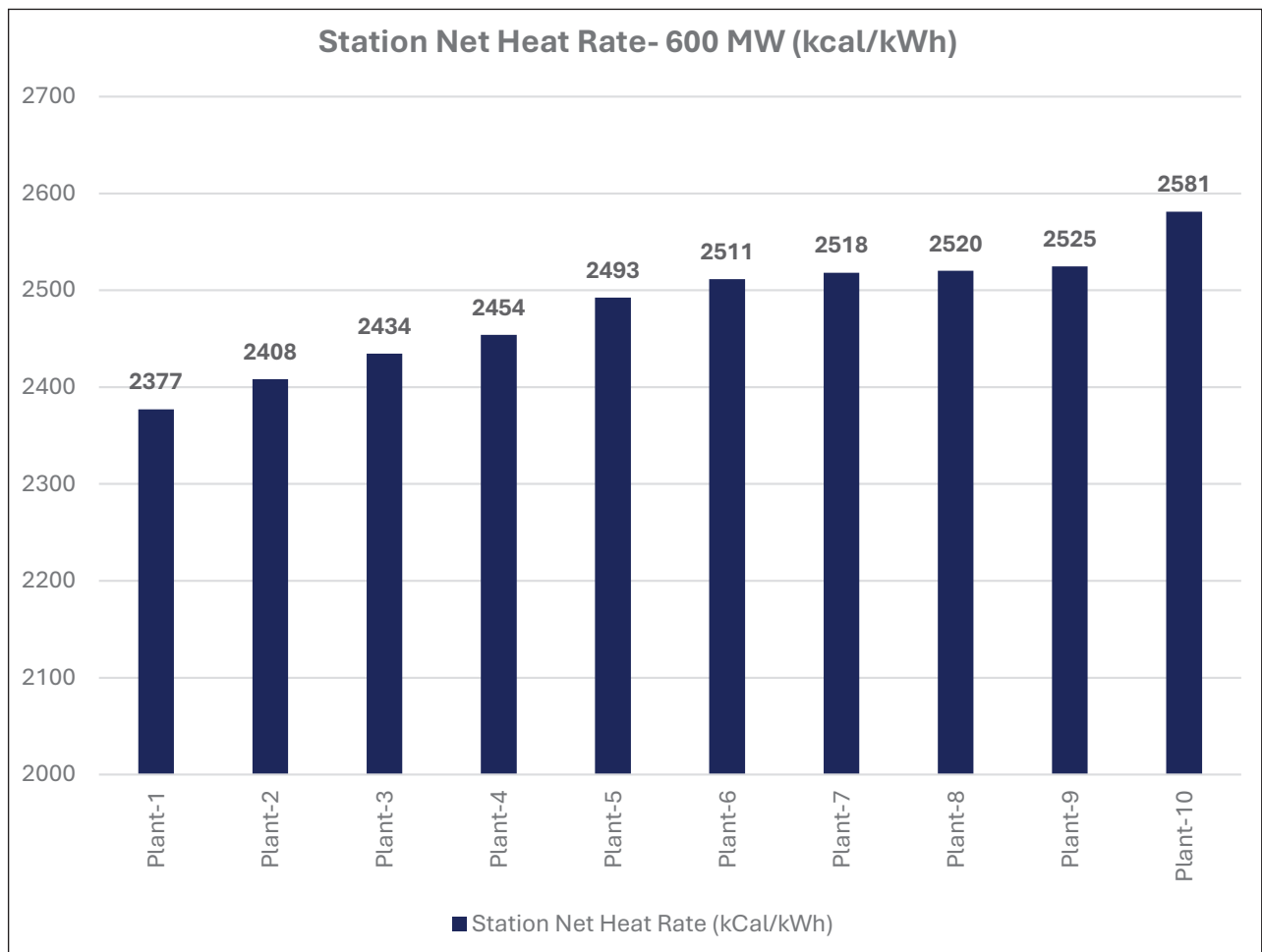


Figure 7: Station net heat rate of 600 MW category

Table 6: Key parameters affecting SNHR of 600 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
Station Net Heat Rate	kcal/kWh	2377	2408	2430	2454	2493	2511	2518	2520	2525	2581
Average station capacity	MW	600	600	425	600	525	500	500	600	500	366
MS Temp (Actual)	°C	536	539	537	540	541	537	505	541	535	537
RH Temp (Actual)	°C	533	538	537	540	538	537	542	541	527	537
Turbine Heat Rate	kcal/kWh	1953	1997	1975	2012	1997	2057	2030	2024	1997	2041
Boiler efficiency	%	86.58	87.43	86.73	86.83	85.03	86.85	86.58	86.52	84.64	85.70
APC	%	5.11	5.15	6.46	5.59	5.78	5.70	6.89	7.17	6.57	7.74
Condenser vacuum	Kg/cm ² (g)	-0.914	-0.910	-0.903	-0.891	-0.908	-0.910	-0.840	-0.902	-0.900	-0.895
Fuel type	Indian/ Imported	Indian	Indian	Indian	Indian	Blended	Indian	Indian	Indian	Indian	Indian
Coal GCV	Kcal/kg	3100-3300	3100-3300	2900-3100	3600-3800	3800-4000	3700-4000	3600-3900	3600-3800	3100-3300	3700-3900

3.1.3 Benchmarking of Station Net Heat Rate - 660 MW

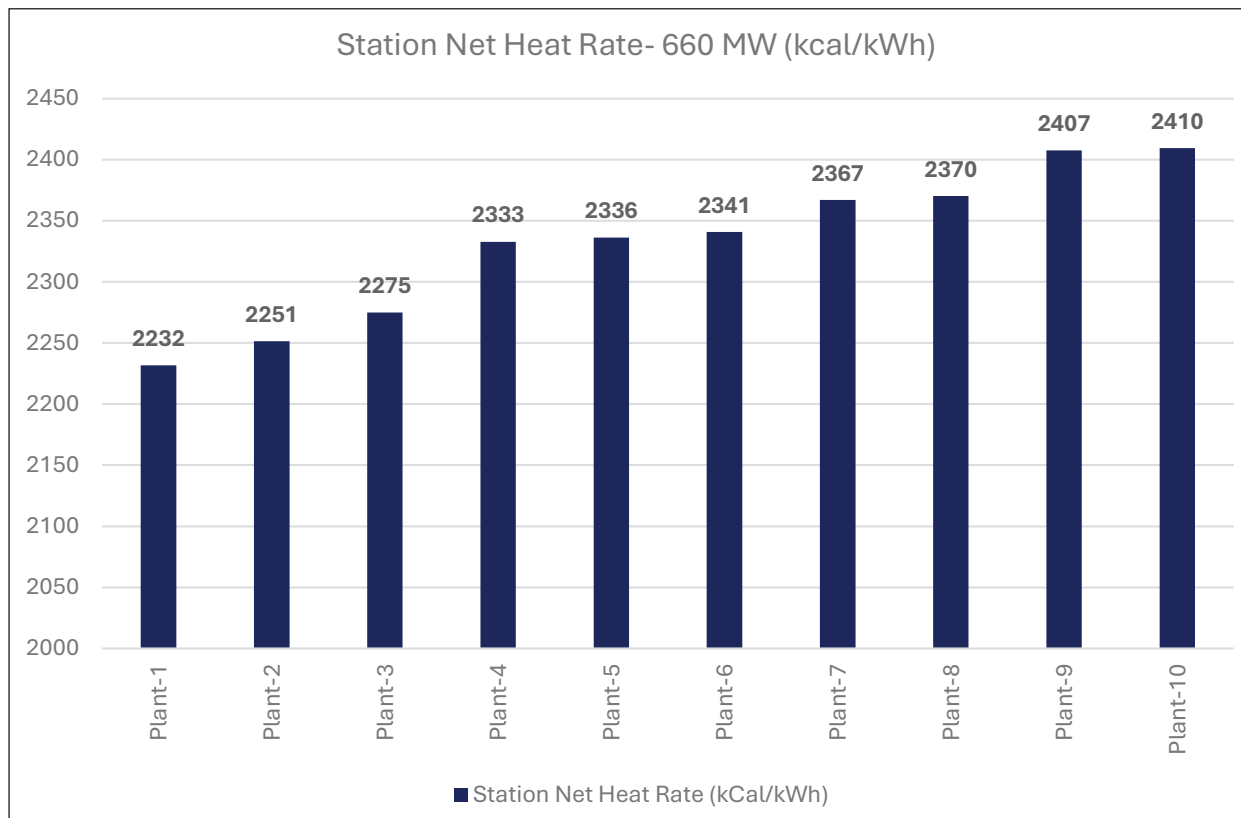


Figure 8: Station net heat rate of 660 MW category

Table 7: Key parameters affecting SNHR of 660 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
Station Net Heat Rate	kcal/kWh	2232	2251	2275	2333	2336	2341	2367	2370	2407	2410
Avg station capacity	MW	660	800	660	660	800	660	660	800	660	596
MS Temp (Actual)	°C	568	600	567	568	570	596	566	568	565	540
RH Temp (Actual)	°C	596	610	597	604	589	600	582	596	598	562
Turbine Heat Rate	kcal/kWh	1782	1819	1867	1954	1869	1924	1918	1819	1930	1949
Boiler efficiency	%	85.98	86.82	86.12	87.68	85.48	88.00	85.90	85.00	85.10	85.96
APC	%	7.15	6.94	4.70	4.45	6.41	6.60	5.67	6.72	5.80	5.89
Condenser vacuum	Kg/cm ² (g)	-0.917	-0.920	-0.930	-0.889	-0.911	-0.915	-0.903	-0.908	-0.900	-0.908
Fuel type	Indian/Imported	Indian	Blended	Indian	Indian	Indian	Imported	Blended	Indian	Blended	Indian
Coal GCV	kcal/kg	2800-3000	3300-3500	3600-3800	3600-3800	2800-3000	5100-5300	3600-3800	3200-3400	3400-3600	3400-3600

3.1.4 Conclusion on SNHR-based benchmarking

- 660 MW category records the best overall performance with SNHR as low as 2232 kcal/kWh. The superior performance of this category can be attributed to the inherent efficiency in the supercritical steam cycle, better SH & RH temperatures and pressure improving Rankine cycle efficiency, and lower APC, as all plants are installed with TDBFPs and NDCTs. Additionally, the improved control and monitoring systems also play a critical role in ensuring a high level of cycle efficiency at various loads.
- The benchmark data also indicates that SNHR is influenced by the cumulative effect of boiler performance, THR, APC, and operating discipline. Plants that consistently rank among the top performers demonstrate balanced performance across all these parameters rather than excelling in only one area.
- Following table shows the effect of degradation in APC, boiler efficiency and THR on SNHR. For the analysis, a 600 MW unit operating at a THR of 1995 kcal/kWh, APC of 5.5% boiler efficiency of 87% and SNHR of 2427 kcal/kWh is considered.

Table 8: Effect of APC, boiler efficiency and THR on SNHR

Parameter	Baseline	Revised	Change	Resulting SNHR (kcal/kWh)	Impact on SNHR (kcal/kWh)
APC (%)	5.5%	6.0%	+0.5% pt.	2439	+12
Boiler efficiency (%)	87%	86.5%	-0.5% pt.	2441	+14
THR (kcal/kWh)	1995	2005	+0.5%	2439	+12

- Top-performing plants also exhibit better condenser vacuum and lower turbine heat rates, indicating effective cooling water system management, clean condenser tubes, and efficient turbine operation. Even small improvements in condenser vacuum can result in measurable reductions in heat rate and fuel consumption. For 660 MW unit with a design condenser vacuum of 0.926 kg/cm² a degradation of 0.025 kg/cm² can cause the unit heat rate to rise by 2% along with a sharp drop in generation.¹⁸ The rise in heat rate may vary from plant to plant. To arrive at the actual effect of the degradation, correction curves of the unit should be referred.
- Another critical area is the mode of operation. While most of the plants operates at lower load during the solar hours, it is important that plants should operate on sliding pressure mode instead of the constant pressure.

¹⁸Correction curve of 660 MW unit.

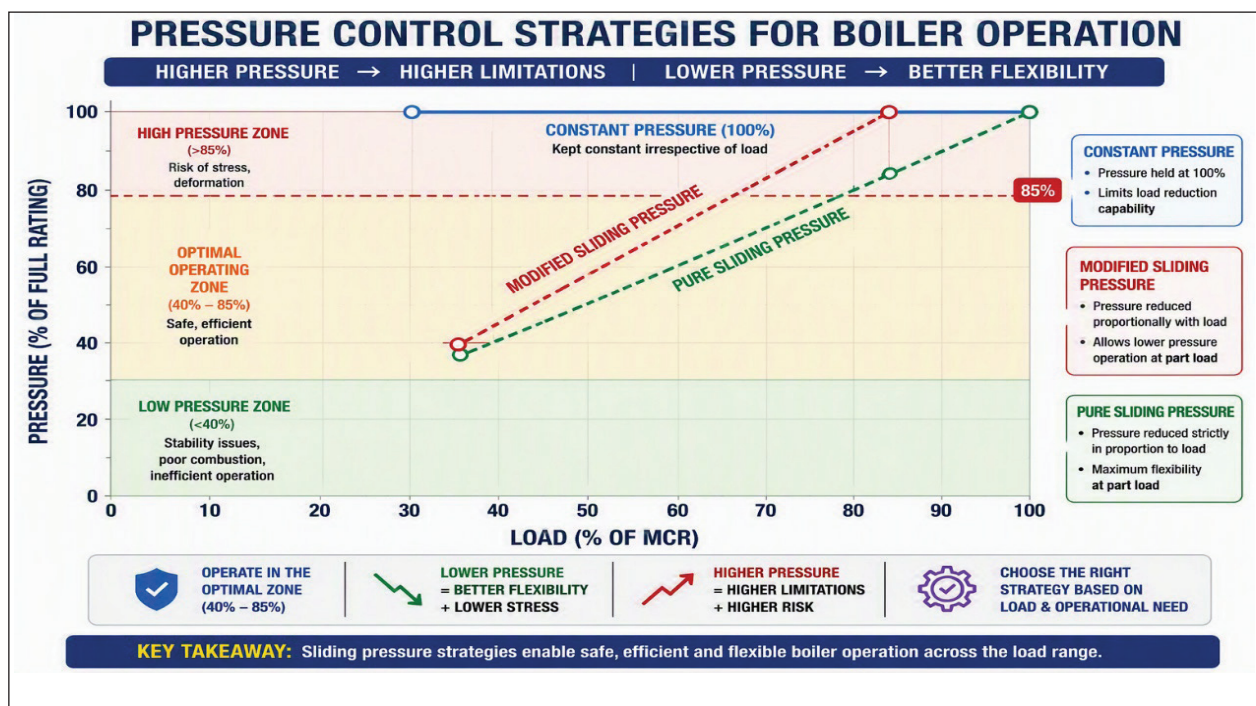


Figure 9: Advantages of Pure Sliding, Modified Sliding and Constant Pressure Operation

- Apart from the major areas mentioned above for improvement, there are other areas which can help the plants to achieve benchmark numbers. These are mentioned below:
 - Operate the plant operating parameters (MS temperature, MS pressure, RH temperature) near to the designed values as recommended by OEM to achieve the designed cycle efficiency.
 - Maintain the superheater (SH) and reheater (RH) spray at the optimal level. Consider techniques like burner tilting and coal adjustment in upper mills to maintain the temperature instead of using spray.
 - Ensure the pressure drop in RH is as per the design and as low as possible.
 - Ensure the pressure drop at the MS & RH steam strainers are as low as possible or as per the design.
 - Implementation of AI-based solutions should be considered to monitor real-time boiler efficiency, turbine heat rate, and deviations from the design. Maintaining the operating parameters near the design can greatly help to improve the SNHR.

3.2 Station Gross Heat Rate (SGHR)- Design vs Operating

Station Gross Heat Rate (SGHR) is a critical performance indicator that measures the efficiency of a thermal power plant in converting fuel energy into electrical energy. It is defined as the amount of heat input required to generate one unit of electricity, typically expressed in kcal/kWh or kJ/kWh. A lower SGHR indicates better plant efficiency, as less fuel is needed to produce the same amount of power. The station heat rate reflects the combined performance of major plant equipment, including boilers, turbines, generators, and auxiliary systems, and is therefore widely used as an overall indicator of plant operational efficiency.

This section compares the actual operating Station Gross Heat Rate of power plants with their design Station Gross Heat Rate to identify performance gaps and deviations across the industry. Such deviations can arise due to equipment degradation, suboptimal operation, poor maintenance practices, fuel quality variations, and aging infrastructure. By benchmarking operating SHR against design values, the analysis highlights the extent of efficiency losses, identifies opportunities for performance improvement, and provides insights into industry-wide operational trends. This comparison is essential for reducing fuel consumption, lowering generation costs, and improving the environmental performance of thermal power stations.

3.2.1 Benchmarking of Operating Station Gross Heat Rate (O-SGHR) vs Design Station Gross Heat Rate (D-SGHR)- 300 MW

Figure 10: Operating vs Design deviation for Station Gross Heat Rate- 300 MW category

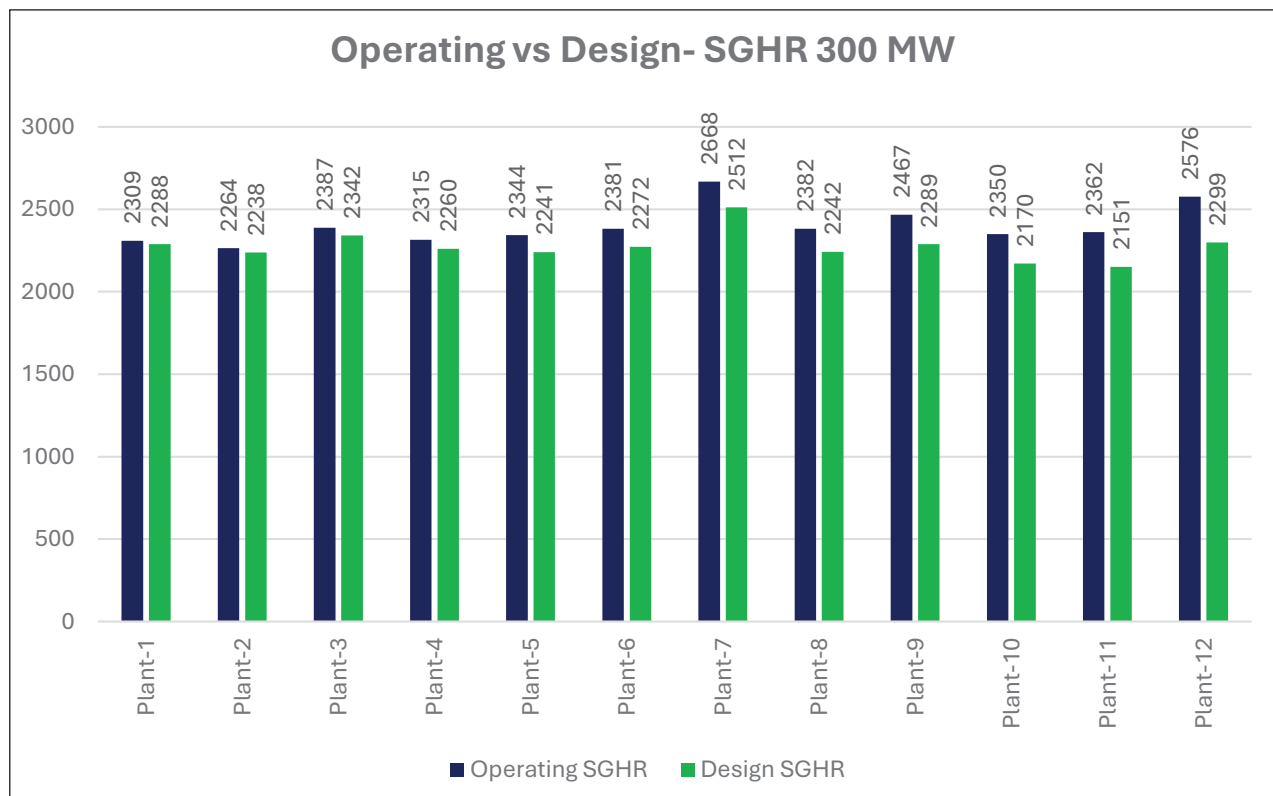


Table 9: Operating vs Design deviation for Station Gross Heat Rate- 300 MW category

	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10	Plant-11	Plant-12
Operating Performance	Turbine Heat Rate	1964	1975	2062	2012	2032	2046	2098	2046	2099	2042	2003	2178
	Boiler Efficiency	85.23	87.12	86.43	87.03	87.03	86.21	79.94	86.83	85.86	87.23	85.00	85.00
	Station Heat Rate	2309	2264	2387	2315	2344	2381	2668	2382	2467	2350	2362	2576
Design Performance	Design THR	1944	1944	2049	1975	1943	1959	2027	1926	1972	1930	1910	1944
	Design Boiler Efficiency	85	87	87	87	87	86	81	86	86	89	89	85
	Design SHR	2288	2238	2342	2260	2241	2272	2512	2242	2289	2170	2151	2299
	Deviation from Design	0.90	1.13	1.93	2.41	4.58	4.82	6.19	6.24	7.78	8.25	9.83	12.04
	Year of Establishment	2019	2010	1982	2013	2012	1993	1985	2016	1986	2000	2010	2007
	Coal GCV	3600-3900	3400-3600	3700-3900	3000-3200	3400-3600	3500-3700	3400-3600	3300-3400	3700-3800	5600-5800	5300-5500	3100-3300

3.2.2 Benchmarking of Operating Station Gross Heat Rate (O-SGHR) vs Design Station Gross Heat Rate (D-SGHR)- 600 MW

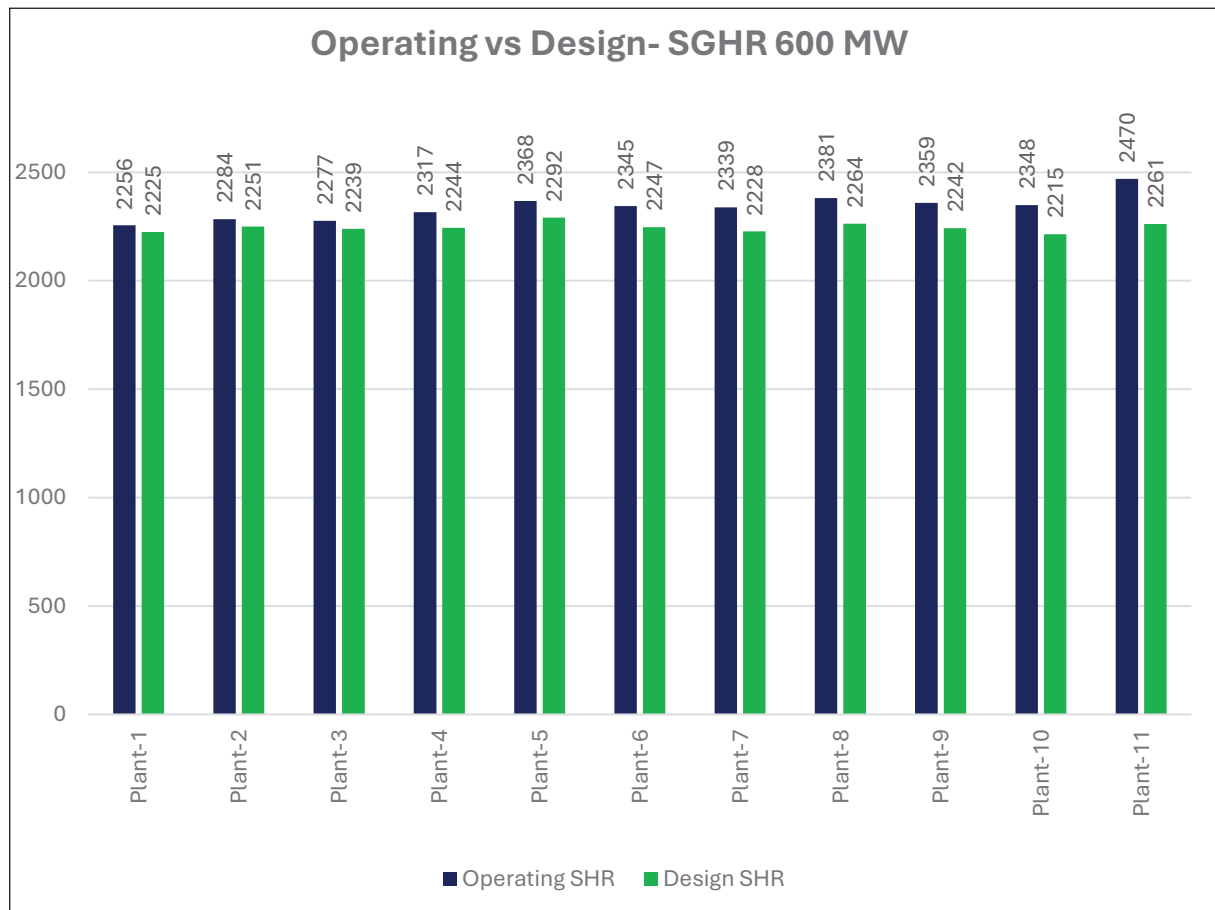


Figure 11: Operating vs Design deviation for Station Gross Heat Rate- 600 MW category

Table 10: Operating vs Design deviation for Station Gross Heat Rate- 600 MW category

	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10	Plant-11
Operating Performance	Turbine Heat Rate	1953	1997	1975	2012	2057	2030	2024	2041	1997	1997	2098
	Boiler Efficiency	86.58	87.43	86.73	86.83	86.85	86.58	86.52	85.70	84.64	85.03	84.93
	Station Heat Rate	2256	2284	2277	2317	2368	2345	2339	2381	2359	2348	2470
Design Performance	Design THR	1927	1944	1946	1936	1945	1942	1950	1965	1959	1945	1932
	Design Boiler Efficiency	86.60	86.37	86.91	86.29	84.85	86.42	87.54	86.80	87.35	87.80	85.44
	Design SHR	2225	2251	2239	2244	2292	2247	2228	2264	2242	2215	2261
	Deviation from Design	1.37	1.48	1.70	3.25	3.34	4.34	5.02	5.19	5.19	6.01	9.23
	Year of Establishment	2015	2014	2007	2011	2008	1988	2008	1987	1995	2011	2006
	Coal GCV	3100-3300	3100-3300	2900-3100	3600-3800	3700-3900	3600-3800	3500-3700	3700-3900	3100-3300	3800-4000	3700-3900

3.2.3 Benchmarking of Operating Station Gross Heat Rate (O-SGHR) vs Design Station Gross Heat Rate (D-SGHR)- 660 MW

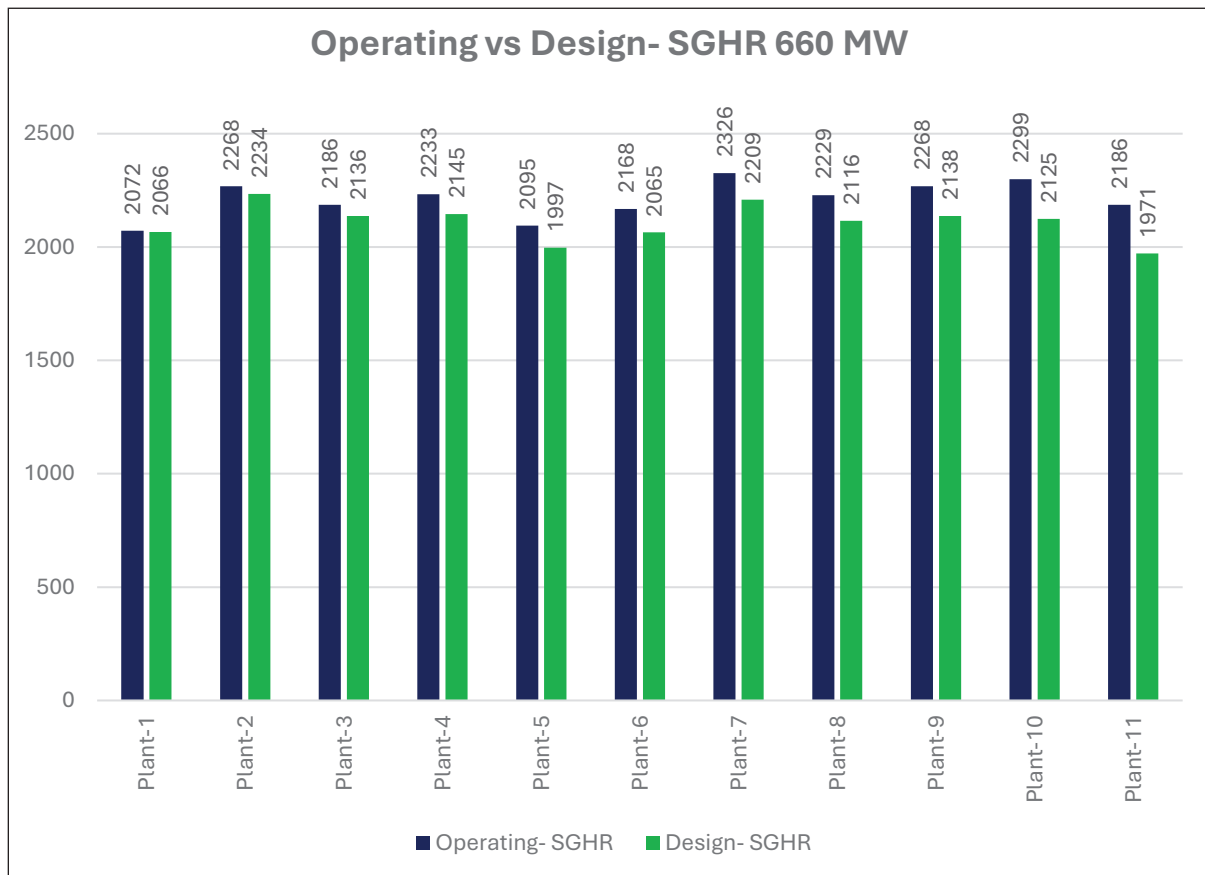


Figure 12: Operating vs Design deviation for Station Gross Heat Rate- 660 MW category

Table 11: Operating vs Design deviation for Station Gross Heat Rate- 660 MW category

	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10	Plant-11
Operating Performance	Turbine Heat Rate	1782	1949	1869	1918	1819	1867	1961	1954	1930	1950	1924
	Boiler Efficiency	85.98	85.96	85.48	85.90	86.82	86.12	84.32	87.68	85.10	84.81	88.00
	Station Heat Rate	2072	2268	2186	2233	2095	2168	2326	2229	2268	2299	2186
Design Performance	Design THR	1781	1917	1816	1832	1749	1854	1874	1849	1849	1818	1759
	Design Boiler Efficiency	86.19	85.82	85.01	85.42	87.60	89.78	84.84	87.40	86.50	85.56	89.20
	Design SHR	2066	2234	2136	2145	1997	2065	2209	2116	2138	2125	1971
	Deviation from Design	0.30	1.50	2.35	4.11	4.94	4.98	5.27	5.36	6.10	8.19	10.90
	Year of Establishment	2020	2008	2021	2019	2023	2008	2013	2007	2015	2000	2014
	Coal GCV	2800-3000	3400-3600	2700-2900	3600-3800	3600-3800	3600-3800	3200-3400	3600-3800	3400-3600	3600-3800	5100-5300

3.2.4 Conclusion on Station Gross Heat Rate-based benchmarking

- The chart clearly shows that the 660 MW category has the lowest Design SGHR (2109 kcal/kWh) and the lowest Operating SGHR (2212 kcal/kWh) among all categories, indicating that these units are the most thermally efficient. A lower SGHR signifies lower heat input required per unit of electricity generation and therefore better efficiency.

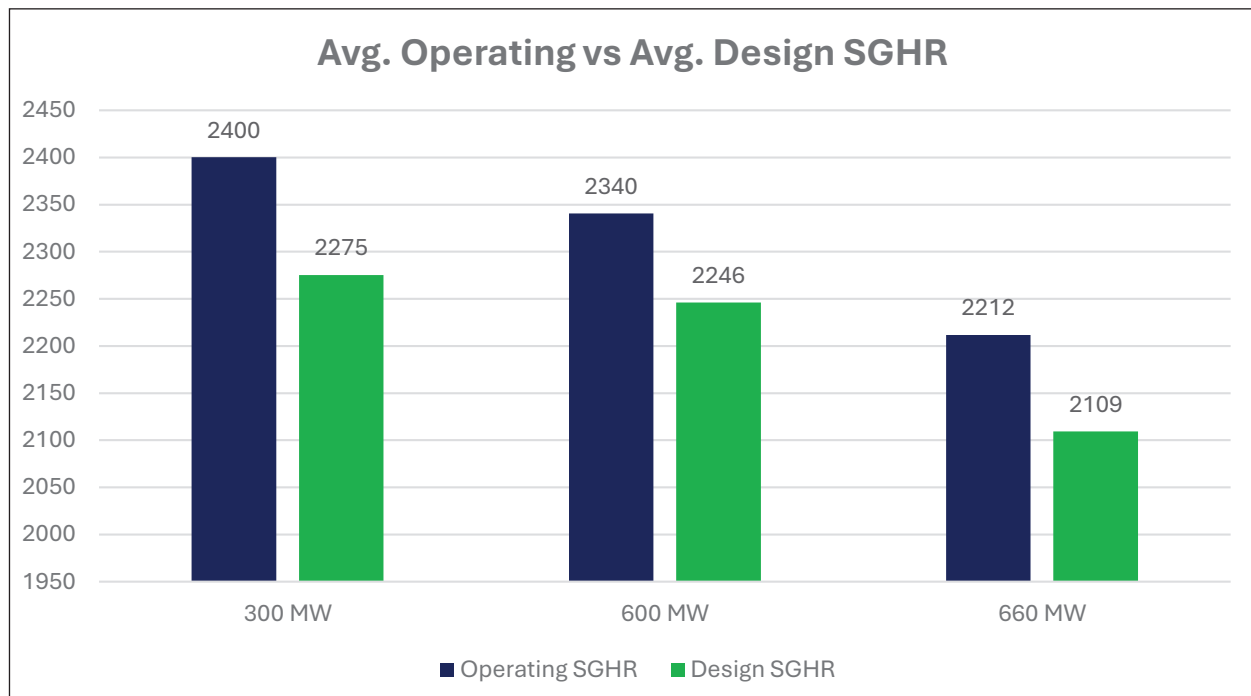


Figure 13: Comparison of design and operating SGHR

- Several factors may contribute to the superior performance of the 660 MW category:
 - Relatively newer plants compared to the 300 MW and 600 MW categories.
 - Deployment of advanced control systems, digital monitoring, and optimised combustion technologies.
 - Improved turbine and boiler design with higher cycle efficiencies.
 - Better automation and performance monitoring lead to tighter process control.
- The 600 MW category exhibits the lowest deviation from design performance, with a gap of only 94 kcal/kWh (4.2%). This suggests that these units are being operated and maintained close to their intended design conditions.
- Although the 660 MW category has a slightly higher deviation (103 kcal/kWh) than the 600 MW category, they still achieve the lowest absolute operating SGHR (2212 kcal/kWh). This means that even with a marginally larger performance gap, the 660 MW category remains the most efficient overall.
- The key to achieving better performance is to conduct strict monitoring of performance parameters like Turbine Heat Rate and Boiler Efficiency. Conducting internal performance audits (monthly) and external audits (annually) can greatly help to identify and fill the performance gaps.
- Maintaining operating parameters close to their design values can significantly help bridge the gap between design and actual operating SGHR. Developing and adhering to Standard Operating Procedures (SOPs) for critical processes such as ramp-up, ramp-down, startup, shutdown, equipment changeover, and emergency situations can help ensure that the unit operates as close as possible to its design parameters.

- Heat loss surveys like Boiler insulation survey, steam trap survey, and high-temperature drain valve passing survey can help arrest the heat which is getting lost from the system without giving useful output.
- Plants should develop daily, weekly, monthly, and annual monitoring plans to identify areas where significant improvement opportunities exist. A sample monitoring plan is provided in the annexure, which can be used directly or customised according to the installed systems and technologies.

3.3 Auxiliary Power Consumption (APC)

Auxiliary Power Consumption (APC) is a key performance indicator that represents the percentage of gross power generation consumed by the station's own equipment and auxiliaries for power production. These include boiler feed pumps, condensate extraction pumps, cooling water pumps, ID/FD/PA fans, coal handling systems, ash handling systems, cooling towers, and other balance-of-plant equipment. Lower APC indicates more efficient utilisation of generated power and results in higher net power export to the grid.

APC has a direct impact on Station Net Heat Rate (SNHR). For a given fuel input and gross generation, higher auxiliary power consumption reduces net generation, thereby increasing the SNHR. Conversely, reducing APC improves net plant efficiency by increasing the amount of electricity available for export without any additional fuel consumption.

The major factors influencing APC include plant load factor (PLF), operating regime of large auxiliaries, efficiency of pumps and fans, condenser and cooling system performance, coal quality, ambient conditions, maintenance practices, and the adoption of energy-efficient technologies such as variable frequency drives (VFDs). Effective monitoring and optimisation of these parameters can lead to substantial energy savings and improved plant economics.

The category-wise benchmarking values for Auxiliary Power Consumption (APC) for 300 MW thermal power generating units are presented below.

3.3.1 Benchmarking of APC - 300 MW

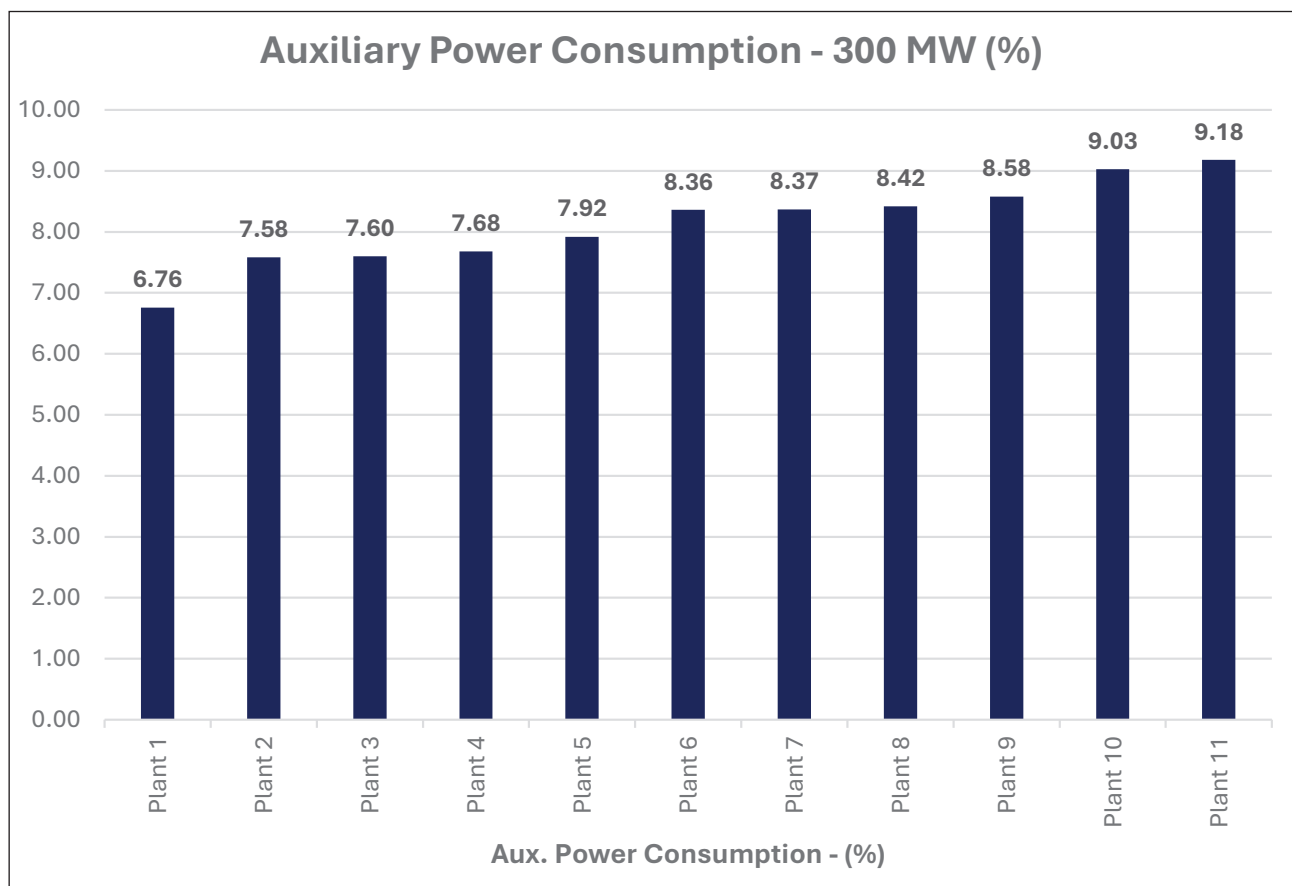


Figure 14: APC of 300 MW category

The following figure shows the share of each equipment/area along with its specific power consumption (kW/MW) for the best-performing plant in the 300 MW category on the lowest APC Day.

1. For the 300 MW category with TDBFP

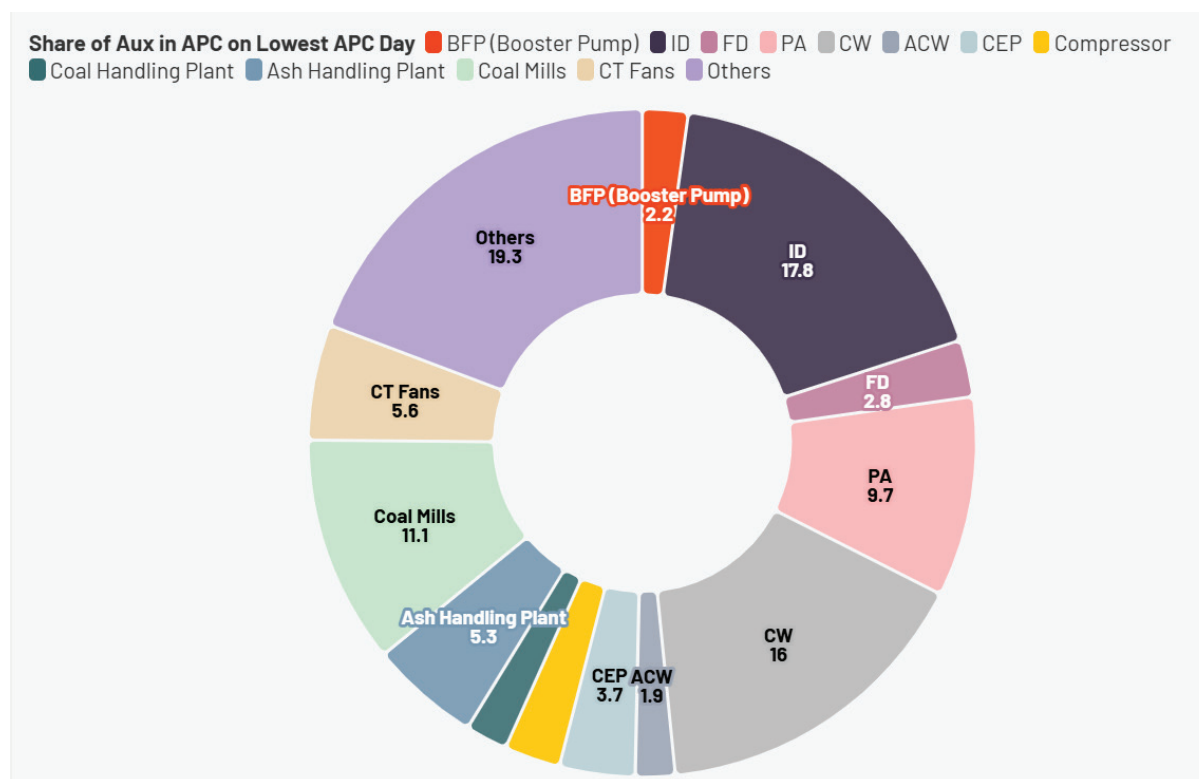


Figure 15: Share in APC for best-performing plant- 300 MW (with TDBFP)

Table 12: Share of Auxiliary in APC for best-performing plant- 300 MW (with TDBFP)

Auxiliary	UOM	Share in APC	Sp. Power Consumption (kW/MW)
BFP (booster pump)	%	2.21	1.28
ID Fan	%	17.81	10.31
FD Fan	%	2.76	1.60
PA Fan	%	9.69	5.61
Cooling Water Pump	%	15.95	9.23
Aux Cooling Water Pump	%	1.92	1.11
CEP	%	3.66	2.12
Compressors	%	2.72	1.58
Coal Handling Plant	%	2.04	1.18
Ash Handling Plant	%	5.33	3.09
Coal Mills	%	11.05	6.40
CT Fans	%	5.60	3.24

2. For 300 MW Category with MDBFP

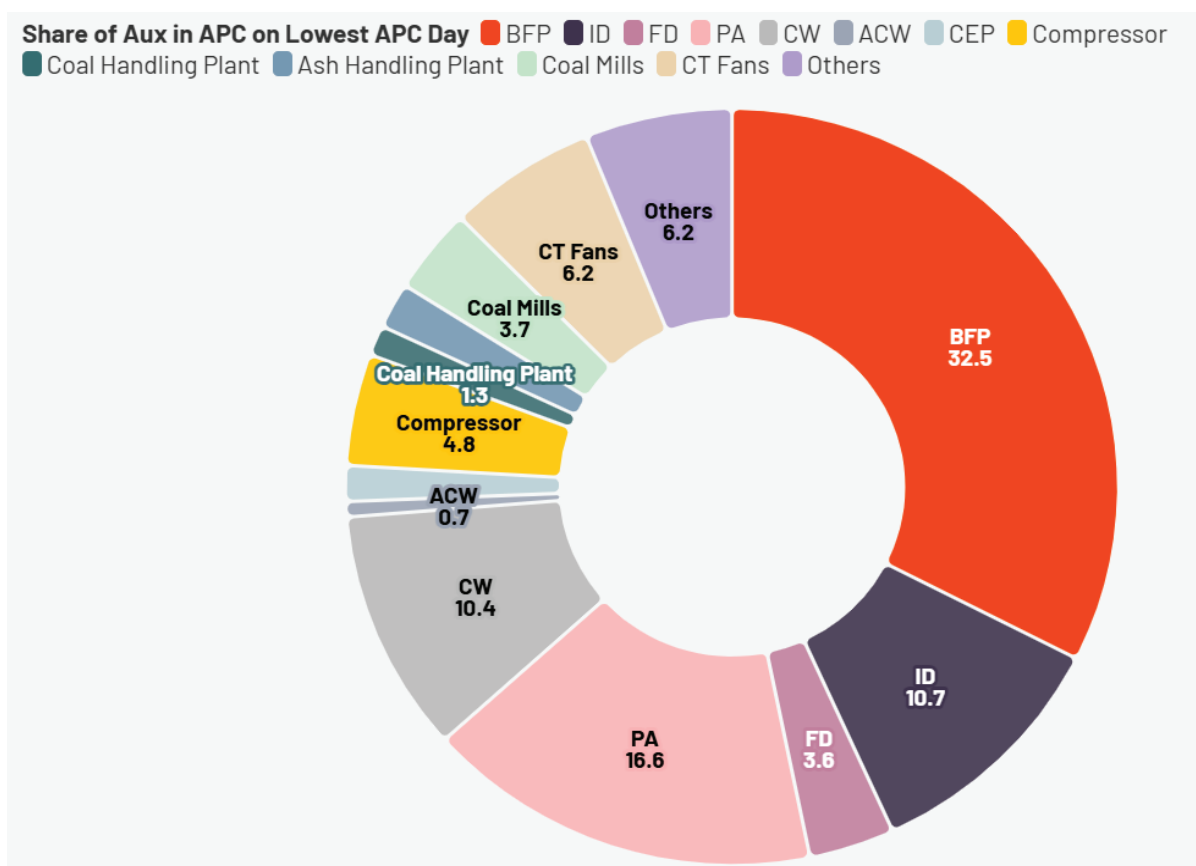


Figure 16: Share in APC for best-performing plant- 300 MW (with MDBFP)

Table 13: Share of Auxiliary in APC for best-performing plant- 300 MW (with MDBFP)

Auxiliary	UOM	Share in APC	Sp. Power Consumption (kW/MW)
Boiler Feed Pump	%	32.49	20.70
ID Fan	%	10.68	6.80
FD Fan	%	3.59	2.29
PA Fan	%	16.59	10.57
Cooling Water Pump	%	10.38	6.61
Aux Cooling Water Pump	%	0.66	0.42
CEP	%	1.52	0.97
Compressors	%	4.78	3.04
Coal Handling Plant	%	1.29	0.82
Ash Handling Plant	%	1.96	1.25
Coal Mills	%	3.66	2.33
CT Fans	%	6.24	3.97

Table 14: Key parameters affecting the APC 300 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
APC	%	6.76	7.58	7.60	7.68	7.92	8.36	8.37	8.42	8.58	9.03
Station Net Heat Rate	kcal/kWh	2482	2542	2488	2686	2584	2557	2383	2724	2356	2615
Fuel type	Indian/ Imported	Indian	Imported	Indian	Indian	Imported	Indian	Indian	Indian	Indian	Indian
Type of BFP	TDBFP/ MDBFP	TDBFP	MDBFP	MDBFP	MDBFP	MDBFP	MDBFP	MDBFP	MDBFP	MDBFP	MDBFP
Type of CT	NDCT/ IDCT	Induced Draft	Induced Draft	Induced Draft	-	Induced Draft	Induced Draft	-	Natural Draft	Induced Draft	Induced Draft
Coal Mill Classifier	Dynamic/ Static	Static	Static	Dynamic	-	Static	Static	-	Static	Static	Dynamic
Condenser	Water Cooled/ Air Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled
Year of Establishment	-	2013	2000	2010	1986	2010	2012	1982	1993	2007	2016
Coal GCV	kcal/kg	3000-3200	5600-5800	3400-3600	3700-3900	5300-5500	3400-3600	3700-3900	3400-3600	3100-3300	3200-3400
Whether Plant has FGD	Y/N	N	N	N	N	N	Y	Y	Y	N	N
Type of FGD	Dry/Wet FGD	-	-	-	-	-	DRY	DRY	WET	-	-

3.3.2 Benchmarking of APC - 600 MW

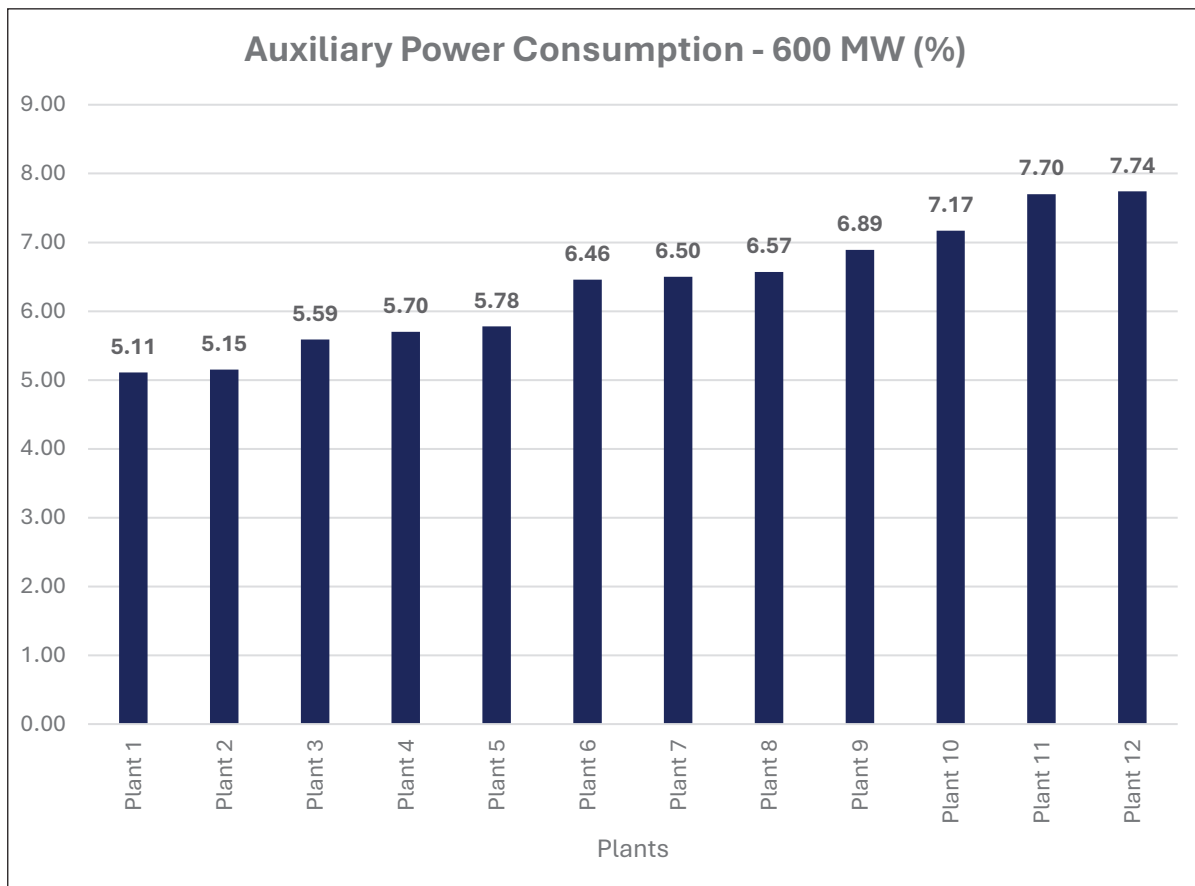


Figure 17: APC of 600 MW category

The following figure shows the share of each equipment/area along with its specific power consumption (kW/MW) for the best-performing plant in the 600 MW category on the lowest APC Day.

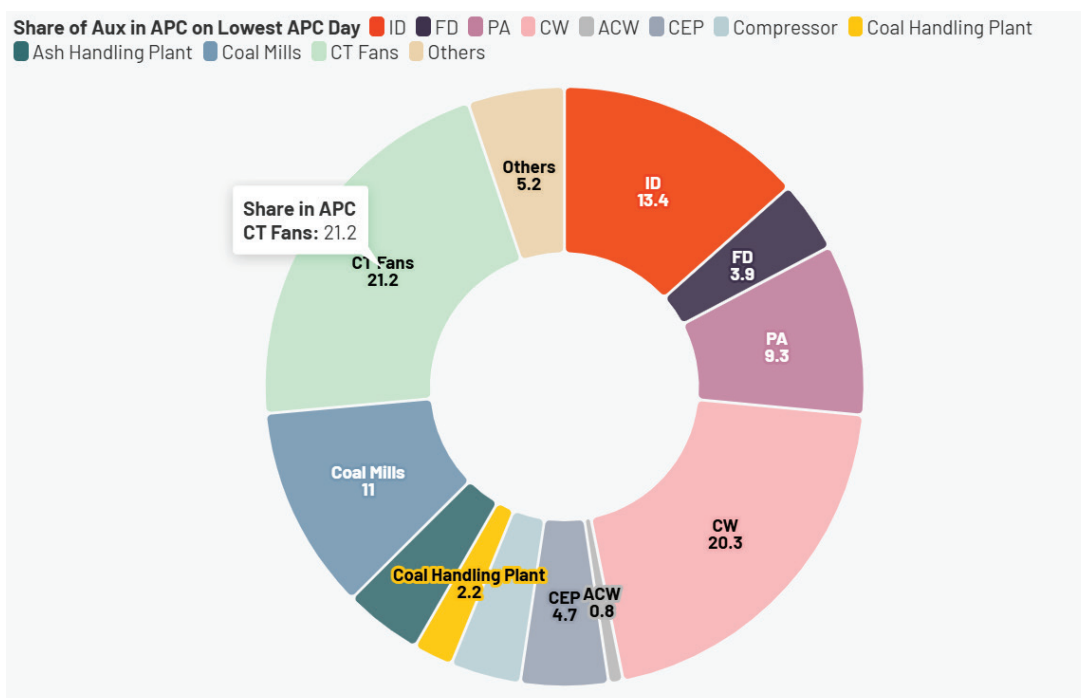


Figure 18: Share in APC for best-performing plant- 600 MW

Table 15: Share in APC for best-performing plant- 600 MW

Auxiliary	UOM	Share in APC	Sp. Power Consumption (kW/MW)
ID Fan	%	13.41	6.34
FD Fan	%	3.85	1.82
PA Fan	%	9.26	4.38
Cooling Water Pump	%	20.34	9.62
Aux Cooling Water Pump	%	0.78	0.37
CEP	%	4.73	2.24
Compressors	%	3.81	1.80
Coal Handling Plant	%	2.15	1.02
Ash Handling Plant	%	4.21	1.99
Coal Mills	%	11.04	5.22
CT Fans	%	21.21	10.03

Table 16: Key parameters affecting APC 600 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
APC	%	5.11	5.15	5.59	5.70	5.78	6.46	6.50	6.57	6.89	7.17
Station Net Heat Rate	kcal/kWh	2377	2408	2454	2511	2492	2434	2480	2524	2518	2520
Fuel type	Indian/ Imported	Indian	Indian	Indian	Indian	Blended	Indian	Indian	Indian	Indian	Indian
Type of BFP	TDBFP/ MDBFP	TDBFP	TDBFP	TDBFP	TDBFP	TDBFP	MDBFP	TDBFP	TDBFP	TDBFP	TDBFP
Type of CT	NDCT/ IDCT	Induced Draft	Natural Draft	Induced Draft	Natural Draft	Induced Draft	Induced Draft	Induced Draft	Induced Draft	Induced Draft	Induced Draft
Coal Mill Classifier	Dynamic/ Static	Dynamic	Static	Static	Static	Static	Static	Static	Static	Static	Dynamic
Condenser	Water Cooled/ Air Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled
Year of Establishment	-	2015	2014	2011	2008	2011	2007	1995	1988	2008	2006
Coal GCV	kcal/kg	3100-3300	3100-3300	3600-3800	3700-3900	3800-4000	2900-3100	3100-3300	3600-3800	3500-3700	3500-3700
Whether Plant has FGD	Y/N	N	Y	N	Y	Y	N	N	Y	Y	N
Type of FGD	Dry/Wet FGD	-	WET	-	WET	WET	-	-	WET	WET	-

3.3.3 Benchmarking of APC - 660 MW

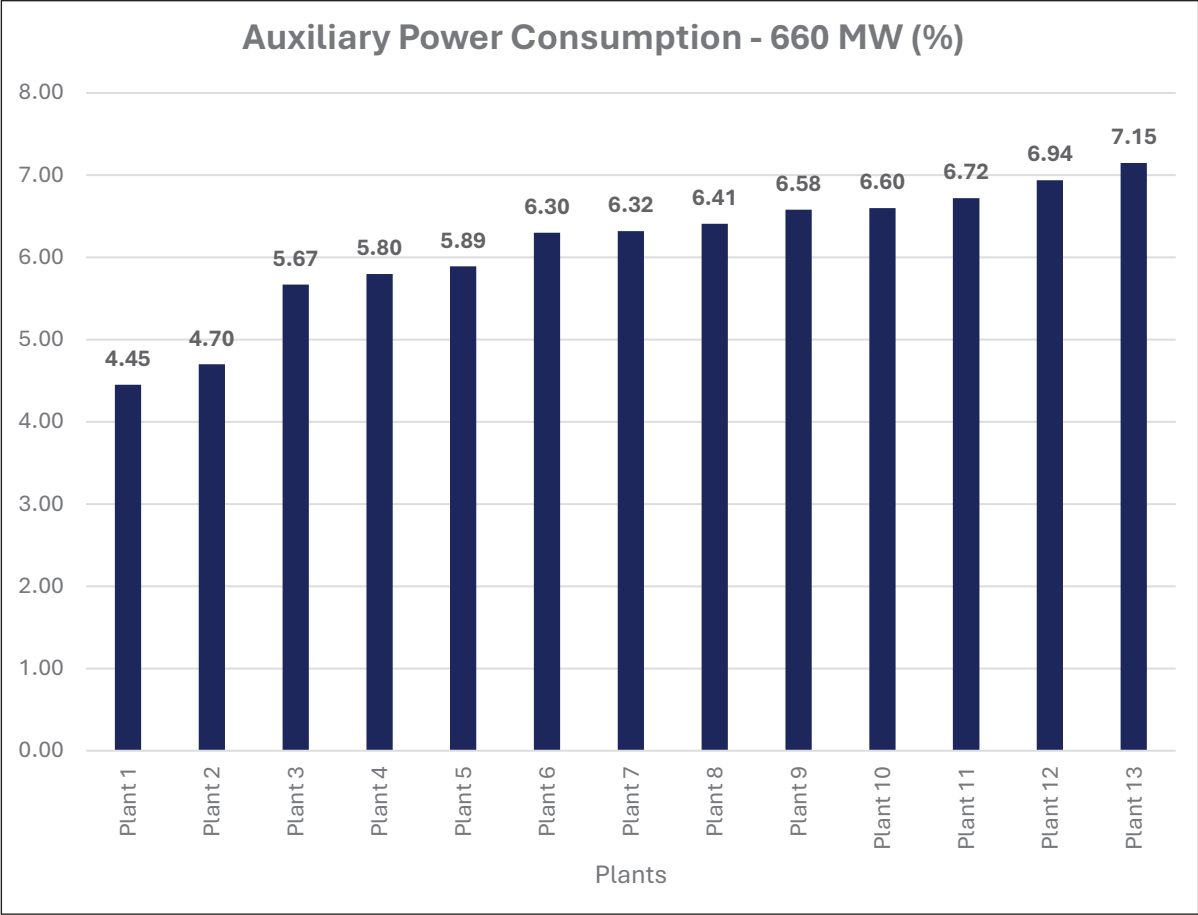


Figure 19: APC of 660 MW category

The following figure shows the share of each equipment/area along with its specific power consumption (kW/MW) for the best-performing plant in the 660 MW category on the lowest APC Day.

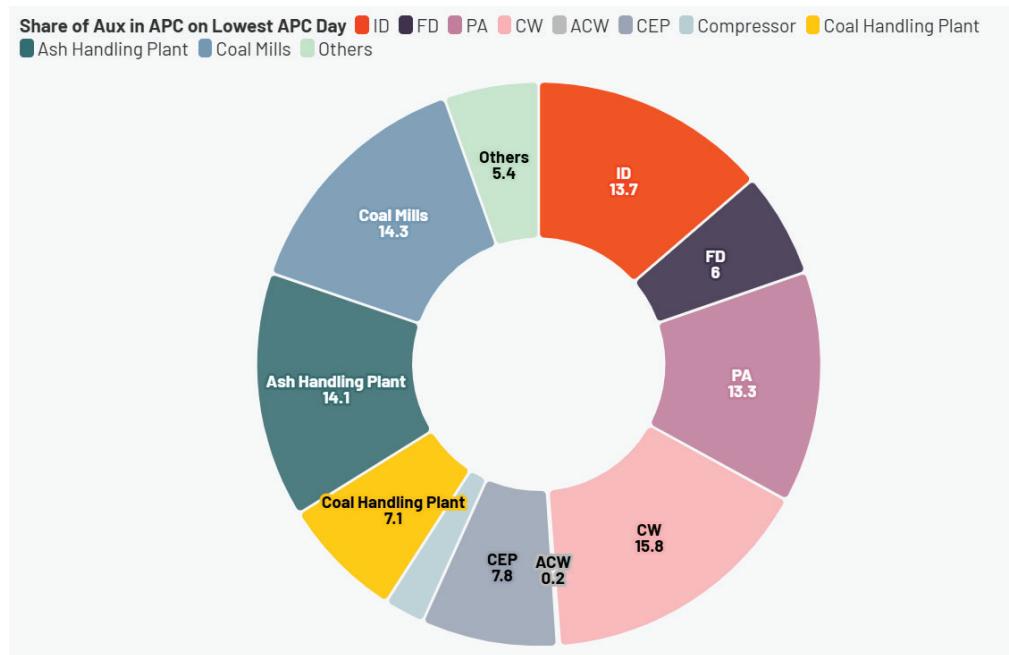


Figure 20: Share in APC for best-performing plant- 660 MW

Table 17: Share in APC for best-performing plant- 660 MW

Auxiliary	UOM	Share in APC	Sp. Power Consumption (kW/MW)
ID Fan	%	13.66	5.15
FD Fan	%	6.04	2.28
PA Fan	%	13.29	5.01
Cooling Water Pump	%	15.81	5.96
Aux Cooling Water Pump	%	0.17	0.06
CEP	%	7.78	2.93
Compressors	%	2.35	0.89
Coal Handling Plant	%	7.05	2.66
Ash Handling Plant	%	14.09	5.31
Coal Mills	%	14.34	5.41

Table 18: Key parameters affecting the APC of the 660 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
APC	%	4.45	4.70	5.67	5.80	5.89	6.30	6.32	6.41	6.58	6.60
Station Net Heat Rate	kcal/kWh	2332	2274	2367	2407	2409	2826	2482	2336	2460	2340
Fuel type	Indian/ Imported	Indian	Indian	Blended	Blended	Indian	Indian	Indian	Indian	Indian	Imported
Type of BFP	TDBFP/ MDBFP	TDBFP	TDBFP	TDBFP	TDBFP	TDBFP	TDBFP	TDBFP	TDBFP	TDBFP	TDBFP
Type of CT	NDCT/ IDCT	Natural Draft	Natural Draft	Induced Draft	Natural Draft	Induced Draft	Induced Draft	Induced Draft	Induced Draft	Natural Draft	Induced Draft
Coal Mill Classifier	Dynamic/ Static	Dynamic	Dynamic	Static	Static	Static	Static	Static	Static	Dynamic	Dynamic
Condenser	Water Cooled/ Air Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled	Water Cooled
Year of Establishment	-	2007	2008	2019	2015	2008	2019	2013	2021	2000	2014
Coal GCV	kcal/kg	3600-3800	3600-3800	3600-3800	3400-3600	3400-3600	3500-3700	3200-3400	2700-2900	3600-3800	5100-5300
Whether Plant has FGD	Y/N	Y	N	N	N	Y	Y	Y	Y	Y	Y
Type of FGD	Dry/Wet FGD	WET	-	-	-	WET	WET	WET	WET	WET	WET

3.3.4 Conclusion from APC Benchmarking

- The benchmarking results indicate that the 660 MW category consistently demonstrates the lowest APC values, primarily due to the adoption of energy-efficient technologies such as Turbine Driven Boiler Feed Pumps (TDBFPs), optimised cooling systems, NDCT, and advanced process control systems. These design advantages significantly reduce internal power consumption and improve net station efficiency.
- It may be noted that most of the best-performing plants with the lowest APC do not have FGD systems installed. The operation of an FGD system typically increases APC by at least 1%, depending on the type of FGD technology deployed.
- The study highlights that APC performance is not governed by a single auxiliary system but by the combined performance of major power-consuming equipment, including boiler feed pumps (BFP), Induced Draught (ID), Forced Draught (FD), Primary Air (PA) fans, cooling water pumps (CWP), condensate extraction pumps (CEP), ash handling plants (AHP), and coal handling plants (CHP). Stations achieving the best APC figures have successfully optimised the operation of all major auxiliaries while maintaining equipment efficiency and reliability.
- APC also has a direct impact on Station Net Heat Rate (SNHR) and ultimately on the emissions of the plant. A 1% pt. increase in APC can increase emission intensity by 0.01 kg CO₂/kWh. This increase in emission intensity for a 600 MW unit operating at 70% PLF translates to additional 31,000- 32,000 tons of CO₂ emissions annually.
- Top-performing plants also demonstrate superior equipment health and operational discipline through optimised pump and fan operation, effective condenser and cooling system management, deployment of Variable Frequency Drives (VFDs), and proactive maintenance practices. These measures help minimise avoidable energy losses and sustain low auxiliary consumption across varying operating conditions.
- To achieve lower APC plants should consider the following:
 - Replace old inefficient IE-2 motors with IE-3 or IE-4 motors with better efficiency.
 - Conduct VFD feasibility studies within the plant and explore opportunities to install VFD in equipment like CEP, Cooling Tower Fans, Cooling Water Pumps, ACW pumps etc.
 - Maintain Δp across the Feedwater station as low as possible (preferred < 3 kg/cm²).
 - Replace BFP cartridge once it reaches the end of its service life.
 - Carryout APH leakage study monthly to reduce FD & ID fan power consumption.

3.4 Boiler Efficiency

Boiler efficiency represents the effectiveness of converting fuel energy into useful steam energy. Even a small improvement in boiler efficiency can result in significant reductions in coal consumption, heat rate, and carbon emissions. Boiler efficiency has a direct effect on Scope 1 emissions, making it a critical KPI for emission reduction. Factors affecting boiler efficiency include coal quality, excess air levels, flue gas exit temperature, air heater performance, coal fineness, combustion quality, and soot blowing effectiveness.

The benchmarking based on boiler efficiency for various categories is shown as follows:

3.4.1 Benchmarking of Boiler Efficiency - 300 MW

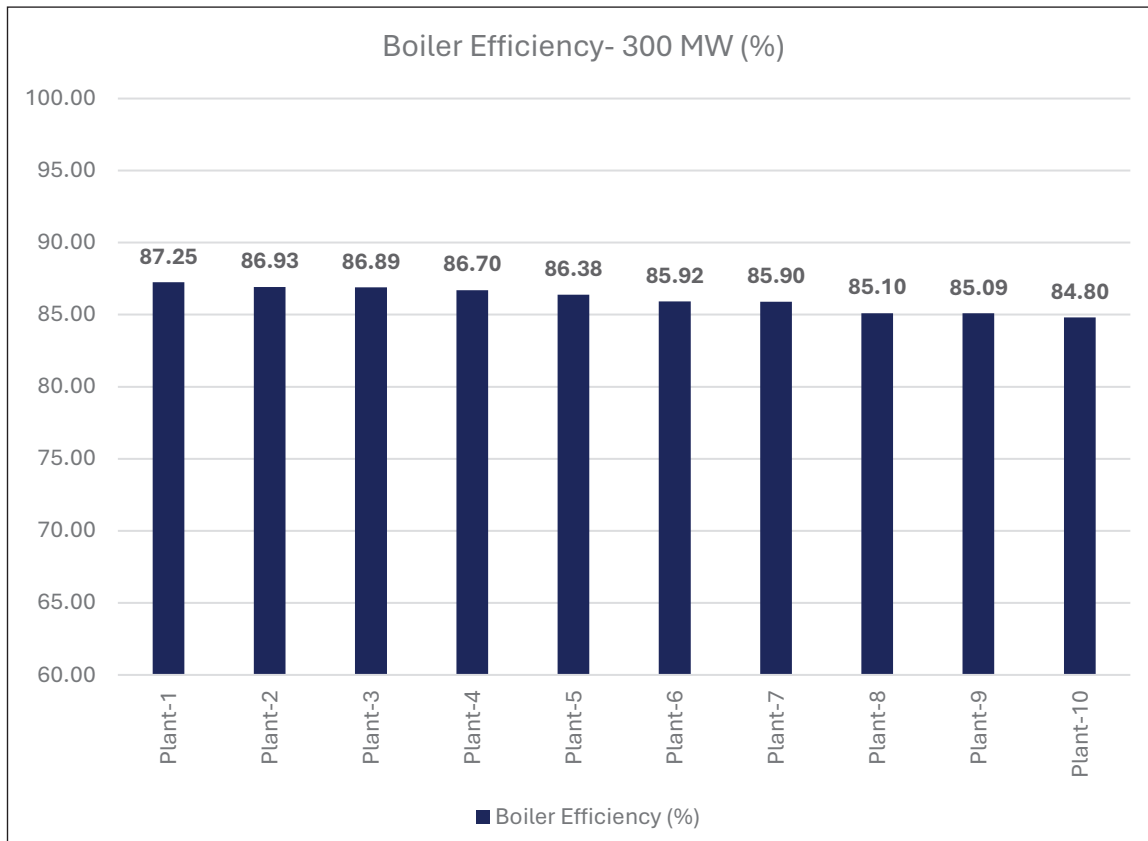


Figure 21: Boiler efficiency 300 MW category

Table 19: Key parameters affecting boiler efficiency of 300 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
Boiler Efficiency	%	87.25	86.93	86.89	86.70	86.38	85.92	85.90	85.10	85.09	84.80
Fuel Type	Indian/ Imported	Indian	Indian	Imported	Indian	Indian	Indian	Indian	Indian	Indian	Imported
Coal GCV	kcal/kg	3500-3600	3100-3200	5700-5800	3500-3600	3800-3900	3500-3600	3300-3400	3700-3900	3700-3900	5200-5500
O2 level	%	2.80	3.36	4.22	3.33	3.50	3.00	3.00	3.50	3.40	3.40
Exit FG temp	°C	146	130	140	129	135	153	140	129	160	135
Year of Establishment	-	2010	2013	2000	2012	1982	1993	2016	1986	2019	2010

3.4.2 Benchmarking of Boiler Efficiency - 600 MW

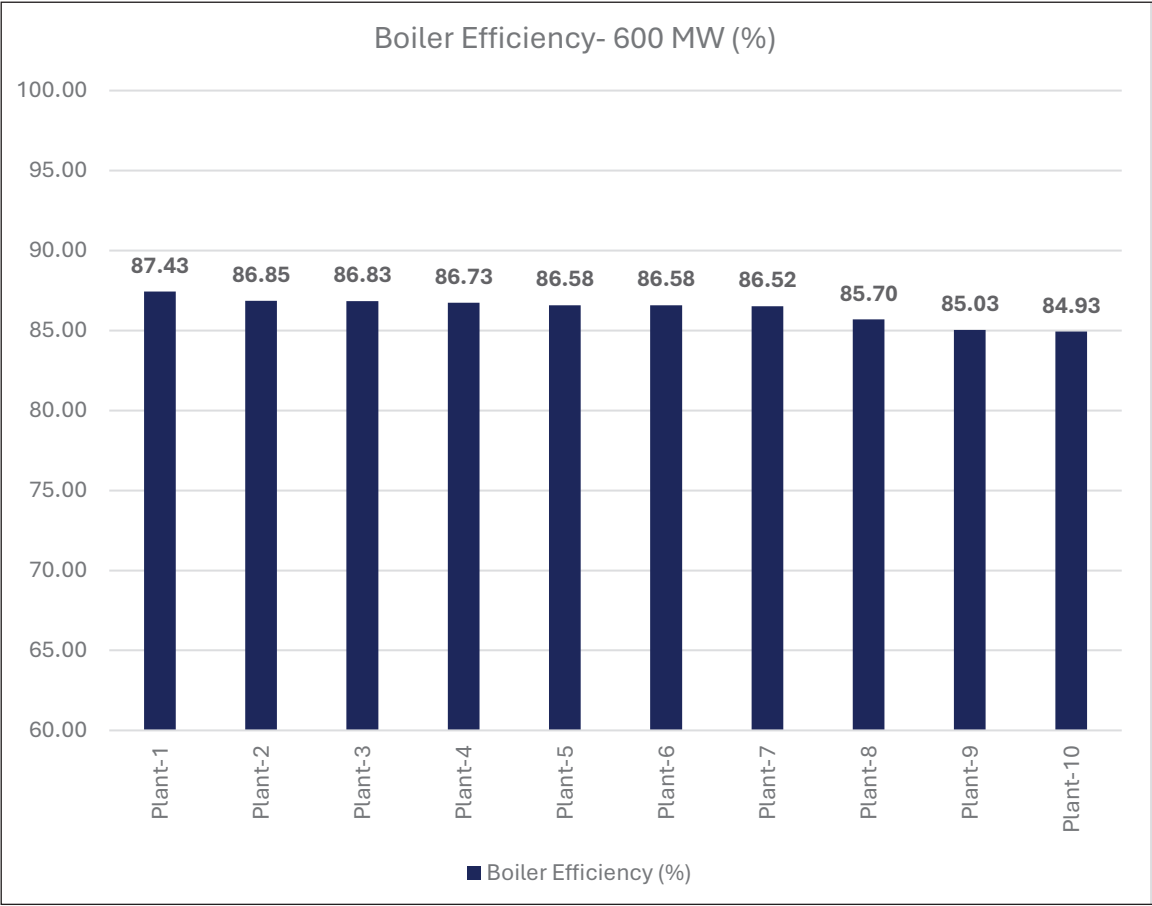


Figure 22: Boiler efficiency of 600 MW category

Table 20: Key parameters affecting boiler efficiency of 600 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
Boiler Efficiency	%	87.43	86.85	86.83	86.73	86.58	86.58	86.52	85.70	85.03	84.93
Fuel Type	Indian/ Imported	Indian	Indian	Indian	Indian	Indian	Indian	Indian	Indian	Blended	Indian
GCV of coal	kcal/kg	3200-4000	3800-4000	3700-3900	3000-3200	3200-3400	3700-3900	3600-3800	3800-4000	3900-4000	3500-3700
O2 level	%	3.00	3.50	2.72	3.20	4.10	4.06	2.87	3.00	3.15	3.71
Exit FG temp	°C	142	140	133	135	135	149	130	140	149	150
Year of Establishment	-	2014	2008	2011	2007	2015	1988	2008	1987	2011	2006

3.4.3 Benchmarking of Boiler Efficiency - 660 MW

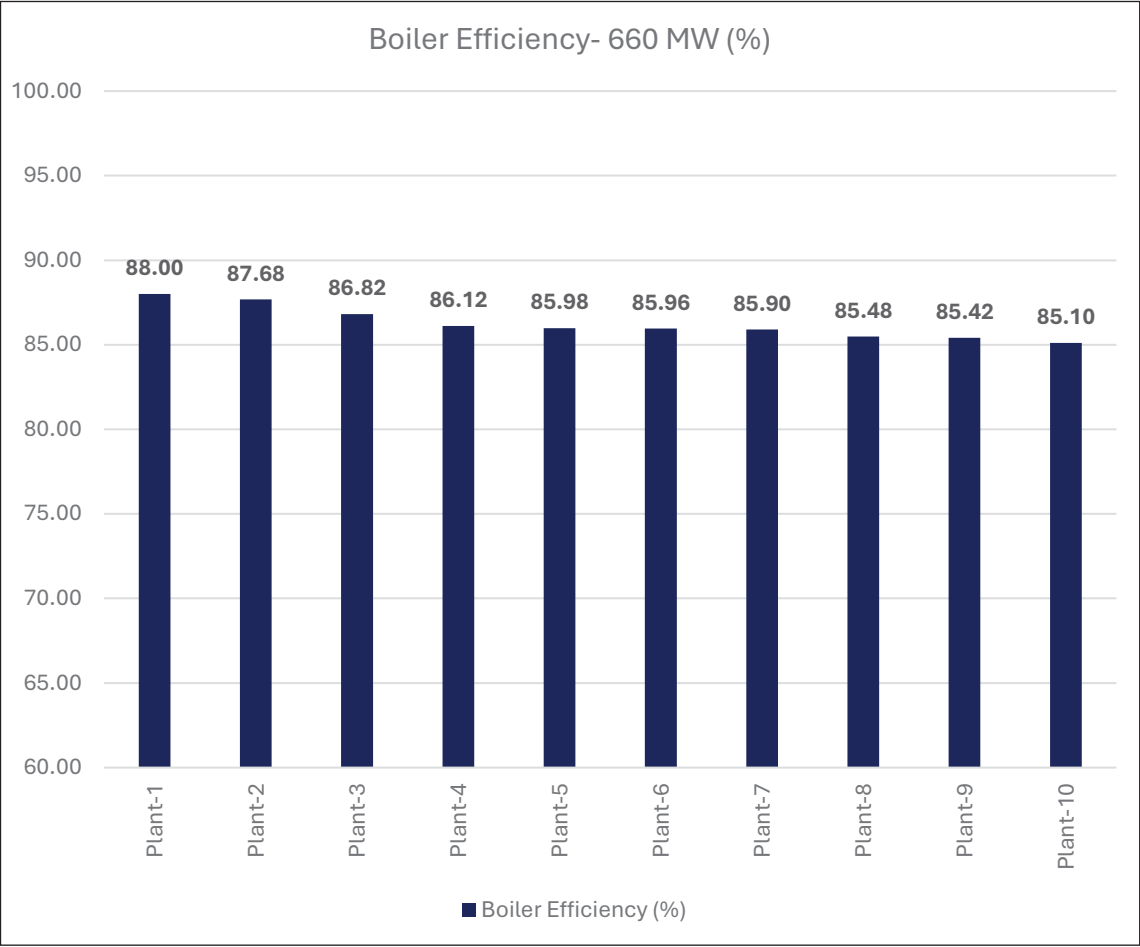


Figure 23: Boiler efficiency of 660 MW category

Table 21: Key parameters affecting the boiler efficiency of the 660 MW category

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
Boiler Efficiency	%	88.00	87.68	86.12	85.98	85.96	85.90	85.48	85.42	85.10	85.00
Fuel Type	Indian/ Imported	Imported	Indian	Indian	Indian	Indian	Blended	Indian	Indian	Blended	Indian
GCV of coal	kcal/kg	5200-5400	3700-3800	3600-3800	2900-3200	3400-3600	3600- 3800	2700-2900	3600-3800	3400-3600	3300- 3500
O2 level	%	4.25	2.70	3.20	3.55	3.20	3.84	3.45	3.59	3.30	3.50
Exit FG temp	°C	145	131	130	144	135	135	146	137	147	124
Year of Establishment	-	2014	2007	2023	2008	2020	2008	2019	2021	2019	2015

3.4.4 Conclusion based on Boiler Efficiency benchmarking

- The 660 MW category delivers the highest benchmark efficiency, reaching 88%, reflecting the advantages of large supercritical units and advanced combustion systems. Higher steam temperatures and advanced boiler designs contribute to improved heat absorption and reduced thermal losses. The findings indicate that modern supercritical units can consistently achieve higher boiler efficiencies than older subcritical units when operated under optimal conditions.
- The best-performing boilers maintain an optimum balance between combustion efficiency and heat recovery. While sufficient excess air is necessary for complete combustion, excessive oxygen levels increase dry flue gas losses and reduce efficiency. The top-performing plants generally maintain O₂ levels within a tightly controlled range, reflecting better combustion control and burner management.
- Flue gas exit temperature is another key differentiator. Plants with lower exit gas temperatures generally achieve higher boiler efficiencies because more heat is recovered through economisers and air preheaters. Higher stack temperatures often indicate fouling of heat-transfer surfaces, air heater leakage, soot deposition, or ineffective soot blowing. Every 22°C rise in exit flue gas temperature decreases the boiler efficiency by 1%.
- The influence of fuel quality is also evident. Plants using imported or blended coal with higher GCV often achieve stable combustion and lower unburnt carbon losses. However, fuel quality alone does not guarantee high boiler efficiency. Several stations operating on lower-GCV Indian coal are among the top performers, demonstrating the importance of combustion optimisation and effective boiler operation.
- To achieve higher boiler efficiency, plants should consider the following:
 - Maintain the feed water inlet (higher is better, but steaming in economiser should be avoided) temperature and flue gas exit temperature (lower is better, but the temperature should not be dropped below the sulphur dew point).
 - Maintain residual oxygen near to the design or slightly lower (unburnt in fuel and CO formation should be monitored while lowering residual oxygen below the recommended levels).
 - Coal fineness should be as per the design. Adjust mill classifier to achieve the desired fineness of the coal.
 - Fuel should be properly stacked and covered to prevent moisture ingress, especially during the monsoon season. Provision of covered sheds should also be considered for better protection against moisture and weather exposure.

3.5 Flexible Operations

With the increasing penetration of renewable energy sources such as solar and wind power, coal-based thermal power plants are increasingly required to operate beyond their traditional baseload role and provide the flexibility necessary to balance grid fluctuations and maintain system reliability. As power systems transition towards cleaner energy portfolios, operational flexibility has become a critical capability that enables thermal power plants to respond rapidly to changing demand patterns, variable renewable generation, and grid dispatch requirements. Flexibility benchmarking provides a systematic framework for evaluating a plant's ability to operate safely, efficiently, and reliably under dynamic operating conditions while supporting higher renewable energy integration. By assessing flexibility performance across comparable stations, utilities can identify improvement opportunities, adopt best practices, and enhance their readiness to meet future grid requirements.

Unlike the earlier sections, where categorisation was based on station capacity, the benchmarking of flexibility performance was carried out by classifying power plants according to their installed technology, namely subcritical and supercritical units. Based on the data submitted by participating power plants under the CII's 27th National Awards for Excellence in Energy Management- 2026, the benchmarking has been conducted considering the following technological advancements:

1. Deviation in critical parameters during part load compared to full load. The parameters include: excess air, boiler efficiency, APC, etc.
2. Mode of operation during part load, i.e., sliding pressure or constant pressure operation
3. Flexibility-related readiness levels, which include various modifications in the plant system, are as follows:
 - Modification in Standard Operating Procedures (SOP) to take care of higher ramp rates without temperature excursions.
 - Extension of metal temperature monitoring (MTM) to cover larger areas in the 2nd pass to identify hotspots and temperature excursions during load changes.
 - Installation of SCAPH to avoid lower exit flue gas temperatures causing cold end corrosion in the APH, ESP, and associated ducts.
 - Replacement of the ON/OFF type BFP recirculation valve with a regulating valve for better drum level control while ensuring adequate flow through the feed pump
 - Replacement of flame scanners with new and improved scanners for accurate detection of flame during low load operations.

To assess the flexibility readiness of thermal power plants, EPRI's Flexibility Assessment Tool has been adopted.¹⁹ The tool evaluates plant preparedness for flexible operation across ten critical performance areas that influence the ability of a generating unit to operate safely and efficiently under varying load conditions. These areas encompass equipment operating modes, pressure part management, operations, maintenance practices, combustion and performance management, instrumentation, controls and automation, environmental control systems, cycle chemistry, turbine-generator systems, and balance-of-plant facilities. The assessment provides a comprehensive measure of a plant's capability to support renewable energy integration, load-following operation, lower technical minimum loads, and faster ramp rates while maintaining operational reliability and equipment health.

The overall flexibility readiness score is derived from the weighted evaluation of these ten assessment areas, enabling utilities to identify performance gaps and prioritise modifications required for enhanced flexible operation in a renewable-rich power system.

¹⁹ <https://www.netl.doe.gov/flextool>

3.5.1 Flexibility readiness benchmarking for subcritical plants

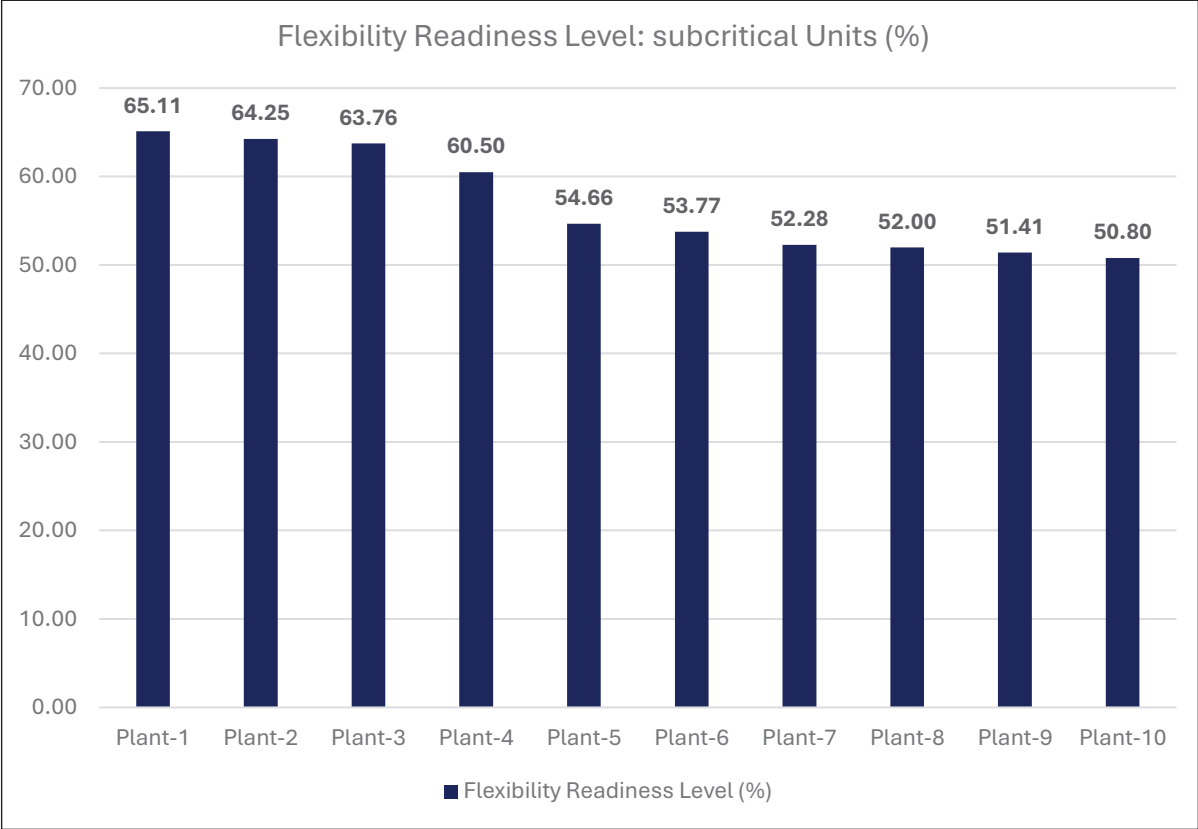


Figure 24: Flexibility readiness level of subcritical plants

Table 22: Key parameters affecting flexibility of subcritical plants

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7	Plant-8	Plant-9	Plant-10
Flexibility Readiness Level	%	65.10	64.20	63.80	60.50	54.70	53.80	52.30	52.00	51.40	50.80
Mode of Operation	Sliding/ Constant	Sliding Pressure	Sliding Pressure	Sliding Pressure	Sliding Pressure	Sliding Pressure	Sliding Pressure	Sliding Pressure	Sliding Pressure	Sliding Pressure	Sliding Pressure
Modified SOP	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Extended MTM	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
SCAPH Installed	Y/N	Y	Y	Y	Y	Y	N	Y	Y	N	N
Regulating R/C for BFP	Y/N	Y	Y	Y	N	Y	Y	N	N	Y	N
Improved Flame Scanners	Y/N	N	Y	N	Y	N	N	Y	Y	N	Y
Year of Establishment	-	2010	1993	2013	2016	1995	2011	2019	2007	2000	2014
Type of Coal	Indian/ Imported	Indian	Indian	Blended	Blended	Indian	Indian	Blended	Indian	Indian	Blended
Coal GCV	kcal/kg	3600-3800	3500-3700	3600-3800	3600-3800	2800-3000	3200-3400	3400-3600	3600-3800	3500-3700	3600-3800

3.5.2 Flexibility readiness benchmarking for supercritical plants

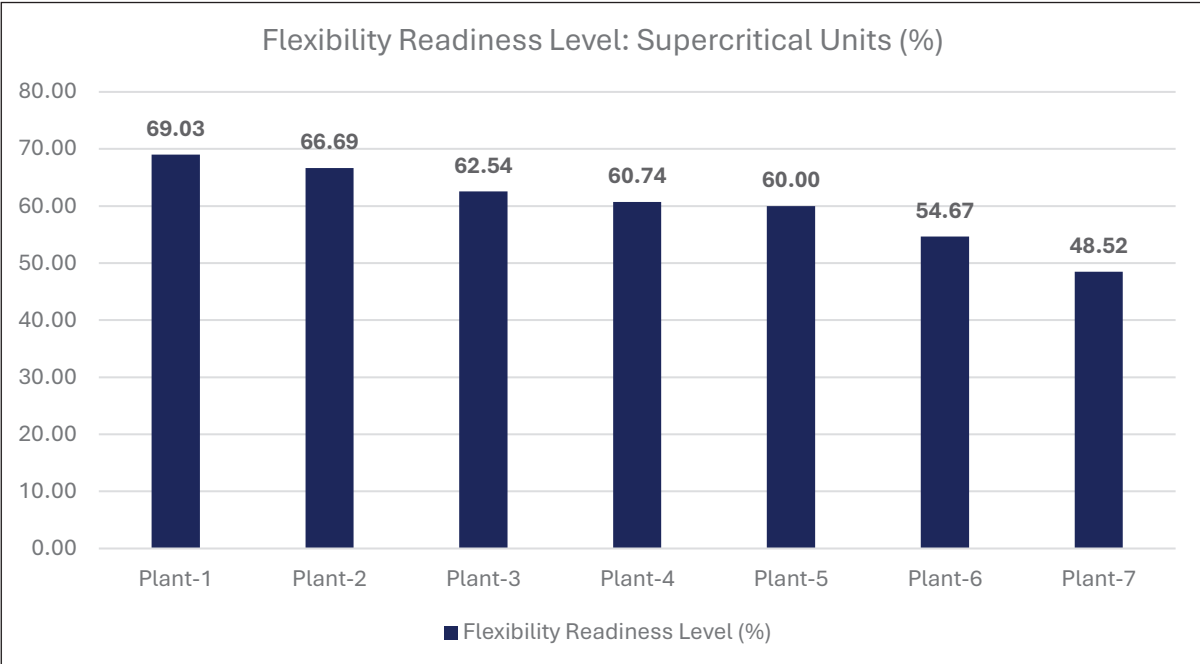


Figure 25: Flexibility readiness level of supercritical plants

Table 23: Key parameters affecting flexibility of supercritical plants

Parameters	UOM	Plant-1	Plant-2	Plant-3	Plant-4	Plant-5	Plant-6	Plant-7
Flexibility Readiness Level	%	69.03	66.70	62.50	60.70	60.00	54.70	48.50
Mode of Operation	Sliding/ Constant	Sliding pressure	Sliding pressure	Sliding pressure	Sliding pressure	Sliding pressure	Sliding pressure	Sliding pressure
Modified SOP	Y/N	Y	Y	Y	Y	Y	Y	Y
Extended MTM	Y/N	Y	Y	Y	Y	Y	Y	Y
SCAPH Installed	Y/N	Y	Y	Y	Y	Y	Y	N
Regulating R/C for BFP	Y/N	Y	Y	Y	Y	Y	N	Y
Improved Flame Scanners	Y/N	N	Y	N	Y	Y	N	N
Year of Establishment	-	2008	2019	2023	2019	2020	2013	2015
Type of Coal	Indian/ Imported	Indian	Indian	Blended	Blended	Indian	Indian	Blended
Coal GCV	kcal/kg	3600-3800	3500-3700	3600-3800	3600-3800	2800-3000	3200-3400	3400-3600

3.5.3 Conclusion based on Flexibility-based benchmarking

- Supercritical units exhibit a higher maximum readiness level (69.0%) than subcritical units (65.1%). While the average flexibility level of supercritical units is 60.31%, the subcritical units show average flexibility readiness levels of 56.86%, indicating superior readiness for flexible operation.
- Higher flexibility enables a power plant to cycle up and down more effectively, with improved ramp rates while imposing minimal stress on critical equipment and assets. This capability is increasingly important with the growing share of renewable energy in the grid, as renewable generation is inherently variable and difficult to predict. Consequently, thermal power plants must operate flexibly to balance fluctuations in renewable output and reliably bridge the resulting supply-demand gaps.
- The larger spread in the supercritical fleet indicates that flexibility performance is not solely dependent on technology; implementation of flexibility measures significantly influences readiness
- All top-performing supercritical plants run under sliding pressure mode. This is particularly important because supercritical units derive significant efficiency benefits when pressure is allowed to vary with load. It also helps in reducing throttling losses and thermal stress during load changes
- While it is evident that the supercritical units show higher readiness levels for flexible operations, with modifications such as advanced process controls, better SOPs, improved scanners and monitoring systems, installation of SCAPH, and replacement of the BFP recirculation valve with a regulating valve, a subcritical unit can also achieve flexibility levels comparable to a supercritical unit.
- To achieve higher levels of flexibility, plants should consider the following:
 - Training and skill development of operators is considered one of the most important factors.
 - Specific SOPs to be developed for low-load operations and procedures for emergency handling
 - Install Flex-Ready technologies within the plant to achieve better control of critical operating parameters across a wide operating range, thereby enhancing operational flexibility, improving ramping capability, and reducing equipment stress during cycling operations.
 - Maintaining operating parameters near to the design during the low load operations.

3.6 Specific Raw Water Consumption

Efficient water management is a key component of sustainable thermal power plant operation. Water is extensively used for cooling, steam generation, ash handling, flue gas Desulphurisation (FGD), and various auxiliary systems. Therefore, monitoring and benchmarking water consumption parameters is essential for improving resource efficiency and reducing environmental impact.

Specific Raw Water Consumption (SWC) represents the quantity of fresh water consumed per unit of electricity generated. The Ministry of Environment, Forest and Climate Change (MoEF&CC), with technical input from CEA, has prescribed water consumption standards for thermal power stations to promote efficient utilisation of water resources. Existing cooling tower-based plants are required to limit specific water consumption to 3.5 m³/MWh, while new plants commissioned on or after 1 January 2017 are required to limit consumption to 3.0 m³/MWh and operate with Zero Liquid Discharge (ZLD) systems.

Lower specific water consumption reflects better cooling system performance, efficient blowdown management, increased wastewater recycling, ash water recirculation, and optimised operation of water-intensive systems. Plants operating significantly below the regulatory limits may be considered industry leaders in water conservation.

3.6.1 Benchmarking of Raw Water Consumption- 300 MW

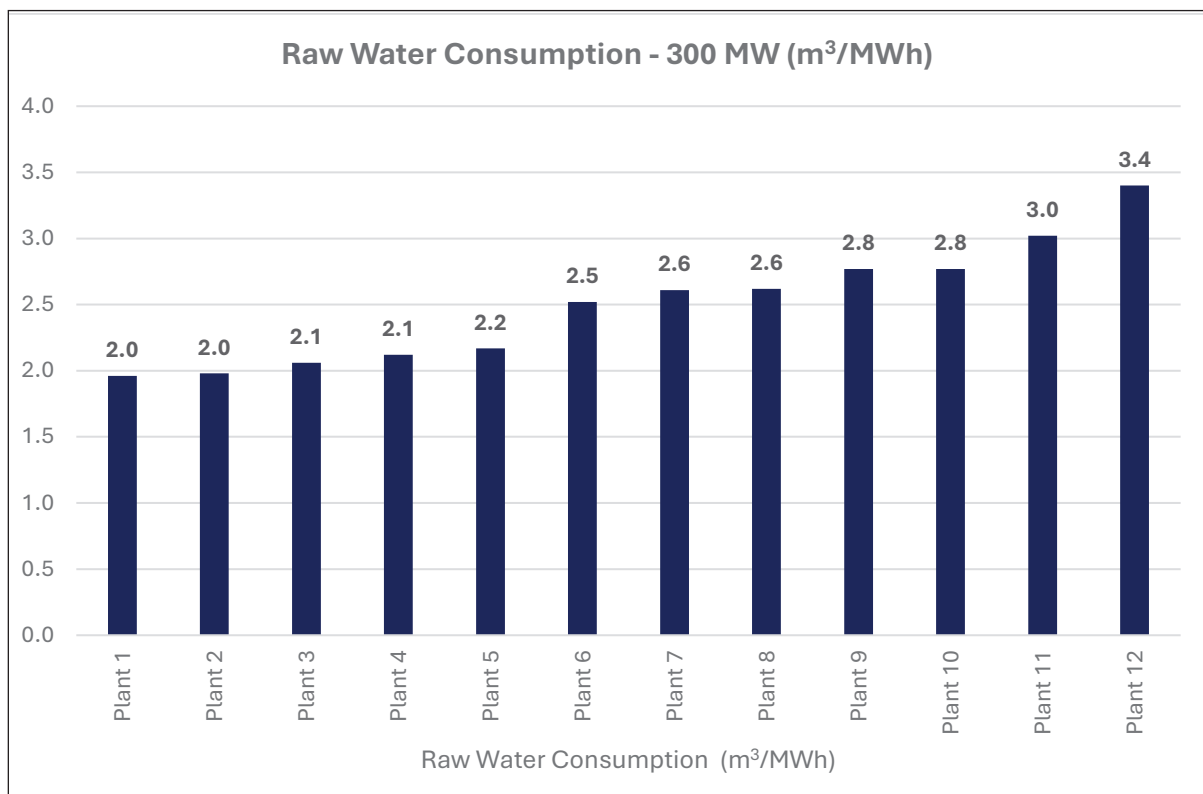


Figure 26: Raw water consumption of 300 MW

3.6.2 Benchmarking of Raw Water Consumption- 600 MW

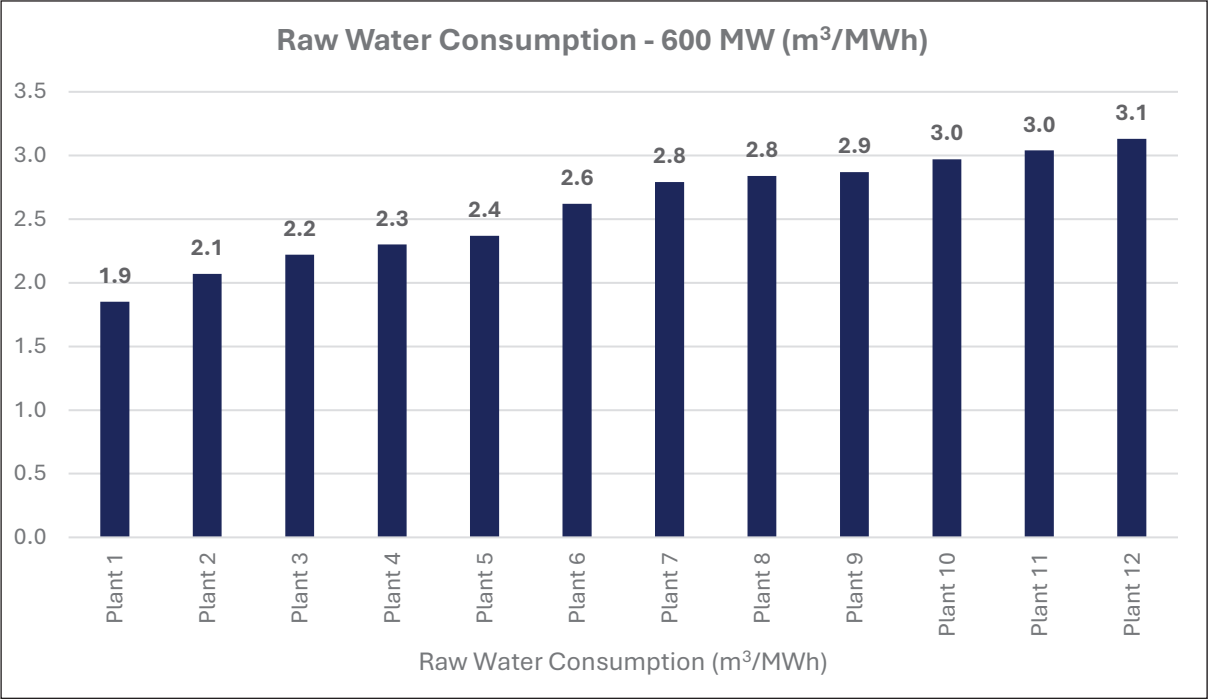


Figure 27: Raw water consumption of 600 MW

3.6.3 Benchmarking of Raw Water Consumption- 660 MW

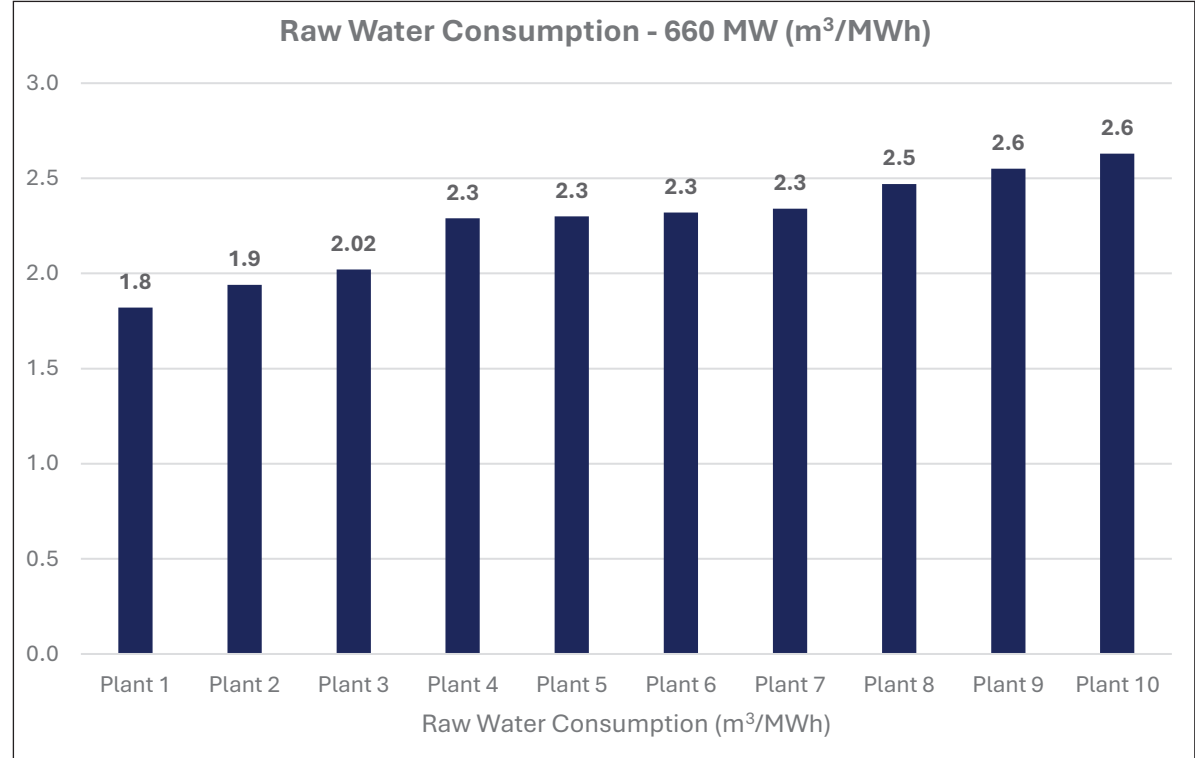


Figure 28: Raw water consumption of 660 MW

3.7 Specific DM Water Consumption

DM (Demineralised) Water Make-up Consumption indicates the quantity of high-purity water required to compensate for losses in the boiler-turbine cycle arising from blowdowns, valve leakages, drain losses, startup and shutdown operations, gland steam losses, and condenser vacuum leakages.

Unlike raw water consumption, there is no specific CEA statutory norm for DM make-up water consumption. However, industry operating experience suggests that efficient units typically maintain cycle make-up water consumption below 0.5-0.6% of Boiler Maximum Continuous Rating (BMCR/MCR), while values above 1.0% generally indicate opportunities for performance improvement through leakage control and condensate recovery optimisation.

Reduction in DM make-up water consumption not only conserves water but also decreases heat loss, auxiliary power consumption, chemical consumption, and overall operating costs. Hence, DM water consumption serves as an important indicator of cycle integrity and operational excellence.

3.7.1 Benchmarking of DM Water Consumption - 300 MW

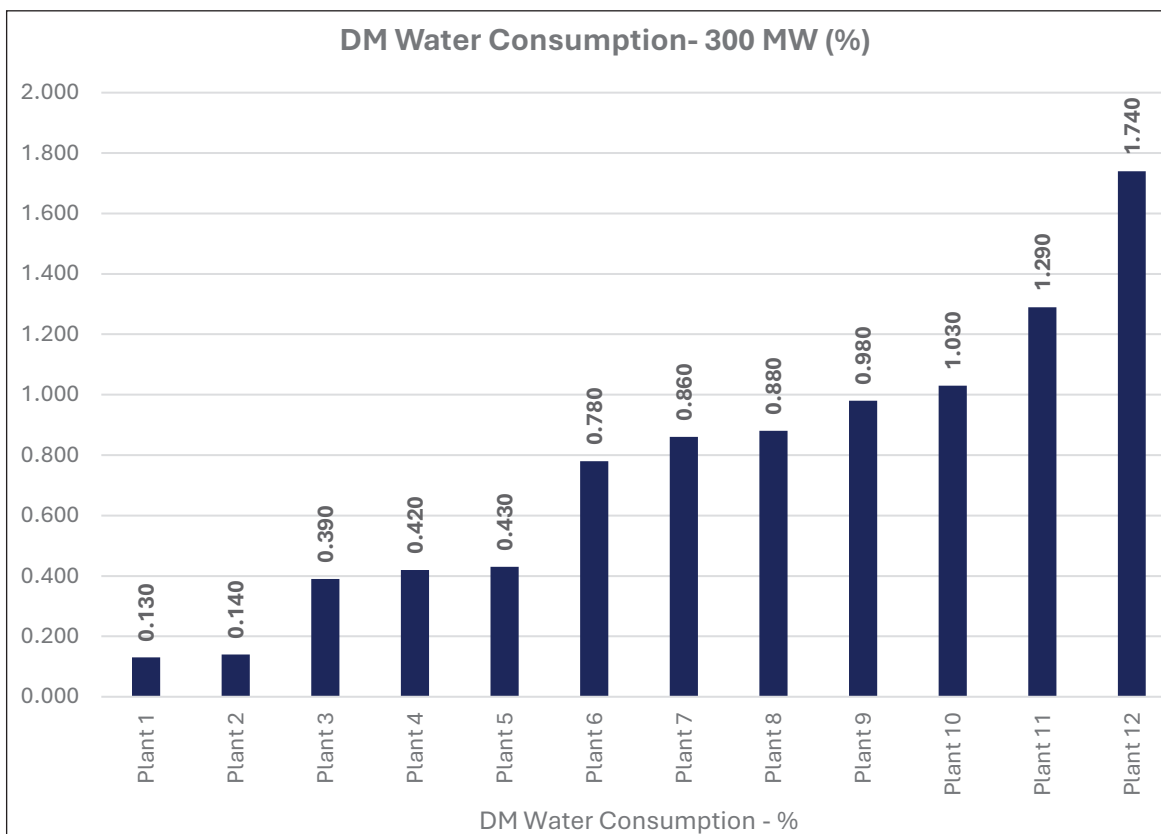


Figure 29: DM Water Consumption of 300 MW

3.7.2 Benchmarking of DM Water Consumption - 600 MW

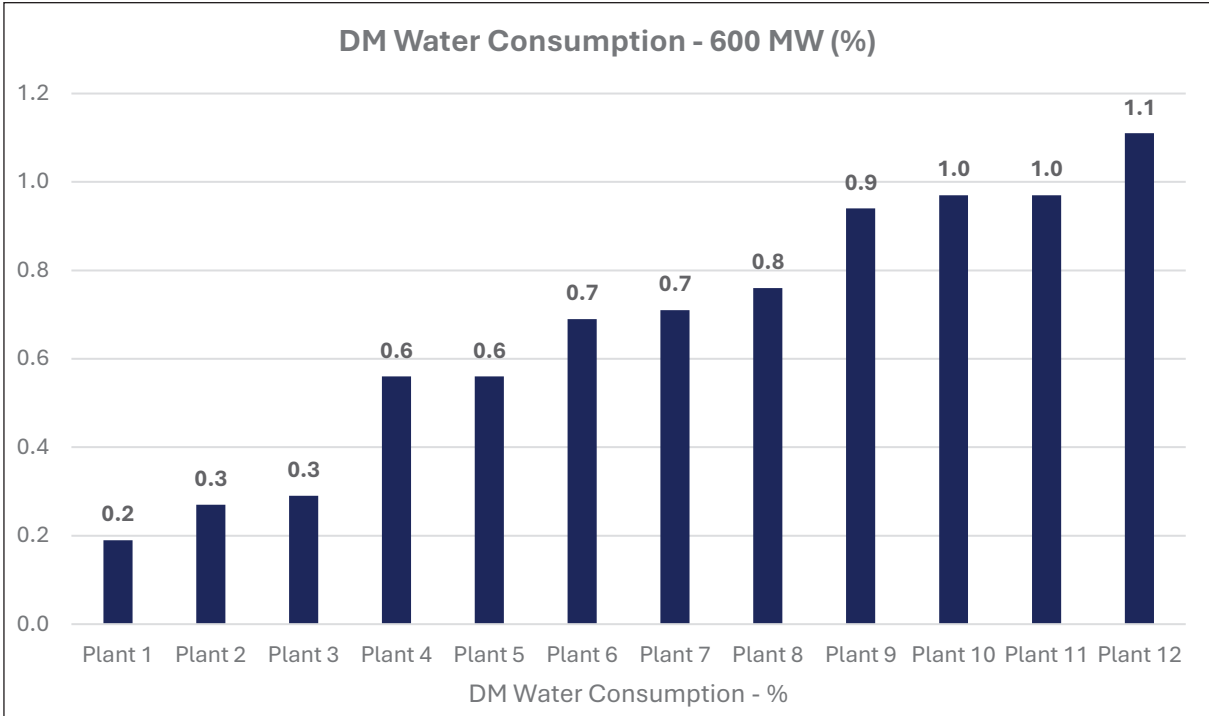


Figure 30: DM Water Consumption of 600 MW

3.7.3 Benchmarking of DM Water Consumption - 660 MW

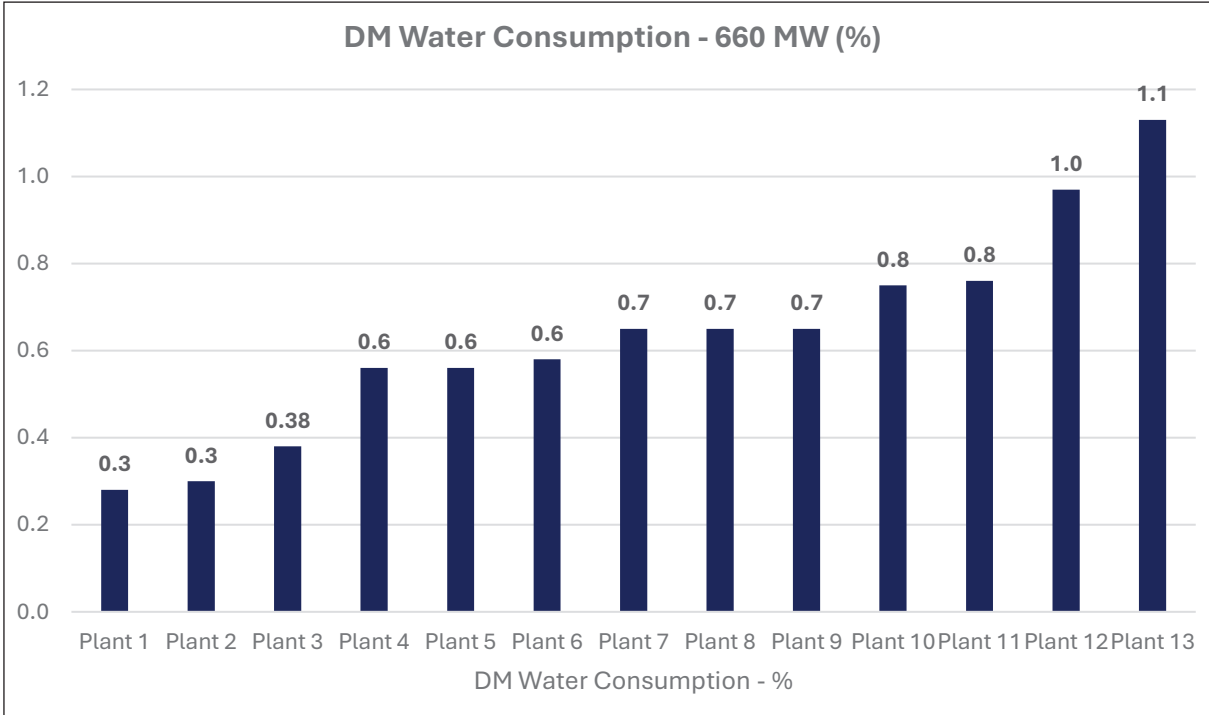


Figure 31: DM Water Consumption of 660 MW

3.7.4 Conclusion based on DM water consumption benchmarking

- The analysis indicates that lower DM water consumption is generally associated with:
 - Better condensate recovery and return systems.
 - Minimal passing of high-temperature drains and vent valves.
 - Effective gland steam management.
 - Reduced boiler blowdown requirements through improved cycle chemistry control.
 - Good condenser vacuum integrity and lower air ingress.
 - Strong preventive maintenance practices to identify and eliminate steam and water losses.
- High DM water consumption not only increases raw water demand but also results in higher heat losses, increased auxiliary power consumption in the DM plant, greater chemical usage, and elevated operating costs.
- Every tonne of avoidable DM make-up water represents a loss of treated high-purity water, thermal energy, and associated treatment chemicals. Therefore, DM water consumption should be viewed as a critical indicator of overall steam-water cycle health rather than merely a water management parameter.
- To achieve best-in-class DM water consumption and maintain cycle make-up below 0.5% of BMCR/MCR, plants should focus on the following priority actions:
 - Establish a station-wide steam and water leakage reduction program with monthly audits covering drains, vents, gland systems, safety valves, condensate systems, and feedwater circuits.
 - Repair or isolate all passing drain valves on priority, particularly high-temperature drains, start-up drains, and warm-up drains, which can account for significant DM water and heat losses.
 - Maximise condensate recovery from all feasible sources, including turbine gland condensers, flash steam recovery systems, and miscellaneous condensate collection points.
 - Optimise boiler blowdown rates through stringent cycle chemistry control and continuous monitoring of conductivity, silica, and dissolved solids.
 - Leverage predictive maintenance and digital monitoring tools to identify hidden losses before they become significant contributors to DM water make-up.

3.8 Ash Utilisation

Ash utilisation is one of the most important environmental performance indicators for coal-based thermal power plants. It reflects the extent to which fly ash and bottom ash generated during power generation are gainfully utilised in productive applications rather than being disposed of in ash ponds. Higher ash utilisation not only minimises environmental impacts and land requirements for ash disposal but also promotes circular economy principles through the use of ash as a valuable resource in construction and infrastructure sectors.

The analysis of 38 generating stations indicates significant variation in ash utilisation performance, with few plants achieving ash utilisation over 160%. Stations have achieved utilisation levels above 100% through the consumption of legacy ash accumulated in ash ponds. Approximately two-thirds of the stations have achieved 100% or higher ash utilisation, demonstrating successful implementation of ash management programs and effective linkage with user industries.

The major avenues of ash utilisation observed across the benchmarked stations include:

- Cement and concrete manufacturing
- Brick and block production
- Mine filling and stowing operations
- Road embankment and pavement construction
- Reclamation of low-lying areas
- Infrastructure and project work
- Manufacture of value-added ash products

Among these applications, cement and concrete manufacturing remain the dominant utilisation route for many stations, while several plants have successfully adopted mine filling and road construction as major disposal avenues. A few stations have demonstrated exceptional utilisation performance through extensive use of ash for road embankment projects and mine reclamation activities.

The benchmarking exercise also revealed a strong relationship between ash utilisation performance and ash handling infrastructure. Stations with higher proportions of dry ash collection and evacuation systems generally exhibited better utilisation performance due to the superior quality and marketability of dry fly ash. Conversely, plants relying predominantly on wet ash handling systems encountered greater challenges in achieving high utilisation levels.

The findings further indicate that:

- Best-performing stations achieved utilisation levels exceeding 160%, primarily through excavation and utilisation of pond ash in addition to current ash generation.
- The majority of high-performing plants operate with predominantly dry ash handling systems, enabling efficient transportation and utilisation by cement and construction industries.
- Stations with utilisation levels below 70% typically exhibited a higher dependence on wet ash handling or limited access to nearby ash-consuming industries.
- A small number of stations reported negligible or zero utilisation, indicating substantial scope for improvement through development of utilisation channels and enhancement of ash evacuation infrastructure.

3.9 Emission Intensity (kg CO₂/kWh)

Carbon dioxide (CO₂) is the principal greenhouse gas emitted from coal-based thermal power plants and is directly associated with the combustion of fossil fuels for electricity generation. Unlike conventional pollutants such as SO_x, NO_x, and particulate matter, CO₂ is not currently regulated through plant-specific emission limits in India; however, it remains one of the most important indicators of environmental sustainability and energy efficiency.

Specific CO₂ emission intensity, expressed as kg CO₂ per kWh of electricity generated, reflects the efficiency with which fuel energy is converted into electrical energy. Plants with superior boiler efficiency, lower Station Net Heat Rate (SNHR), optimised turbine cycle performance, lower auxiliary power consumption, and higher operating efficiency generally exhibit lower CO₂ emission intensity. Consequently, CO₂ emissions provide an integrated measure of both environmental and operational performance.

The benchmarking based on scope-1 emissions for various categories is shown as follows:

3.9.1 Benchmarking based on emission intensity - 300 MW

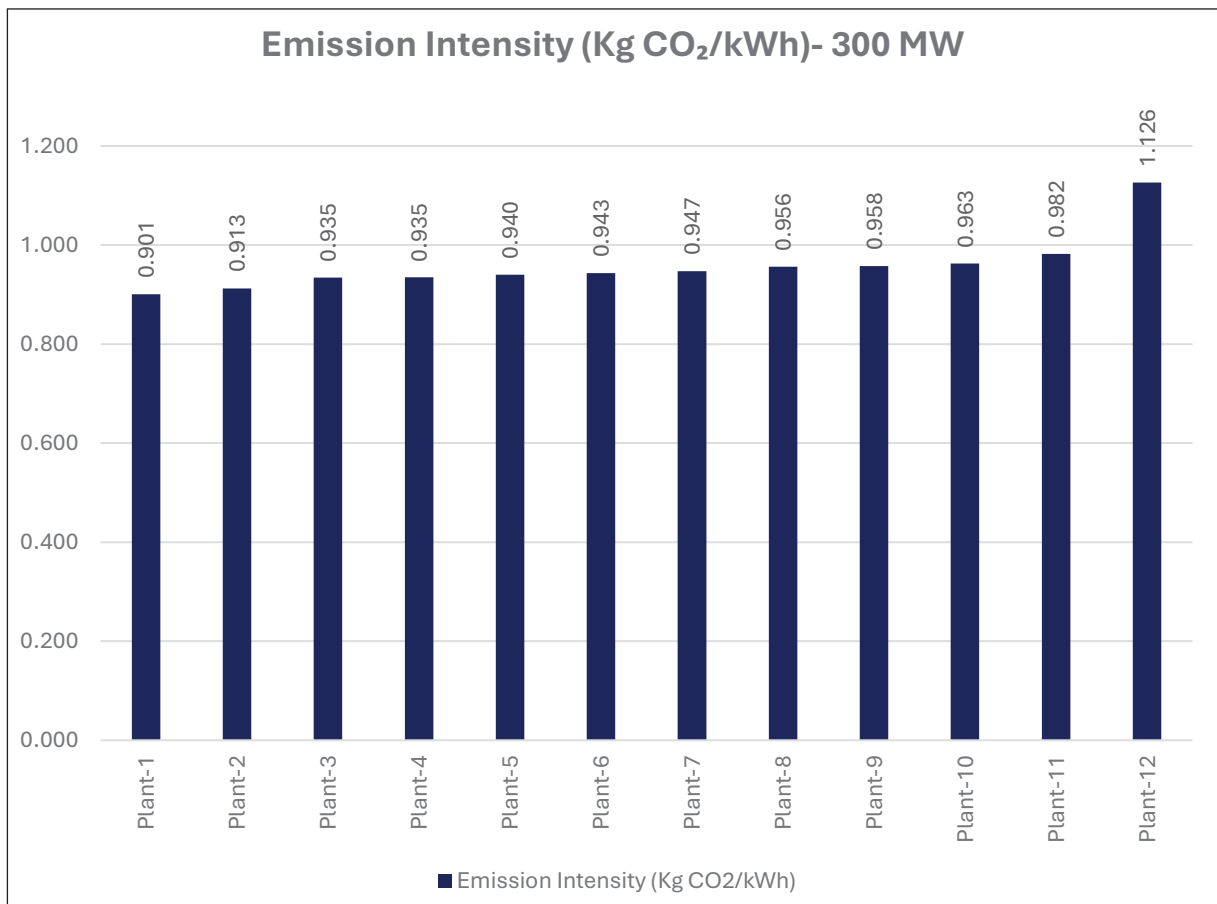


Figure 32: Emission Intensity of 300 MW

Table 24: Key parameters affecting emission intensity of the 300 MW category

Parameters	UOM	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10	Plant 11	Plant 12
Emission Intensity	Kg CO ₂ /kWh	0.901	0.913	0.935	0.935	0.940	0.943	0.947	0.956	0.958	0.963	0.982	1.126
Station Net Heat Rate	kcal/kWh	2450	2482	2542	2542	2558	2565	2818	2600	2605	2618	2672	3063
Station Gross Heat Rate	kcal/kWh	2264	2315	2309	2350	2344	2362	2781	2381	2387	2382	2467	2668
Turbine Heat Rate	kcal/kWh	1975	2012	1964	2042	2032	2003	2178	2046	2062	2046	2099	2098
Boiler Efficiency	%	87.25	86.93	85.09	86.89	86.7	84.8	84.55	85.92	86.38	85.9	85.1	78.64
APC	%	7.60	6.76	9.18	7.58	8.36	7.92	8.58	8.42	8.37	9.03	7.68	12.91
Type of Coal	Indian/ Imported	Indian	Indian	Indian	Imported	Indian	Imported	Indian	Indian	Indian	Indian	Indian	Blended
Coal GCV	kcal/kg	3500-3600	3100-3300	3700-3900	5600-5900	3400-3600	5300-5600	3200-3400	3400-3600	3700-3800	3300-3400	3700-3900	2500-2700
Year of Establishment	-	2010	2013	2019	2000	2012	2010	1993	1982	2016	1986	2007	1985

3.9.2 Benchmarking based on emission intensity - 600 MW

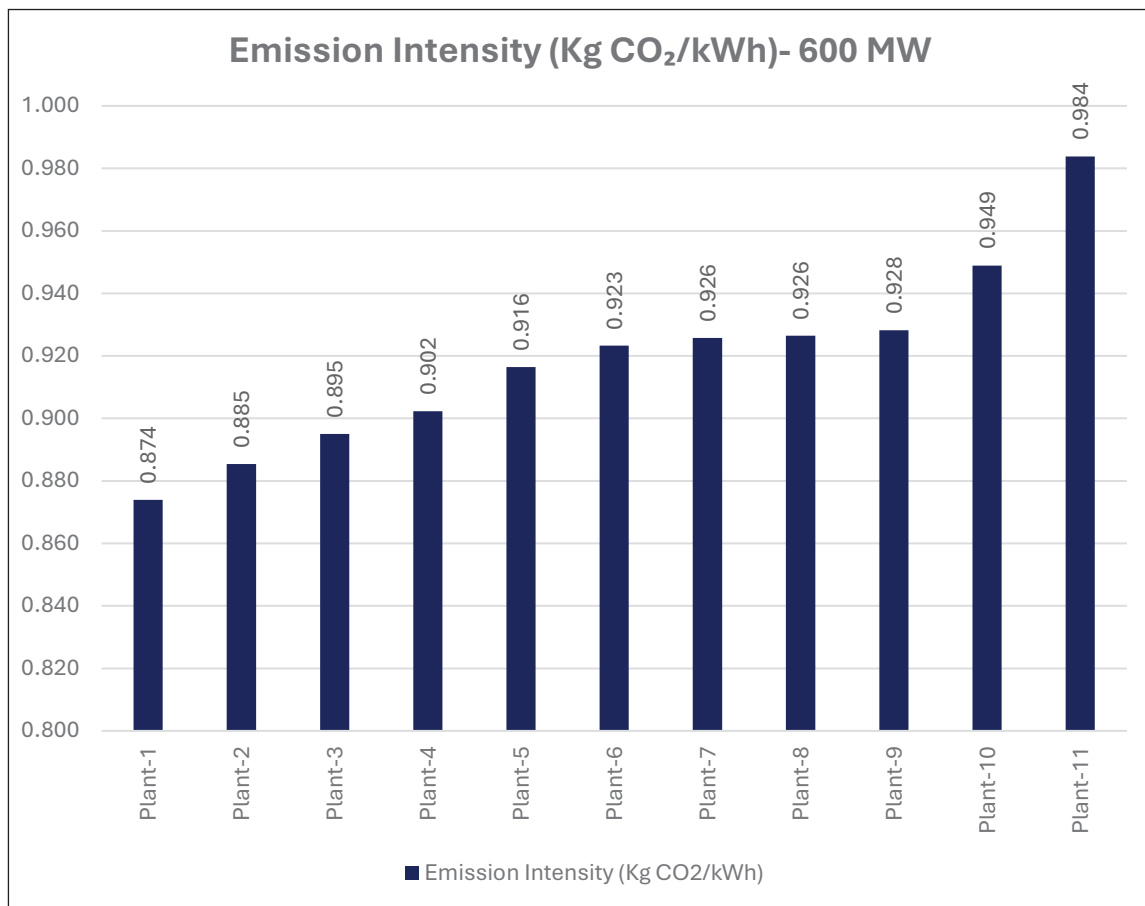


Figure 33: Emission Intensity of 600 MW

Table 25: Key parameters affecting emission intensity of 600 MW category

Parameters	UOM	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10	Plant 11
Emission Intensity	Kg CO ₂ /kWh	0.874	0.885	0.895	0.902	0.916	0.923	0.926	0.926	0.928	0.949	0.984
Station Net Heat Rate	kcal/kWh	2377	2408	2430	2454	2493	2399	2517	2497	2525	2581	2695
Station Gross Heat Rate	kcal/kWh	2256	2284	2277	2317	2348	2368	2345	2339	2359	2381	2470
Turbine Heat Rate	kcal/kWh	1953	1997	1975	2012	1997	2057	2030	2024	1997	2041	2098
Boiler Efficiency	%	86.58	87.43	86.73	86.83	85.03	86.85	86.58	86.52	84.64	85.70	84.93
APC	%	5.11	5.15	6.46	5.59	5.78	5.70	6.89	7.17	6.57	7.74	7.70
Type of Coal	Indian/ Imported	Indian	Indian	Indian	Indian	Blended	Indian	Indian	Indian	Indian	Indian	Indian
Coal GCV	kcal/kg	3200-3300	3200-3400	3000-3200	3700-3900	3800-4000	3800-4000	3800-4000	3500-3700	3100-3300	3700-3900	3600-3700
Year of Establishment	-	1987	2008	2011	2006	2015	1995	2007	2008	1988	2014	2011

3.9.3 Benchmarking based on emission intensity - 660 MW

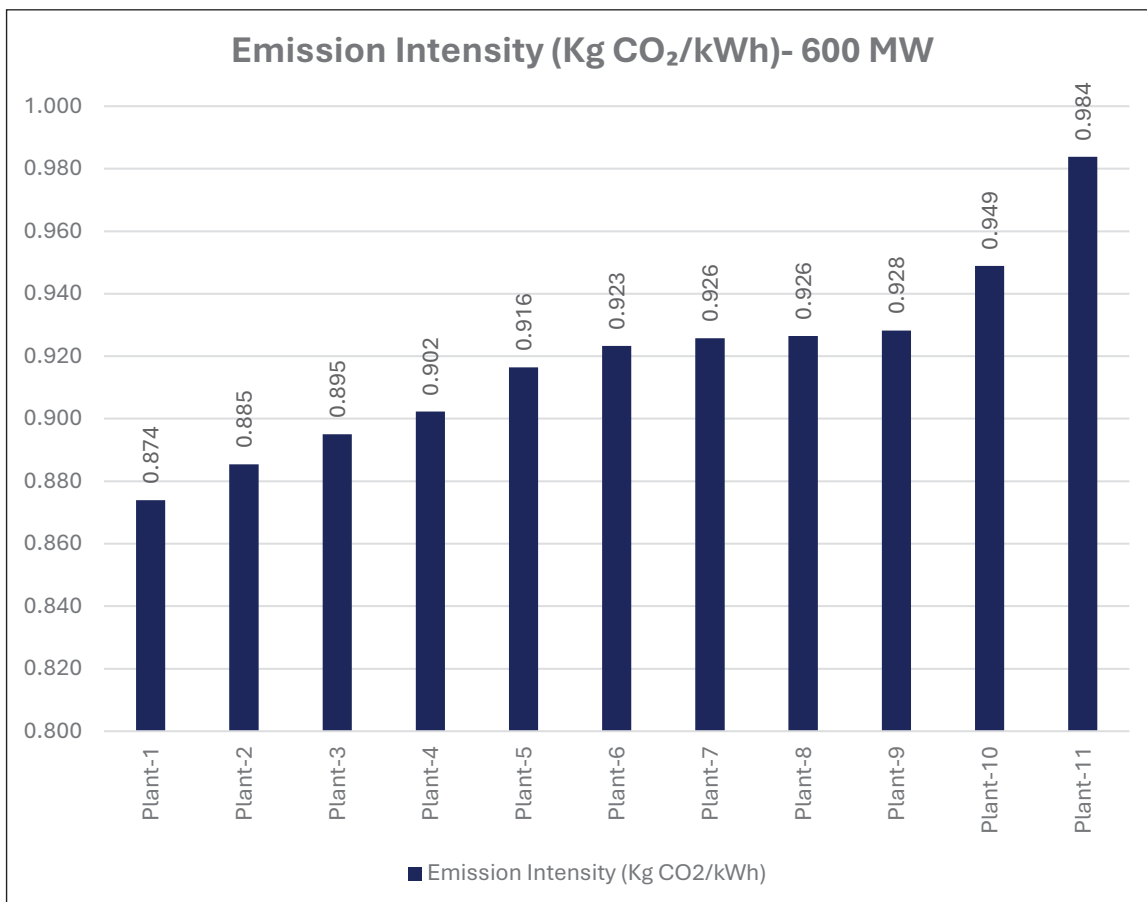


Figure 34: Emission Intensity of 660 MW

Table 26: Key parameters affecting emission intensity of the 660 MW category

Parameters	UOM	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10	Plant 11
Emission Intensity	Kg CO ₂ /kWh	0.821	0.828	0.836	0.858	0.859	0.861	0.870	0.871	0.885	0.886	0.905
Station Net Heat Rate	kcal/kWh	2232	2251	2275	2332	2336	2340	2366	2370	2408	2409	2461
Station Gross Heat Rate	kcal/kWh	2072	2095	2168	2229	2186	2186	2233	2211	2268	2268	2299
Turbine Heat Rate	kcal/kWh	1782	1819	1867	1954	1869	1924	1918	1819	1930	1949	1950
Boiler Efficiency	%	85.98	86.82	86.12	87.68	85.48	88.00	85.90	85.00	85.10	85.96	84.81
APC	%	7.15	6.94	4.70	4.45	6.41	6.60	5.67	6.72	5.80	5.89	6.58
Type of Coal	Indian/ Imported	Indian	Blended	Indian	Indian	Indian	Imported	Blended	Indian	Blended	Indian	Indian
Coal GCV	kcal/kg	2800-3000	3600-3800	3600-3800	3700-3900	2700-2900	5200-5400	3700-3900	3200-3400	3400-3600	3400-3600	3600-3900
Year of Establishment	-	2020	2023	2008	2007	2021	2014	2019	2016	2015	2008	2000

3.9.4 Conclusion based on emission intensity benchmarking

- 660 MW category emerged as the best performers in CO₂ emission benchmarking, recording the lowest specific carbon emissions owing to superior thermal efficiency, higher steam parameters, lower SNHR, and reduced specific coal consumption compared to subcritical units.
- The benchmarking results demonstrate a strong correlation between CO₂ emissions and plant efficiency parameters. Stations with lower SNHR, lower APC, higher boiler efficiency, and better turbine cycle performance consistently achieved lower carbon emission intensity per unit of electricity generated.
- A reduction of 10 kcal/kWh in SNHR for a 600 MW unit can reduce annual CO₂ emissions by approximately 12,000-13,000 tonnes, assuming a 70% PLF and the use of Indian sub-bituminous coal with an emission factor of 0.387 g CO₂/kcal. This corresponds to a specific emission reduction of approximately 0.0039 kg CO₂/kWh generated.
- Another important lever for emission reduction is maximizing biomass co-firing. Under the current regulatory framework, thermal power plants are mandated to undertake 5% biomass co-firing. Taking the same 600 MW plant example considered earlier, every 1% increase in biomass co-firing can reduce CO₂ emissions by approximately 29,000-30,000 tonnes annually. This demonstrates that biomass co-firing offers a significantly larger decarbonisation impact compared to other reduction techniques, making it one of the most effective short-term strategies for reducing the carbon footprint of coal-based generation.
- To achieve lower emissions, the plant should work on individual performance levers such as APC, THR, and boiler efficiency. The cumulative impact of improvements in these areas will help reduce the carbon footprint of the facility.
- In addition, the plant should focus on reducing unburnt carbon losses, improving condenser performance and vacuum, optimizing excess air levels, enhancing coal quality and blending practices, minimizing startup oil consumption, reducing auxiliary steam consumption, controlling turbine cycle losses, and adopting advanced digital optimisation tools such as AI-based combustion control and predictive maintenance. Integration of renewable energy, biomass co-firing, and carbon capture technologies can further accelerate emissions reduction.

RECOMMENDATIONS FOR IMPROVEMENT



4. RECOMMENDATIONS FOR IMPROVEMENT

The benchmarking results clearly indicate that significant performance variation exists across Indian thermal power plants in all benchmark areas. While supercritical units generally outperform subcritical units, several subcritical plants have demonstrated that disciplined operation, robust maintenance practices, and targeted technology upgrades can achieve performance close to best-in-class plants.

Performance improvement should be pursued through a combination of operational excellence, digitalisation, equipment modernisation, predictive maintenance, process optimisation, and resource conservation. Experience from leading utilities indicates that improvements in heat rate, auxiliary consumption, water efficiency, and operational flexibility can typically deliver rapid economic returns while simultaneously reducing emissions.

This chapter provides practical and actionable recommendations for thermal power plants to improve efficiency, enhance operational flexibility, optimise resource utilisation, and reduce emissions. The proposed measures are intended to help plants bridge performance gaps, adopt best practices, and achieve sustainable improvements in operational and environmental performance.

4.1 Station Net Heat Rate (SNHR)

1. Establish an online heat-rate monitoring system that can evaluate real-time heat rate at running load, compare it with the design, and highlight deviations in the parameters with suggestions.
2. Conduct monthly heat-rate and cycle efficiency audits internally and at least once a year by external agencies.
3. Maintain main steam and reheat steam temperatures closer to design values.
4. Minimise steam leaks, drain losses, and high-temperature drain valve passing by forming a steam leakage identification team within each plant to carry out a monthly survey.
5. Optimise soot-blowing based on heat-transfer performance instead of fixed schedules.

4.2 Auxiliary Power Consumption (APC)

1. Carry out a VFD feasibility study to avoid system inefficiencies due to throttling.
2. Optimise excess air levels using advanced combustion controls.
3. Eliminate air ingress by carrying out an airtightness test during each shutdown.
4. Replace old motors with IE3/IE4 efficiency motors.
5. Improve power factor by installing an Automatic Power Factor Correction (APFC) panel.
6. Install an Energy Management System (EMS) within the plant to capture energy usage patterns in every section.
7. Install VFDs in cooling tower fans and modulate with the sump temperature.
8. Identify and arrest leakages in the compressed air system. Operate the compressor at optimal discharge pressure. Install the compressor with a VFD to take care of the demand surges.

4.3 Boiler Efficiency

1. Maintain residual O₂ levels as low as possible (2.8-3.5% preferred). Conduct residual O₂, CO₂, and CO profiling for each load to arrive at the lowest residual O₂ levels while avoiding CO formation.
2. Minimise APH leakages by monitoring residual O₂ at APH inlet and outlet.
3. Ensure APH heat transfer surfaces are clean to avoid high exit gas temperatures.
4. Ensure correct fineness of coal to avoid unburnt losses.
5. Carry out boiler insulation surveys monthly to avoid heat loss due to radiation.
6. Ensure rated feed water temperature at the boiler inlet to maintain high mean temperature of heat addition of the cycle.
7. Improve fuel yard management to minimise moisture variations.
8. Conduct regular burner tuning and balancing during the shutdown to avoid unburnt fuel due to misalignment of the burners.

4.4 Flexible Operations

1. Conduct low load tests frequently and for longer durations to identify bottlenecks and highlight areas requiring attention.
2. Adopt sliding pressure or at least modified sliding pressure operations to avoid throttling losses at the control valves of the turbine at lower loads.
3. Deploy 'Flexibility Assessment Tool' at unit level to assess the present flexibility levels and create a roadmap to achieve higher levels of Flexibility for the areas which are lacking flexibility as per the tool.
4. Install Advanced Process Controls (APC) to reduce critical parameter fluctuations while operating at lower loads.
5. Install Steam Coil Air Preheater (SCAPH) at the inlet of the APH to avoid flue gas temperatures going below the Sulphur dew point.
6. Install advanced Flame Scanners to accurately detect flame inside the furnace during low-load operations and avoid spurious boiler outages due to flame failure.
7. Replace the ON-OFF type BFP recirculation valve with a regulating valve to ensure minimum flow through the BFP at lower loads while accurately maintaining drum levels.
8. Improve start-up and shut-down procedures to reduce the time required.
9. Develop flexibility-specific operating procedures.
10. Conduct operator training on low-load operations and handling emergencies during low loads.

4.5 Raw Water and DM Water Consumption

1. Maximise wastewater recycling and reuse.
2. Optimise cooling tower Cycles of Concentration (COC).
3. Recover ash-pond water.
4. Deploy a utility monitoring system to monitor water consumption and air consumption section-wise.
5. Implement Zero Liquid Discharge (ZLD) within the plant
6. Install ECO-STP by replacing the conventional STP to reduce wastewater.
7. Conduct steam-water cycle leakage audits.
8. Improve condensate recovery by diverting CBD flash steam to the deaerator.
9. Repair passing drain valves and glands.
10. Implement online DM make-up monitoring with sectional accountability, enabling shift-wise and unit-wise tracking of abnormal water consumption trends.
11. Benchmark DM water consumption at unit level and establish an internal target of less than 0.5% BMCR/MCR, with action plans triggered whenever consumption exceeds this limit.
12. Integrate DM water consumption into plant KPI dashboards, alongside SNHR, APC, and Boiler Efficiency, to ensure continuous management focus.

4.6 Ash Utilisation

1. Establish long-term agreements with cement or brick manufacturers and other off-takers of ash.
2. Expand partnerships with infrastructure developers like road construction.
3. Explore mine-filling opportunities.
4. Promote value-added ash products.

4.7 Emission Intensity

1. Improve overall efficiency through actions recommended in previous sections.
2. Increase biomass co-firing to replace fossil fuel.
3. Implement integrated energy management systems.
4. Strengthen waste heat recovery, such as feedwater heating from the IBD water. Maximise recovery of low-grade heat wherever possible and technically feasible.
5. Optimise the regenerative feedwater heating system. Improve performance of feedwater heaters and the condensate system.
6. Avoid subcooling in the hotwell by modulating CW flow or temperature.
7. Undertake overhauling of the unit strictly after the completion of running hours.
8. Undertake Renovation and Modernisation (R&M) programs for older units and components.
9. Evaluate Carbon Capture, Utilisation and Storage (CCUS) opportunities in the plant.
10. Explore opportunities for integration of thermal plants with renewable energy and energy storage systems.
11. Prioritise deployment of supercritical and ultra-supercritical technologies for new installations.

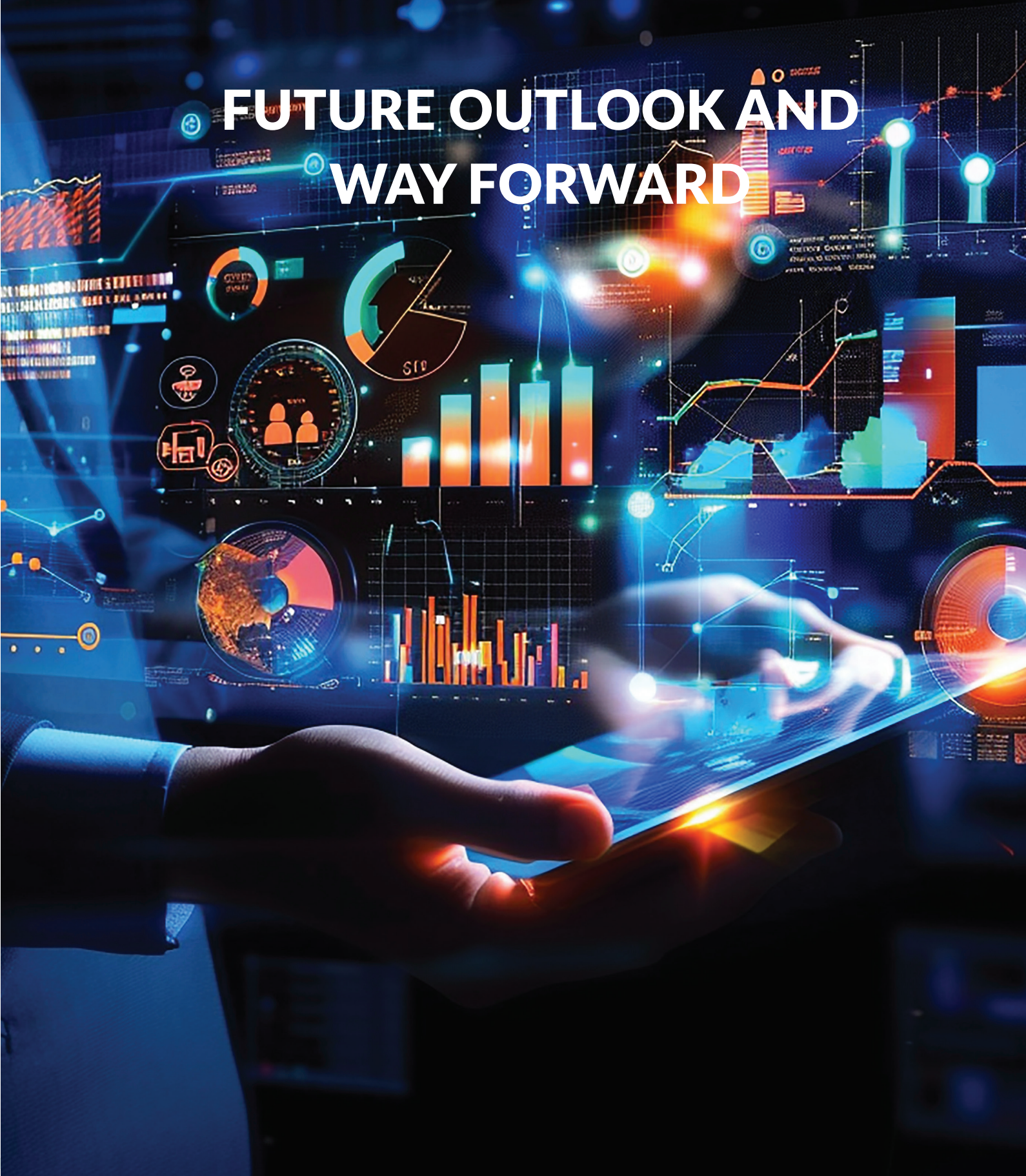
4.8 Performance Monitoring and Measurement Plan for Thermal Power Plant Efficiency Improvement

Table 27: Key Measurements and Monitoring Schedule for Plant Efficiency Improvement

Sr. No.	Activity	Area of Impact	Instruments or Source of Parameters	Frequency
1	Boiler efficiency- by indirect method	Station Heat Rate	DCS data	Preferred in real-time
2	Turbine Heat Rate	Station Heat Rate	DCS data	Preferred in real-time
3	Unburnt carbon in fly ash & bottom ash	Boiler efficiency	Internal lab test	Daily
4	Residual oxygen measurement at APH inlet- traverse reading	Boiler efficiency, APC	Flue gas analyser	Monthly
5	CO in flue gas at APH inlet- traverse reading	Boiler efficiency	Flue gas analyser	Monthly
6	APH leakage- APH inlet & outlet oxygen measurement	APC	Flue gas analyser	Monthly
7	APH performance- Gas side efficiency, X- Ratio, Effectiveness	Boiler efficiency, APC	Temperature Indicator	Monthly
8	Low-pressure heater (LPH) & High-pressure heater (HPH) performance- Range, TTD & DCA	Cycle efficiency	DCS data	Monthly
9	Cooling tower performance- Range, Approach & Effectiveness	Cycle efficiency, APC	Temperature Indicator & Psychrometer	Monthly
10	Condenser air ingress	Cycle efficiency, APC	Ultrasonic leak detector	Monthly
11	Compressed air leakages	APC	Ultrasonic leak detector & Audible inspections	Quarterly
12	BFP & CEP recirculation line passing survey	APC	Ultrasonic flow meter & Temperature indicator	Quarterly
13	Oil cooler effectiveness	APC	IR temperature gun	Quarterly
14	High-temperature drain passing survey	Cycle efficiency	Ultrasonic leak detector Thermography camera & IR temperature gun	Quarterly

Sr. No.	Activity	Area of Impact	Instruments or Source of Parameters	Frequency
15	Airtightness test of boiler & flue gas duct	APC	Soap solution test	Half Yearly
16	Compressor efficiency- Free Air Delivery Test	APC	Stopwatch	Half Yearly
17	Pump efficiency	APC	Ultrasonic flow meter & Inline flow meter	Half Yearly
18	Fan efficiency	APC	Pitot tube & digital manometer	Half Yearly
19	Boiler insulation survey	Boiler efficiency	Visual inspection or Thermography camera	Half Yearly
20	Mill dirty air flow test	Boiler efficiency	Pitot tube & digital manometer	Half Yearly
21	Energy Audit by external agency	Cycle efficiency, APC, emission reduction	-	Annually
22	Steam pipe insulation survey	Cycle efficiency	Visual inspection or Thermography camera	Annually
23	Power factor survey	APC	Power analyser	Annually
24	Transformer loading survey	APC	Power analyser	Annually

FUTURE OUTLOOK AND WAY FORWARD



5. FUTURE OUTLOOK AND WAY FORWARD

5.1 Evolving Role of Thermal Power Plants

India's thermal power sector is entering a phase of transformation. While renewable energy capacity continues to expand rapidly, thermal power plants will remain critical for ensuring grid stability, system reliability, and energy security. The future role of thermal generation will increasingly shift from traditional baseload operation toward flexible, responsive, and efficient operation capable of complementing large-scale renewable energy integration.

5.2 Key Priorities for the Next Decade

As the power sector transitions towards higher renewable energy penetration, thermal power plants must evolve to operate more efficiently, flexibly, and sustainably. Key priorities for the next decade include:

- **Improving Efficiency:** Reduce heat rate and fuel consumption through continuous performance optimisation.
- **Enhancing Flexibility:** Improve ramp rates, lower minimum load operation, and support grid balancing requirements.
- **Accelerating Digitalisation:** Leverage AI, Digital Twins, advanced analytics, and predictive maintenance for data-driven decision-making.
- **Reducing Auxiliary Power Consumption:** Adopt energy-efficient technologies and optimise auxiliary systems.
- **Strengthening Water Management:** Minimise water consumption through improved recovery, reuse, and conservation practices.
- **Advancing Decarbonisation:** Promote biomass co-firing, low-carbon technologies, and CCUS solutions.
- **Improving Reliability:** Implement condition-based maintenance and asset health monitoring to reduce forced outages.
- **Building Workforce Capability:** Develop competencies in digital technologies, flexible operations, and sustainability practices.
- Future-ready thermal power plants will be those that combine efficiency, flexibility, digitalisation, reliability, and environmental sustainability to remain competitive in an increasingly renewable-dominated energy landscape.

5.3 Emerging Technologies

Future performance improvements are expected to be driven by:

- **Artificial Intelligence and Advanced Analytics:** AI and advanced analytics can enable data-driven decision-making by identifying performance improvement opportunities, optimizing operations, and predicting potential equipment failures.
- **Digital Twins:** Digital Twins can provide real-time virtual replication of plant systems, enabling performance optimisation, operational flexibility, and proactive asset management.
- **Predictive Maintenance:** Predictive maintenance can minimise unplanned outages and maintenance costs by identifying equipment degradation and failure risks before they occur.
- **Advanced Process Controls:** Advanced Process Controls can enhance plant efficiency, stability, and responsiveness through automated optimisation of critical process parameters.
- **Green Hydrogen Integration:** Green hydrogen integration can support decarbonisation efforts by enabling cleaner fuel utilisation and reducing carbon emissions from power generation.

- **Carbon Capture Utilisation and Storage (CCUS):** CCUS can significantly reduce CO₂ emissions by capturing carbon from flue gases for utilisation or permanent storage.
- **Battery and Storage Integration:** Battery energy storage systems can improve grid stability and facilitate renewable energy integration by providing fast-response balancing and ancillary services.

5.4 The Role of Benchmarking

Benchmarking is a powerful management tool that enables thermal power plants to evaluate their performance against industry peers and best-in-class operating practices. By systematically comparing key performance indicators such as Station Net Heat Rate, Auxiliary Power Consumption, Boiler Efficiency, Specific Oil Consumption, DM Water Consumption, and Availability, utilities can identify performance gaps, prioritise improvement initiatives, and track progress over time.

Benchmarking not only highlights areas requiring attention but also facilitates the sharing of best practices across stations, fostering a culture of continuous improvement. It provides plant management with objective insights into operational efficiency, reliability, resource utilisation, and cost competitiveness, enabling informed decision-making and targeted investment planning.

Regular benchmarking helps utilities:

- Identify performance gaps and improvement opportunities.
- Establish realistic and achievable performance targets.
- Adopt best practices from high-performing stations.
- Improve operational efficiency and asset reliability.
- Optimise resource consumption and reduce operating costs.
- Monitor the effectiveness of improvement initiatives.
- Support strategic planning and long-term performance enhancement.

As the power sector evolves towards greater flexibility, digitalisation, and sustainability, benchmarking will continue to serve as a critical tool for driving operational excellence and ensuring that thermal power plants remain competitive, reliable, and future-ready.

5.5 Concluding Remarks

The benchmarking exercise highlights that future improvements in thermal power plant performance will increasingly depend on the adoption of advanced technologies and digital solutions. While conventional operational and maintenance practices will continue to play a vital role, emerging technologies such as Artificial Intelligence, Digital Twins, Predictive Maintenance, Advanced Process Controls, Green Hydrogen, CCUS, and Energy Storage Systems offer significant potential to improve efficiency, flexibility, reliability, and environmental sustainability.

As thermal power plants transition from traditional baseload operation to a more dynamic grid-support role, utilities should proactively evaluate and adopt technologies that enhance operational agility, reduce operating costs, optimise asset utilisation, and support decarbonisation objectives. A phased and strategically planned technology adoption approach will be essential to ensure long-term competitiveness and sustainability in an increasingly renewable-intensive power system.



ANNEXURE

ANNEXURE

Key Policy Highlights

1. Co-firing of Biomass Pellets and Torrefied Charcoal – November 2025:

The Ministry of Power's revised policy promotes the use of biomass pellets and MSW-based torrefied charcoal in coal-based thermal power plants, with a minimum 5% co-firing requirement from FY 2025–26 and an additional 2% requirement for plants located in the NCR, subject to technical feasibility. The policy also provides revised provisions for biomass procurement, contracting and pricing to facilitate reliable fuel supply.

As of 30 June 2026, 75 thermal power plants across India, including 12 plants in the NCR, had commenced biomass co-firing. The cumulative biomass co-fired stood at 63.06 lakh metric tonne (LMT) across India, including 44.93 LMT in NCR plants, resulting in cumulative power generation of approximately 7,948 million units (MU) and 5,564 MU, respectively. Biomass co-firing has cumulatively contributed to an estimated 75.67 LMT of CO₂ emission savings across India, including 53.92 LMT in NCR plants, demonstrating its potential to reduce coal consumption, utilise agricultural and municipal waste resources, and support decarbonisation of the thermal power sector.²⁰

Table 28: Status of Biomass Co-Firing as on 30.06.2026

Parameters	All India TPPs	NCR TPPs
TPPs that started co-firing (nos.)	75	12
Cumulative Biomass Co-fired (LMT)	63.06	44.93
Cumulative Power Generated (MU)	7948	5564
Cumulative CO ₂ saved by Biomass Co-firing (LMT)	75.67	53.92

Despite its advantages, several challenges continue to hinder large-scale implementation. Key roadblocks include:

- Inconsistent availability of biomass feedstock, seasonal fluctuations in agricultural residue generation, high transportation and logistics costs, lack of pellet manufacturing infrastructure, storage challenges due to biomass moisture content, and concerns regarding boiler performance at higher co-firing ratios.
- Establishing long-term biomass supply contracts and ensuring fuel quality remain critical issues for power plant operators.
- Future progress will depend on expanding pelletisation capacity, improving supply-chain efficiency, increasing torrefied biomass production, providing policy incentives, and integrating biomass co-firing into broader clean energy and circular economy initiatives.
- With continued policy support and infrastructure development, biomass co-firing can become a major contributor to decarbonizing India's thermal power sector while simultaneously addressing agricultural waste management and rural economic development.

²⁰ <https://samarth.powermin.gov.in/>

2. SHAKTI- May 2025:

The Scheme for Harnessing and Allocating Koyala (Coal) Transparently in India (SHAKTI) Policy is a landmark coal-sector reform that ensures transparent and market-oriented allocation of domestic coal to thermal power generators. The revised SHAKTI Policy 2025 simplifies the linkage framework into two allocation windows, increases flexibility for power producers, promotes efficient utilisation of domestic coal resources, reduces import dependence, and strengthens India's energy security while supporting affordable and reliable power supply. The revised framework introduced two windows for coal allocation²¹:

- **Window-I:**
 - Available to Central GENCOs, State Governments, State GENCOs, and eligible projects.
 - Coal is supplied at the notified price.
 - States can utilise allocated coal for their own generating companies or through competitively selected power producers.
 - Supports affordable power supply to consumers.
- **Window-II:**
 - Open to all power generators, including independent power producers and imported-coal-based plants.
 - Coal is allocated through an auction mechanism at a premium above the notified price.
 - Plants receive flexibility to sell generated electricity through power exchanges, bilateral contracts, or other market mechanisms.
 - Linkages can be granted for short-term periods as well as up to 25 years.

The policy also facilitates better utilisation of existing thermal power assets, including stressed and underutilised plants, while encouraging the development of pit-head power projects and reducing dependence on imported coal. Furthermore, generators receiving coal under the revised framework can utilise surplus generation capacity and participate more actively in power markets, leading to improved plant load factors and enhanced market liquidity. By ensuring greater availability of affordable domestic coal, the policy is expected to result in lower power generation costs, improved energy security, increased economic activity, higher state revenues from coal-producing regions, and a more resilient electricity sector capable of meeting India's growing power demand.

3. SHANTI BILL- 2025:

The SHANTI Bill (Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India Bill, 2025) is a landmark Indian law aimed at modernizing the country's nuclear energy framework. The Bill replaces the Atomic Energy Act, 1962 and the Civil Liability for Nuclear Damage Act, 2010, creating a unified legal structure for nuclear energy development. It allows limited private sector participation in nuclear power generation under strict government regulation, strengthens the role of the Atomic Energy Regulatory Board (AERB), and supports India's goal of achieving 100 GW of nuclear power capacity by 2047.

The SHANTI Bill is expected to create significant opportunities for Captive Power Plants (CPPs), particularly for energy-intensive industries such as aluminium, cement, steel, data centres, semiconductor manufacturing, and AI-related infrastructure. The draft regulations explicitly recognise captive nuclear power generation, allowing industries to explore nuclear energy as a reliable source of long-term power supply.

²¹<https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2127409®=48&lang=2>

One of the key benefits for CPP operators is enhanced energy security. Unlike conventional captive power sources that depend on coal, gas, or fluctuating renewable generation, nuclear power can provide continuous baseload electricity with very high plant availability. This reduces exposure to fuel price volatility, grid disturbances, and supply chain disruptions, enabling industries to achieve more predictable operating costs and improve business competitiveness.

The SHANTI framework can support a more diversified energy portfolio. Nuclear energy can operate alongside renewable sources such as solar and wind, providing stable round-the-clock power when renewable generation is unavailable. This enables industries to optimise energy procurement strategies, reduce dependence on fossil fuels, and meet sustainability and decarbonisation targets without compromising operational reliability.

4. National Green Hydrogen Mission – January 2023:

The Government of India launched the National Green Hydrogen Mission (NGHM) in January 2023 with the objective of establishing India as a global hub for the production, utilisation, and export of green hydrogen. The Mission targets production of at least 5 million metric tonnes (MMT) of green hydrogen per year by 2030, supported by approximately 125 GW of associated renewable energy capacity. It is expected to attract investments of more than ₹8 lakh crore, reduce fossil-fuel imports by more than ₹1 lakh crore annually, and avoid nearly 50 MMT of greenhouse-gas emissions per year by 2030.

Green hydrogen is produced through the electrolysis of water using renewable electricity such as solar and wind power, resulting in zero carbon emissions during production. The mission includes incentives for electrolyser manufacturing and green hydrogen production under the SIGHT program, development of Green Hydrogen Hubs, pilot projects, R&D support, infrastructure development, and a regulatory framework for certification and standards.

Many thermal power plants already have hydrogen generation plants with electrolysers, storage systems, monitoring & safety mechanisms, water intake systems, and land availability. These assets can be leveraged for the production of green hydrogen only by shifting the source of electricity from coal-based to RE. This can help in reducing capital investment and project development timelines.

Additionally, many thermal power stations are located near industrial clusters. Green hydrogen production facilities established at these locations can supply nearby refineries, fertiliser plants, steel industries, and other hard-to-abate sectors, thereby accelerating industrial decarbonisation.

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The CII–Sohrabji Godrej Green Business Centre (CII–GBC) is CII’s Developmental Institute for Green Practices and Businesses, focused on offering world-class advisory services dedicated to the conservation of natural resources. Its mission is to help India emerge as a global leader in green business by 2030.

The Green Business Centre in Hyderabad, Telangana, is housed in one of the greenest buildings in the world. Established in 2004, the Green Business Centre was inaugurated by His Excellency, the late Dr. A. P. J. Abdul Kalam, the then President of India, on 14 July 2004.

The Centre promotes sustainable practices and supports businesses through a comprehensive range of services, including Green Buildings (IGBC), Energy Transition Services, GreenPro Certification, GreenCo Rating System, Green Entrepreneurship Council (GEC), Council on Green Mobility, Green Cooling Council, Solar Vendor Rating Program (VRP), and more.

The Green Business Centre has registered over 20,000 green building projects (through the Indian Green Building Council, IGBC), certified more than 15,100 GreenPro products, conducted over 2,200 energy audits globally, registered more than 1,600 manufacturing facilities under GreenCo Council, and engaged with 300 cleantech startups across India, Sweden, Australia, Ethiopia, Bangladesh & Japan.

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Learn more by logging on to <https://greenbusinesscentre.com>.

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In the journey of India's economic resurgence, CII facilitates the multifaceted contributions of the Indian Industry, charting a path towards a prosperous and sustainable future. With this backdrop, CII has identified "Accelerating Competitiveness: Growth, Resilience, Inclusion, Sustainability, Trust" as its theme for 2026-27, prioritising five key pillars. During the year, CII will align its policy advocacy, institutional initiatives, partnerships, and outreach to support Indian industry in strengthening these five interconnected pillars of competitiveness.

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