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Report No: ICR00004323

IMPLEMENTATION COMPLETION AND RESULTS REPORT

ON A

LOAN

IN THE AMOUNT OF $180 MILLION
(IBRD-76870)

AND
A GLOBAL ENVIRONMENT FACILITY GRANT

IN THE AMOUNT OF $45.4 MILLION
(TF-94676)

TO THE

Republic of India

FOR THE

COAL-FIRED GENERATION REHABILITATION (P100101)

April 29, 2019

Energy & Extractives Global Practice
South Asia Region

CURRENCY EQUIVALENTS

(Exchange Rate Effective March 24, 2019)
Currency Unit = Indian Rupee
Rs. 69.33 = US$1
US$0.014 = Rs.1

FISCAL YEAR
April 1 - March 31

ABBREVIATIONS AND ACRONYMS

AHP	Ash Handling Plant	IRR	Internal Rate of Return
BOP	Balance of Plant	ISR	Implementation Status Report
BTG	Boiler Turbine Generator	KfW	Kreditanstalt fur Wiederaufbau
BTPS	Bandel Thermal Power Station	KPI	Key Performance Indicator
C&I	Control & Instrumentation	KTPS	Koradi Thermal Power Station
CAS	Country Assistance Strategy	LE	Life Extension
CEA	Central Electricity Authority	M&E	Monitoring and Evaluation
CERC	Central Electricity Regulatory Commission	Mahagenco / MSPGCL	Maharashtra State Power Generation Company Limited
CHP	Coal Handling Plant	MW	Mega Watts
CO_2	Carbon Dioxide	MU	Million Units = million kilowatt hours
CPCB	Central Pollution Control Board	NEP	National Electricity Policy
CSR	Corporate Social Responsibility	NTPC	National Thermal Power Corporation
DCRTPP	Deenbandhu Chotu Ram Thermal Power Plant	O&M	Operations and Maintenance
DPP	Direct Post Project	PAD	Project Appraisal Document
DPR	Detailed Project Report	PDO	Project Development Objective
EADD	Environmental Audit Due Diligence	PHRD	Policy & Human Resource Development
EE R&M	Energy Efficient Renovation and Modernization	PG	Performance Guarantee
EHS	Environment, Health and Safety	PiE	Partnership in Excellence
ERP	Enterprise Resource Planning	PLF	Plant Load Factor
ESP	Electro Static Precipitator	PTPS	Panipat Thermal Power Station
FGD	Flue Gas Desulpharization	RF	Results Framework
FM	Financial Management	RGTPP	Rajiv Gandhi Thermal Power Plant
GEF	Global Environment Facility	RLA	Residual Life Assessment
GEO	Global Environment Objective	RP	Restructuring Paper
GHG	Greenhouse Gas	RSA	Rapid Social Assessment
GoI	Government of India	R&M	Renovation and Modernization
HERC	Haryana Electricity Regulatory Commission	SOP	Standard Operating Procedure

HPGCL	Haryana Power Generation Company Limited	SMP	Standard Maintenance Procedure
IBRD	International Bank for Reconstruction and Development	TA	Technical Assistance
ICR	Implementation Completion and Results	TPS	Thermal Power Station
IEP	Integrated Energy Policy	USD/US$	United States Dollar
IP	Implementation Progress	WBPDCL	West Bengal Power Development Corporation Limited

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DATA SHEET

BASIC INFORMATION

Product Information

Project ID	Project Name
P100101	COAL-FIRED GENERATION REHABILITATION (P100101)
Country	**Financing Instrument**
India	Investment Project Financing
Original EA Category	**Revised EA Category**
Partial Assessment (B)	Partial Assessment (B)

Related Projects

Relationship	Project	Approval	Product Line
Supplement	P100531-Coal-Fired Generation Rehabilitation	18-Jun-2009	Global Environment Facility

Organizations

Borrower	Implementing Agency
Republic of India	Central Electricity Authority, Haryana Power Generation Corporation Limited, Maharashtra State Power Generation Company Limited, West Bengal Power Development Corporation Limited

Project Development Objective (PDO)

Original PDO

The objective of the project was to improve energy efficiency of selected coal-fired power generation units through renovation and modernization (R&M) and improved operations and maintenance (O&M).

FINANCING

		Original Amount (US$)	Revised Amount (US$)	Actual Disbursed (US$)
World Bank Financing				
P100101	IBRD-76870	180,000,000	136,160,000	104,137,505
P100531	TF-94676	45,400,000	45,400,000	27,948,461
Total		**225,400,000**	**181,560,000**	**132,085,966**
Non-World Bank Financing				
Borrower		78,000,000	45,119,252	45,119,252
Total		**78,000,000**	**45,119,252**	**45,119,252**
Total Project Cost		**303,400,000**	**226,679,252**	**177,205,218**

KEY DATES

Project	Approval	Effectiveness	MTR Review	Original Closing	Actual Closing
P100101	18-Jun-2009	19-Mar-2010	09-Jul-2012	30-Nov-2014	29-Mar-2018
P100531	18-Jun-2009	19-Mar-2010	09-Jul-2012	30-Nov-2014	29-Mar-2018

RESTRUCTURING AND/OR ADDITIONAL FINANCING

Date(s)	Amount Disbursed (US$M)	Key Revisions
21-Apr-2014	43.63	Partial cancellation of IBRD loan
29-Sep-2014	49.39	Change in Results Framework Change in Loan Closing Date(s) Reallocation between Disbursement Categories Change in Procurement Change in Implementation Schedule Other Change(s)
28-Nov-2016	75.37	Change in Loan Closing Date(s)
29-Nov-2017	83.74	Change in Loan Closing Date(s)

KEY RATINGS

Outcome	Bank Performance	M&E Quality
Moderately Unsatisfactory	Moderately Satisfactory	Substantial

RATINGS OF PROJECT PERFORMANCE IN ISRs

No.	Date ISR Archived	DO Rating	IP Rating	Actual Disbursements (US$M)
01	27-Nov-2009	Satisfactory	Satisfactory	0
02	26-May-2010	Satisfactory	Satisfactory	.45
03	12-Dec-2010	Satisfactory	Satisfactory	.45
04	27-Jun-2011	Satisfactory	Moderately Satisfactory	.45
05	07-Aug-2011	Satisfactory	Moderately Satisfactory	.45
06	31-Mar-2012	Moderately Satisfactory	Moderately Unsatisfactory	.45
07	24-Oct-2012	Moderately Satisfactory	Moderately Unsatisfactory	.45
08	25-Jun-2013	Moderately Satisfactory	Moderately Unsatisfactory	7.01
09	28-Dec-2013	Moderately Satisfactory	Moderately Unsatisfactory	7.05
10	01-Jun-2014	Moderately Satisfactory	Moderately Unsatisfactory	44.08
11	23-Jul-2014	Moderately Satisfactory	Moderately Satisfactory	46.44
12	18-Apr-2015	Moderately Satisfactory	Moderately Unsatisfactory	54.32
13	31-Dec-2015	Moderately Satisfactory	Moderately Unsatisfactory	65.21
14	13-Oct-2016	Moderately Unsatisfactory	Moderately Unsatisfactory	75.28
15	20-Apr-2017	Moderately Unsatisfactory	Moderately Unsatisfactory	80.52
16	16-Jul-2017	Moderately Satisfactory	Moderately Satisfactory	82.39

SECTORS AND THEMES

Sectors

Major Sector/Sector	(%)
Energy and Extractives	**100**
Other Energy and Extractives	100

Themes

Major Theme/ Theme (Level 2)/ Theme (Level 3)	(%)

Private Sector Development	**34**
Jobs	34
Job Creation	34
Urban and Rural Development	**66**
Urban Development	33
Urban Infrastructure and Service Delivery	33
Rural Development	33
Rural Infrastructure and service delivery	33

ADM STAFF

Role	At Approval	At ICR
Regional Vice President:	Isabel M. Guerrero	Hartwig Schafer
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I. Project Context and Development Objectives

A. Context at Appraisal

Country and Sector Context

1. **Challenges in Electricity Sector and Government Strategies:** At the time of appraisal in 2009, India was facing challenges in the electricity sector. Although policy reforms in the power sector were beginning to show results, much remained to be done to meet the generation capacity needs of India's growing economy. The Government of India (GoI) tried to address power shortage through a multipronged strategy including a major generation capacity addition program (80,000 mega-watts [MW] by 2012), renovation and modernization (R&M) of the then existing coal-fired plants (estimated at 27,000 MW), increasing efficiency of the transmission and distribution sectors and promoting demand side management measures.

2. **Government's response to the R&M challenge:** Although GoI had implemented a large R&M investment program and associated policies through late 1980s and 1990s, the program mostly covered essential repairs for plants, many of which were otherwise poorly maintained. GoI's programs for R&M experienced mixed successes and several barriers were identified which deterred utilities from carrying out R&M schemes, especially with focus on energy efficiency. Similarly, the GoI's National Electricity Policy (NEP) also encouraged development of R&M projects by creating an incentive framework to share the benefits of efficiency improvements between the generation utilities and beneficiaries.[1]

3. **Pilots to demonstrate energy efficient R&M (EE R&M) approaches:** In light of the large and growing pool of coal-fired power plants requiring R&M, the GoI decided to seek the World Bank (Bank)-Global Environment Facility (GEF) as well as Kreditanstalt fur Wiederaufbau (KfW) assistance to address barriers to energy efficient R&M (EE R&M) of such plants, including through the implementation of selected pilot investments. These pilots were expected to demonstrate EE R&M approaches for eligible coal-fired generation capacity across select states, incorporating lessons from the past EE R&M projects and international experiences. The pilots were also expected to bring out approaches for successful implementation of such EE R&M projects through suitable risk mitigation strategies and prudent project design and implementation. The GoI had designated these pilots as *Phase-I of the National R&M Program*.

Rationale for the Project

4. The Coal-Fired Generation Rehabilitation Project (Project) was consistent with the Bank's Country Strategy for India and the Bank was well-placed to help the GoI to design and implement an appropriately sequenced program to scale-up the EE R&M of its old, inefficient and polluting coal-fired power generation capacity. This was to help put the sector on a lower carbon path than continuing to operate those plants at their lower efficiency levels while also help in bridging the electricity demand-supply gap. As a GEF Implementing Agency, the Bank secured a commitment from GEF to provide US$45.4 million grant to bring down the capital costs of such investments while also carrying out comprehensive diagnostics of the barriers to effective EE R&M of candidate units. The Project initially targeted demonstration pilots for EE R&M in four electricity generating units of a total capacity of 640 MW. It was expected that the demonstration of successful EE R&M could potentially result in the GoI and states rehabilitating a significant portion of the 27,000 MW capacity already identified for such similar works.

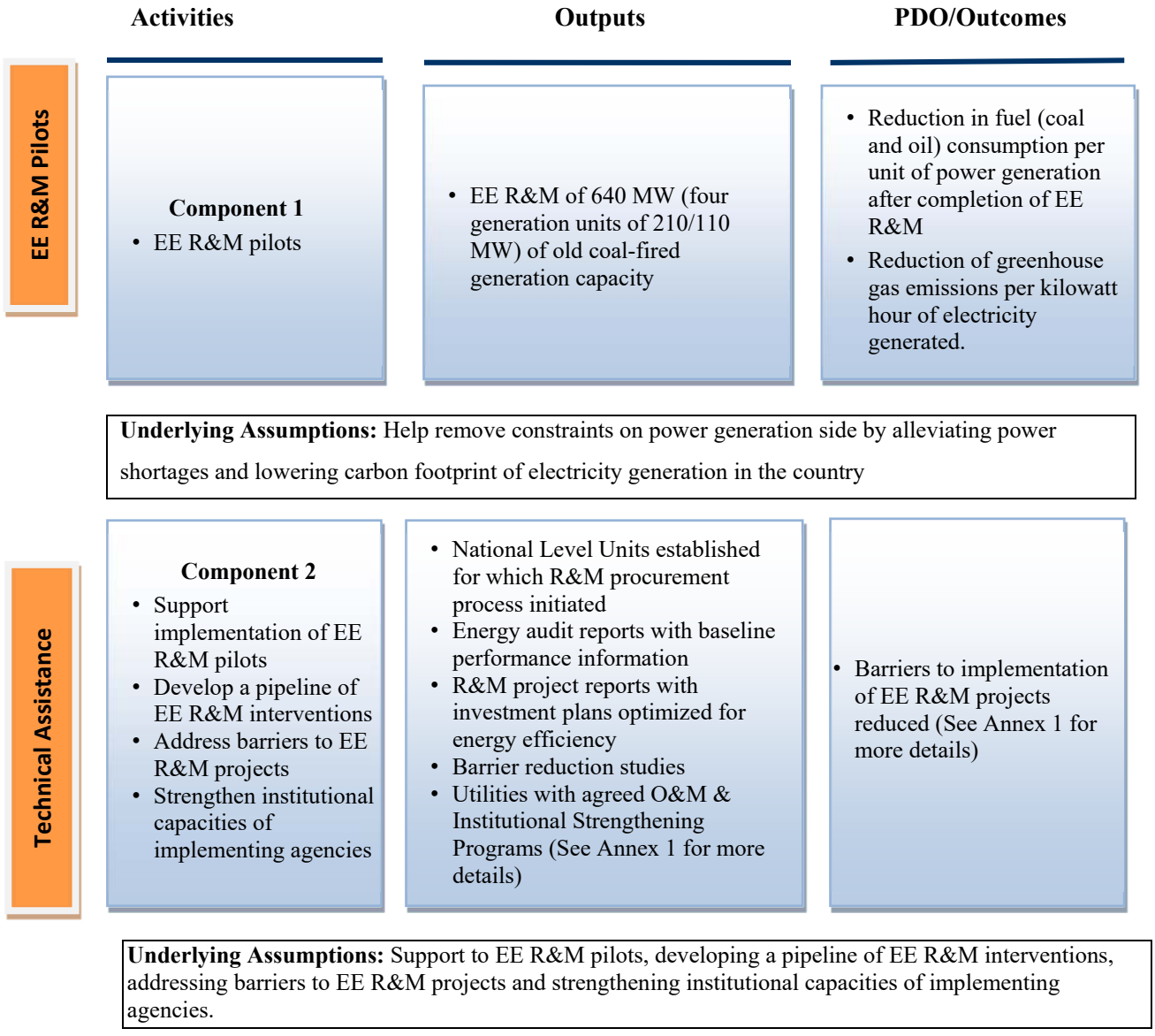
Theory of Change (Results Chain)

5. The key objective of the Project was to assist the GoI in improving energy efficiency of selected coal-fired power generation units through R&M (pilots of total 640 MW capacity) and through developing a pipeline of such interventions, addressing barriers to such projects and strengthening institutional capacities of implementing agencies

[1] The GoI's NEP promoted R&M of old thermal power plants to achieve acceptable performance standards (of efficiency, reliability and environmental performance). Some utilities such as Damodar Valley Corporation (DVC) benefitted significantly, but most others showed little sustained improvement.

for improved operations and maintenance (O&M) practices. The logic of this results chain was valid and a Results Framework (RF) was prepared at the time of appraisal, articulating the Project's pathway from planned interventions to the intended outcomes (Figure 1).

Figure 1: Theory of Change (At Appraisal)



Project Development Objective (PDO)

6. The PDO was to improve energy efficiency of selected coal-fired power generation units through renovation and modernization (R&M) and improved operations and maintenance (O&M).

Key Expected Outcomes and Outcome Indicators

7. The key expected outcomes and outcome indicators are provided in Table 1 below.

Table 1: Key Performance Indicators (KPI) for PDO

Indicator Name	Baseline	End of Project Target
1. **Unit-5, 210 MW, Bandel Thermal Power Station (TPS), West Bengal** • Reduction in Specific Coal Consumption (Kg/kWh) • Reduction in Specific Oil Consumption (ml/ kWh)	 0.684 2.5	 12% 20%
2. **Unit-6, 210 MW, Koradi TPS, Maharashtra** • Reduction in Specific Coal Consumption (Kg/kWh) • Reduction in Specific Oil Consumption (ml/ kWh)	 0.703 2.27	 14% 12%
3. **Unit-3, 110 MW, Panipat TPS, Haryana** • Reduction in Specific Coal Consumption (Kg/kWh) • Reduction in Specific Oil Consumption (ml/ kWh)	 0.825 2.4	 18% 17%
4. **Unit-4, 110 MW, Panipat TPS, Haryana** • Reduction in Specific Coal Consumption (Kg/kWh) • Reduction in Specific Oil Consumption (ml/ kWh)	 0.825 2.5	 18% 20%

Global Environment Objective (GEO)

8. The GEO was reduction of greenhouse gas (GHG) emissions per kilowatt hour of electricity generated.

Key GEO Indicator

9. The GEO indicator was the annual reduction in CO_2 emissions (in million TCO_2 and in percentage) as a result of EE R&M in plants financed under this Project.

Table 2: Key Performance Indicators (KPI) for GEO

Indicator Name	Baseline	End of Project Target
Reduction in CO_2 emission intensity for each of the generation units after completion of R&M (%)	0.00%	10%
Reduction in CO_2 emissions as a result of EE R&M (million TCO_2): - In plants financed under this project - Other plants	 0 0	 0.43 0.30

Components

10. The Project consisted of two components:

11. **Component 1 - EE R&M Pilots:** This component envisaged support to EE R&M of 640 MW (four generation units of 210/110 MW) of old coal-fired generation capacity to demonstrate EE R&M approaches. The following generation units were selected for the pilot investments, and constituted the three sub-components:

12. *Sub-component-1:* Unit-5, Bandel TPS of West Bengal Power Development Corporation (WBPDCL) -210 MW capacity: This Plant had five generation units – four of them of 82.5 MW capacity each (commissioned in late 1965-66), and the fifth of 210 MW capacity (commissioned in 1982). The first four units were planned for replacement with a new unit of at least 500 MW capacity each (from own sources of the utility) and only the fifth unit was covered under the Project.

13. *Sub-component-2:* Unit-6, Koradi TPS of Maharashtra State Power Generation Company Limited (MSPGCL or Mahagenco) -210 MW capacity: This Plant had seven generation units - Units 1 to 4 of 105 MW capacity each, Unit 5 of 200 MW, and Units 6 & 7 of 210 MW capacity each. Only Unit 6 (of 210 MW capacity) was covered under the Project.

14. *Sub-component-3:* Units-3 & 4, Panipat TPS of Haryana Power Generation Company Limited (HPGCL) -110 MW capacity each: This Plant had eight generation units, first four of 110 MW, the next two of 210 MW and the two latest units of 250 MW. Units 3 and 4 (of 110 MW capacity each) which were proposed for EE R&M under the Project, were commissioned in the year 1985 and 1987, respectively.

15. **Component 2 – Technical Assistance (TA):** The TA component, funded completely out of GEF grant, provided support in implementation of pilots, developing a pipeline, addressing barriers to EE R&M projects and strengthening institutional capacities of implementing agencies for improved O&M practices. The sub-components for the TA program covered:

16. *Sub-component-1:* Support for Design of EE R&M: It supported design studies (including Energy Audit, Residual Life Assessment [RLA], Detailed Project Report [DPR]), drafting of technical specifications and conducting bid process), and environmental and social assessment studies for a pipeline of EE R&M sub-projects with a focus on energy efficiency.

17. *Sub-component-2:* Support for Implementation of Pilot EE R&M Investments: It aimed at supporting the monitoring the implementation of EE R&M investments funded under Component 1 of the project in the three pilot states. This included hiring of implementation support consultant (owner's engineer) and quality assurance consultants.[2]

18. *Sub-component-3:* Support for Addressing Barriers to EE R&M Projects: It supported Central Electricity Authority (CEA) in addressing barriers to R&M in India, reviewing experience from pilot EE R&M interventions, and strengthening institutional capacities at CEA.

19. *Sub-component-4:* Support for Strengthening Institutional Capacities of Generation Utilities: This component was to help conduct detailed O&M studies and help implement solutions like conducting a performance improvement program, introducing/strengthening management information system (MIS), drafting of the standard O&M procedures, introduction of measures to expedite decision making, increase accountability and promote use of control systems. In addition, this component also aimed to support initiatives for strengthening overall corporate governance and management systems to allow smoother implementation of more EE R&M projects going forward and enable better management practices for improved operation of the plant.[3]

[2] The implementation support consultants were to assist the utility through the entire implementation phase (from selection of vendor to completion of EE R&M activity) and to ensure that the works are executed as per the schedule. The quality assurance consultants were to ensure that there is no compromise in quality of supplies and works, and to also certify completion of milestones for release of payments.

[3] During preparation phase, under Energy Sector Management Assistance Program (ESMAP) funding, the Bank had hired consultants for Bandel TPS (West Bengal) and Koradi TPS (Maharashtra) for strengthening the O&M practices and procedures. A

B. Significant Changes during Implementation

Revised PDO and Outcome Targets

20. The PDO was not revised, however, the outcome targets were revised in the Results Framework (RF) due to cancellation of EE R&M work for the units 3 and 4 of Panipat TPS as desired by HPGCL. KPIs that presented consolidated targets for all three State utilities at the time of appraisal were accordingly revised.

Revised Components

21. The original EE R&M component included four generation units in the pilot, however in August 2012, HPGCL decided not to undertake EE R&M of its units 3 and 4 (110 MW capacity each) of Panipat TPS. As a result, the allocated funding from the Project to the two units were partially cancelled and reallocated to other units.

Other Significant Changes

22. During implementation the Project underwent four restructurings at the request of GoI as detailed below. These had no impact on the PDO, which remained relevant and valid during implementation. Neither did these changes trigger any new safeguard policies or change the safeguard categorization of the Project, which remained 'B'.

23. **First Project restructuring (April 2014):** In August 2012, HPGCL decided to not proceed with the EE R&M of the two units 3 and 4 (of 110 MW capacity each) at Panipat TPS, as the EE R&M work was found to be financially unviable.[4] This led to the release of the Bank funds of $61.85 million of which $43.84 million was canceled at the Government's request on June 11, 2014.[5]

24. **Second Project restructuring (September 2014):** Due to delays in execution of works at both the two remaining units at Bandel TPS and Koradi TPS, following changes were made to the Project:[6]

(i) *Reallocation of Funds*: Reallocation of $21.84 million[7] of the Bank and GEF funds, which was released through cancelation of EE R&M at Panipat TPS through the first Project restructuring, on pro-rata basis as loan and grant respectively, to WBPDCL to meet the funding gap in the execution of EE R&M of its 210 MW Unit-5 of Bandel TPS was done.

(ii) *Project Closing Date*: The closing date was extended from November 30, 2014 (original) to November 29, 2016, to allow completion of EE R&M works in the pilot units of the Bandel TPS (of WBPDCL) and Koradi TPS (of Mahagenco).

(iii) *KPI:* Since HPGCL was no longer recipient of the investment funds; KPIs linked to only HPGCL were dropped. Other KPIs that presented consolidated targets for all the three state utilities at the time of appraisal were also revised.

similar study needed to be conducted for Panipat TPS (Haryana).

[4] With any change in the station heat rate (if increases to 2575 kcal/kWh, beyond projected station heat rate of 2380 kcal/kWh).

[5] Restructuring Paper dated April 11, 2014 – Report No.: RES14045

[6] Restructuring Paper dated September 24, 2014 – Report No.: RES16149. In this Restructuring, the Eligible Expenditure Category was also revised. With 'goods' as the only category for eligible expenditure, the utilities could not utilize the available funds with total percentage of expenditure to be financed by Bank and GEF. Hence, to enable utilities to disburse the funds up to 74 percent of the Project costs, the 'eligible expenditure category' was modified from only 'goods' to 'works and goods including installation and other services'.

[3] IBRD: $18.01 million (balance left after the cancelation in the first restructuring) and GEF: $3.83 million

25. **Third Project restructuring (November 2016):** This restructuring led to a second extension of the Project closing date from November 29, 2016 to November 29, 2017, to provide yet additional time to complete the unfinished works at Unit-6 of Koradi TPS due to technical problems and contractual issues. [8]

26. **Fourth Project restructuring (November 2017):** During this restructuring, a third extension of the Project closing date of four months was processed, and, as a result the project closing date was extended from November 29, 2017 to March 29, 2018. The extension was provided only for EE R&M works for Unit-6 at Koradi TPS.[9]

Rationale for Changes and Their Implication on the Original Theory of Change

27. The above changes did not have any major implication on the Theory of Change. In fact, the changes provided additional time (closing date extensions) and resources (reallocation) that contributed to more effective linkages in the results chain. However, as noted above certain KPIs (PDO indicators) were revised downwards to account in only for Bandel Unit 5 and Koradi Unit 6 parameters.

II. Outcome

A. Relevance of PDO

28. **The relevance of the PDO is rated as High.** The PDO was consistent with India's priorities identified in the Country Assistance Strategy (CAS) for the period of FY2009-2012dated November 14, 2009[10] and supported its pillar of sustainable development through lowering the carbon foot print of energy generation in the country. The objective was also consistent with the previous CAS for the period of FY 2006-2008[11] which suggested that the Bank seeks ways to further expand its partnership with India on national and global issues through programs financed by the GEF, Montreal Protocol and Carbon Finance. In this regard, the Project utilized the Bank's IBRD loans in conjunction with GEF grants and Indian counterpart financing, to make a systemic impact on R&M in India – by introducing EE R&M approaches and enhancing O&M practices – and hence make long-term and sustained emission reductions. Finally, the PDO was squarely aligned with the India's current Country Partnership Strategy (CPS)[12] which highlights Bank's support in the development of stronger incentive structures, and markets and solutions for energy efficiency to transform the country's energy efficiency market[13].

29. The objective was also consistent with India's 2006 Integrated Energy Policy (IEP)[14], which aimed to reduce non-essential or inefficient energy consumption. The report by the Expert Committee on IEP[15] highlighted the energy demand and supply scenarios, over the next 25 years, and suggested that coal would remain India's primary energy source, accounting for nearly 42 percent of total energy consumption in case of a low carbon growth trajectory, going up to 65 percent in case of mostly coal-based electricity generation.

B. Achievement of PDOs (Efficacy)

Assessment of Achievement of Project Objective/Outcome

[8] Restructuring Paper – Report No.: RES25693. At this time, Unit-5 of Bandel TPS was already commissioned.
[9] Restructuring Paper – Report No.: RES30550. At this Restructuring, the possibility of re-allocation of the balance GEF funds, originally allocated to HPGCL, for $9million (Comprising $9.17 million of $13 million GEF financing for investments and $0.67 million of $1.8 million for TA) to Unit-6 of Koradi TPS was discussed. But later Mahagenco informed that they did not need additional funds for the works. Hence at the end of the Project, these unallocated GEF funds were cancelled.
[10] Refer to the World Bank's Report No. 46509-IN
[11] India Country Assistance Strategy for the period of FY05-08 (India 2004 CAS, Report No. 29374-IN), dated September 15, 2004
[12] India Country Partnership Strategy for the period FY18–FY22 (Report No. 126667-IN), dated July 25, 2018
[13] Country Partnership Strategy, Page 16, Para 1.40
[14] Prepared by Indian Planning Commission
[15] GoI, Planning Commission, New Delhi, dated August 2006

30. **The Efficacy is rated as Modest.** Table 3 below provides progress against PDO indicators and their targets: (i) reduction in specific coal consumption; and (ii) reduction in specific oil consumption:

Table 3: Summary of Achievement of PDO Indicators

PDO Indicator	Base	Target	Actual
Unit-5, Bandel Thermal Power Plant, West Bengal			
(a) Reduction in Specific **Coal** Consumption (kg/k Wh)	0.684	0.602	0.58 (2016-17) 0.56 (2017-18) (09 months)
(b) Reduction in Specific **Oil** Consumption (ml/kWh)	2.50	2.00	3.47 (2016-17) 4.21 (2017-18) (09 months)^
Unit-6, Koradi Thermal Power Plant, Maharashtra			
(a) Reduction in Specific **Coal** Consumption (kg/k Wh)	0.703	0.605	0.730*
(b) Reduction in Specific **Oil** Consumption (ml/kWh)	2.27	2.00	1.215

^An increase in actual value of specific oil consumption (ml/kWh) in Bandel Unit-5 is due to changes in design of certain equipment by the contractor to meet contractually agreed parameters, faster than expected wearing-off of certain equipment parts, and frequent trippings due to multiple other reasons.[16] Corrective measures are being taken by WBPDCL with their own funding sources.

**An increase in actual value of specific coal consumption (kg/kWh) is due to change in assumption in gross calorific value (GCV) of the coal, which has fallen since the time of the appraisal of the Project. If the GCV assumed at the time of appraisal is considered, then the KPI target will be achieved.[17]*

Present Status of Bandel and Koradi Units after EE R&M

Unit 5, Bandel TPS

- After rehabilitation of Unit 5, life of the plant was extended by 15 years, boiler has been designed to burn poor quality coal of calorific value 3300 kilocalorie per kilogram (kCal/kg) against 4500 kCal/kg, capacity increased to 215 MW, unit heat rate to be improved from 2872 to 2345 kCal/kWh, auxiliary consumption reduced from 10.9 percent to 9 percent, and particulate emission in flue gases reduced to 74.5 milligram per normal cubic meter (mg/Nm3) (target was to be lower than 90 mg/ Nm3).

- Performance Guarantee (PG) tests were conducted after commissioning of the Unit and test results were better than specified values. However, after PG test, the Unit had higher specific oil consumption, more than 4.0 ml/unit against requirement of 2.0 ml/unit due to reasons as mentioned in the note of Table 3. It was also noted that the number of shut downs of the Unit after EE R&M are also on a higher side mainly due to a failure of pressure parts after the contractor changed the design of certain equipment (reheater tubes).

- WBPDCL is closely monitoring all the issues and has charted out an action plan[18], with its own resources,

[16] Specifically, there were changes in the design of reheater tubes by the contractor to meet contractually agreed parameters leading to their frequent failures of reheater; faster than expected wearing off replaced oil burners' nozzles, and frequent trippings due to multiple other reasons, such as, repeated failure of belt of raw coal feeder.

[17] For base case, GCV of 4500 kcal/kg was considered to set the target values, however, the actual GCV is 3170 kcal/kg. If we continue to assume GCV at 4500 kcal/kg then actual value of specific coal consumption will be 0.514 kg/kWh, which is better than the target value of 0.605 kg/kWh.

[18] Some of the actions included in the plan are: measures to reduce erosion of reheater coil at top & bottom bank; fitting of perforated plate is fitted at rear wall above of coil, review of past unit tripping events for further corrective actions, procurement of burners

specifically to reduce specific oil consumption. Such corrective actions are being taken sequentially depending on the need basis, availability of the required parts/equipment, and approval for undertaking shutdowns as necessary.

Unit 6, Koradi TPS

- Unit 6, Koradi TPS was planned to achieve full load after EE R&M in May 2016. However, this was achieved only in October 2018. The Unit experienced teething problems thereafter and progressively the issues faced have been resolved. The PG tests were successfully concluded on April 26, 2019. The raw data collected on various parameters reflected significant improvement and were within targets, however the final report will be submitted within a month by the contractor (M/s BHEL).

Assessment of Achievement of GEO Indicators

31. Key parameters pertaining to the carbon accounting are presented in the below table. The analysis here is based on the methodology followed in the project appraisal document (PAD). Post R&M figures have been provided by the respective implementing agencies - WBPDCL and Mahagenco.

Table 4: Key parameters for Carbon Accounting

Unit Name	Heat Rate (kCal / kWh)		Capacity (MW)		Plant Load Factor (%)	
	Pre-R&M (as per PAD)	Post-R&M	Pre-R&M (as per PAD)	Post-R&M	Pre-R&M (as per PAD)	Post-R&M
Bandel TPS, Unit 5	2872	2430	210	215	67%	80%
Koradi TPS, Unit 6	2951[19]	2423	210	228	72.2%	85%

32. A reduction in carbon dioxide (CO_2) emission intensity for each of the generation units after completion of R&M has been observed. As noted in the PAD, this financing window was expected to result in a reduction of unit heat rate of selected pilot generation units by 12 percent to 18 percent, and thereby the same reduction in CO_2 emission intensity of generation from these units. Therefore, the reduction in CO_2 emission intensity for each of the generation units after completion of R&M has been calculated based on the percentage reduction in the heat rate for each unit as per the figures provided in Table 4. For Bandel Unit 5, this implies a reduction of 15.39 percent and for Koradi Unit 6, this implies a reduction of 17.89 percent. These results are summarized in Table 5.

33. As per the methodology followed in the PAD, emission reduction from GEF interventions has three components: (i) Direct Emission Reductions, (ii) Direct Post Project Emission Reduction Effects, and (iii) Replication and Indirect Impacts.

34. **Direct Emission Reductions:** As noted in the PAD, the EE R&M of coal fired generation units would lead to improved energy efficiency as well as a higher amount of power generation due to increased capacity and improved Plant Load Factor (PLF). For the purpose of this analysis (for simplicity and owing to paucity of information regarding alternative sources of generation), it is assumed that at the end of the useful lives (without R&M) of both the units[20], an equivalent power would have been generated from similar units operating at the same pre-R&M parameters described in table 4.[21] It is further noted that the alternative sources of generation cannot be renewable energy sources, since these are still variable and cannot act as base load plants.

35. To calculate direct emission reductions, the emission reduction (or increase) was divided into two parts:

A. Emission Reduction from Present Level of Coal Consumption

from original equipment manufacturer, and replacement of oil burner tip.

[19] The original assumption for the GHG accounting in the PAD was retained here.

[20] Assumed to be seven years each, as in the PAD.

[21] Consistent with the approach followed in the PAD and the Restructuring Paper, the initial year's parameters have been considered pre- and post- R&M, and deterioration factors have not been considered either pre- or post- R&M.

36. With improved energy efficiency, more electricity can be generated from the same amount of coal. Without the Project, the additional electricity generated from the same amount of coal would have been provided from other sources of generation connected to the grid. Therefore, this additional generation avoids emissions from these sources. Keeping the consumption of coal constant, the annual additional electricity generated due to the improvement in heat rate was calculated, and the combined marginal emission factor of 0.92 tCO_2/MWh for the Indian grid was considered in the ICR analysis to estimate the avoided emissions from this additional generation.[22]

B. Change in Emissions from Additional Coal Consumption

37. An increase in capacity of each rehabilitated Unit as well as their higher (improved) PLF led to a higher consumption of coal. The emission factor considered for this additional generation that requires additional coal to be burnt is the difference between the combined marginal emission factor for the national grid (discussed above) and the post-R&M emission factor for the generation unit.[23]

38. **Direct Post Project (DPP) Emission Reduction Effects:** As noted in the PAD, there is no GEF-supported financing mechanism that will continue to support direct investments after the implementation or supervision of the project. Therefore, no DPP emission reduction effects have been calculated for this Project.

39. **Replication and Indirect Emissions Reductions:** In the PAD, using the GEF bottom-up methodology, indirect emission reductions attributable to the Project had been estimated at 11.06 million tonnes of CO_2 eq (assuming a replication factor of 3.0, which was consistent with the EE R&M projects already in the pipeline at the time), and using the GEF top-down methodology, indirect emission reductions attributable to the Project had been estimated at 12.69 million tonnes of CO_2 eq (assuming that the total technological and economic potential for GHG emission reductions in this area over 10 years was 31.7 million tonnes of CO_2 eq, and a project causality factor of 40 percent). However, further replication of R&M activities and indirect emissions reductions are not expected at this stage and have not been considered in the analysis for the ICR.

Table 5: Summary of Achievement of GEO Indicators[24]

GEO Indicator	Baseline	Target & Actual	Cumulative Target Values				
			2014-15	2015-16	2016-17	2017-18*	2018-19*
Reduction in CO_2 emission intensity for each of the generation units after completion of R&M (%)	0%	Target	10%	10%	10%	10%	10%
		Actual	-	Bandel: 15.39% Koradi: -	Bandel: 15.39% Koradi: -	Bandel: 15.39% Koradi: -	Bandel: 15.39% Koradi: 17.89%
Reduction in CO_2 emissions as a result of energy efficient R&M (million TCO_2) - in plants financed	0	Target	0.19	0.19	0.45	0.45	0.45
		Actual	-	0.07 (this is for 4 months for Bandel only. For a full year it would be **0.20**)	0.20	0.20	0.31 (this is for 5 months for Koradi and a full year for Bandel. Considering a full year for Koradi it would be **0.46**)

[22] CO_2 Emission factors provided in CEA - CO_2 Baseline Data for Indian Power Sector Version 13 (June 2018).
[23] It is considered to be 1.05 tCO_2/MWh in the ICR analysis - assumption for 200-250 MW coal unit in CEA - CO_2 Baseline Data for Indian Power Sector Version 13 (June 2018).
[24] This table presents the achievements compared to the formally revised targets in the September 24, 2014 Restructuring Paper (RP). The GEO indicator on "Reduction in CO_2 emissions as a result of energy efficient R&M (million TCO_2) - in other plants" was dropped as per this RP. Targets starting from 2014-15 have been indicated here since the targets prior to this year were "-" in each case. The targets as per the RP were specified up to 2016-17. However, figures have been presented here up to 2018-19 (with the same 2016-17 targets carried forward).

** Note: 2016-17 targets as per the RP dated September 24, 2014*

Justification of Overall Efficacy Rating

40. The overall efficacy is rated as **Modest**. As noted above (Table 3), some of the PDO indicators did not meet the targets, due to the external factors like the deteriorating quality of coal.[25] However, on the positive side, the auxiliary consumption and unit heat rate for both Bandel and Koradi units improved.[26] Furthermore, the electro static precipitator (ESP) outlet dust concentration for Bandel Unit that was designed (after R&M) for less than 90 mg/Nm3 has now performed even better with reduction to 74.5 mg/Nm^3.

C. Efficiency

Economic and Financial Analysis

41. The economic and financial analyses presented in the PAD pertained to Bandel TPS (Unit 5) only. The same methodology adopted in the PAD has been followed here to calculate internal rates of return (IRR) through the project level economic and financial analyses for both Bandel TPS (Unit 5) and Koradi TPS (Unit 6). Details including assumptions are presented in Annex 4.

42. For Bandel TPS (Unit 5), the economic IRR for the base case considered in the PAD was 29.09 percent. However, the economic analysis for the PAD does not seem to have considered O&M costs. Based on the information available, the economic IRR calculated at the ICR stage is 11.94 percent (with O&M costs) and 16.73 percent (without O&M costs), both of which are above the discount rate of 11.07 percent (over the relevant timeframe), demonstrating the economic viability of the Project and hence meeting the expectation of economic viability set at the appraisal stage[27]. Regarding the financial analysis, net incremental cash flows estimated in the ICR analysis in each year are predominantly negative, and the financial IRR was not calculable. In the base case considered in the PAD (considering the existing tariff would continue), the financial IRR was 16.60 percent. One of the key factors impacting the financial IRR for Bandel TPS (Unit 5) is a significant difference in the coal price assumption –actual coal price is more than double the coal price assumed at appraisal.

43. For Koradi TPS (Unit 6), the economic IRR calculated based on information available at the ICR stage (with O&M costs) is 25.62 percent, which is well above the discount rate of 10.75 percent (over the relevant timeframe), demonstrating the economic viability of the project. The estimated base period coal price for Koradi TPS (Unit 6) is nearly half of the estimated base period coal price for Bandel TPS (Unit 5), which largely explains the higher economic IRR for Koradi TPS (Unit 6). Regarding the financial analysis, net incremental cash flows estimated in the ICR analysis are negative for a number of years, and the financial IRR was not calculable.

Aspects of Design and Implementation

44. The Project helped the utilities and the other stakeholders in getting a better understanding about execution of EE R&M for TPS, which is a very challenging task given that the works have to be undertaken in a brownfield project. Such challenges include change in the priority of the GoI (and hence of utilities) from EE R&M of old TPS to replacing them with supercritical plants. Specifically, in terms of the Project design and implementation, several technical surprises unfolded during the construction period (such as discovery of an old oil pipeline that took several weeks to fix and hence resulting in stoppage of work). There were also several mismatches in the design of

[25] In case of Koradi TPS, fall in GCV of coal from the assumed value at appraisal led to an increase in the specific coal consumption (as shown in the note of Table 3, the indicator values are meeting the target values if same value of GCV as assumed at appraisal is considered) while in case of Bandel TPS, the higher oil consumption was due to sub-optimal design/low quality material of reheater tubes, frequent breakdown of raw coal feeder and oil burner nozzles by the contractor.

[26] In Bandel Unit 5, auxiliary consumption improved from 10.9 percent to 9 percent and heat rate from 2872 kcal/kWh to 2430 kcal/kWh. Corresponding figures for Koradi show reduction in auxiliary consumption from 10.65 percent to 9.05 percent and improvements in unit heat rate from 2953 kcal/kWh to 2423 kcal/kWh.

[27] The economic IRR for the base case considered in the PAD was 29.09 percent

new/replaced parts and the original equipment. The experience of R&M in the country was limited to the first few pilots that were undertaken in the country. Given this, the implementing agencies had limited exposure in conducting R&M works that led to frequent changes in the responsible team leading to delays in decision making. This impacted procurement timelines as well, which in turn increased the time span between RLA study and actual execution of the works. During implementation, lack of coordination among different contractors was also noted. These challenges impacted the cost estimations as well. However, the TA under the Project provided the utilities with an additional support in terms of hiring of implementation support and quality assurance consultants that helped in review of the design and construction works. Also, it is extremely important to note that this experience was the underlying objective of the Project as it demonstrated when EE R&M should be undertaken and how to plan such works in advance based on the lessons learned from these units.

Assessment of Efficiency and Rating

45. The Efficiency is rated as **Modest.** This is based on the economic analysis of both the units, where the economic IRR for Bandel TPS (Unit 5) is 11.94 percent (with O&M costs) and is higher than the hurdle rate of 11.07 percent while for Koradi TPS (Unit 6) is 25.62 percent compared to its hurdle rate of 10.75 percent. As noted above, there were several challenges faced during implementation of EE R&M works at both the units and provide the relevant stakeholders a considerable information to adequately design their similar in future, hence meeting the underlying objective of the project. This justifies the efficiency rating.

D. Justification of Overall Outcome Rating

46. The overall outcome is rated as **Moderately Unsatisfactory**[28]. The rating takes into consideration the outcome target of reduction in fuel (coal and oil) consumption per unit of power generation after completion of EE R&M; High rating of Relevance, Modest rating of Efficacy, and Modest rating of Efficiency.

E. Other Outcomes and Impacts (if any)

(a) Gender:

47. The Corporate Social Responsibility (CSR) activities under the Project focused on gender activities in maximizing benefits to women by improving their access to infrastructure and allied services, thereby improving their overall quality of life. Services in the health sector and access to safe drinking water, have improved their basic health and well-being, and reduced drudgery, thereby giving them more time and resources to invest in productive activities as well as leading to empowerment and greater gender equality. Better educational facilities have increased the enrollment of girls in schools. Further, installation of street lights has improved the safety and security of women in public places and enhanced their mobility at night.

(b) Institutional Strengthening:

48. Experience gained from the Project has strengthened the knowledge and technical skills of the staff of both the Koradi and Bandel TPS units on O&M as well as R&M of TPS, along with technical expertise and guidance from implementation support and quality assurance consultants that assisted the utilities.

49. A South-South Knowledge Exchange visit to South Africa in the area of EE R&M in May 2016 helped the officials from WBPDCL, Mahagenco, Ministry of Power, and HPGCL to learn and understand more about EE R&M, related practices, and similar experiences in South Africa. Further, a High-Level Roundtable organized by WBPDCL in Kolkata in April 2016 shared the implementation experiences from Bandel TPS and other similar experiences in India and other countries (including Japan) in R&M.

[28] Rating assigned as per the Bank's ICR guidelines on 'Deriving the Overall Outcome Rating' (Appendix H, page 38 of Bank Guidance on Implementation Completion and Results Report (ICR) for Investment Project Financing (IPF) Operations)

50. The Project interventions also helped in bringing further improvements to financial management and corporate governance aspects within the implementation utilities. Further, the relevant staff of Koradi TPS and Bandel TPS have gained awareness, knowledge and expertise on environmental and social aspects of TPS.

51. Technical reports (RLA and DPR) were also prepared for developing pipeline of investments by WBPDCL and Mahagenco using these TA funds. HPGCL used the TA funds to build its standard operating and maintenance procedures across its all power plants. This will eventually help in improved O&M by HPGCL. Amongst many more studies, the funds also helped HPGCL in undertaking a detailed study on flue gas desulphurization (FGD), which is an important technology to curb sulphur dioxide. The TA component supported CEA, the technical wing of Ministry of Power, in understanding the barriers in uptake of EE R&M, experience of such similar pilots around the world, proposal for developing markets for undertaking such similar investments in the country and building a capacity strengthening plan of CEA itself.

(c) Poverty Reduction and Shared Prosperity:

52. Both the Koradi TPS and Bandel TPS have generated direct and indirect employment and engaged contract laborers in O&M of the power plants. During construction of original plants, Koradi TPS provided employment to 1200 affected families[29] out of 1470 affected (people who were displaced at the time of plant establishment), and Bandel TPS provided employment to one member of each affected family. The displaced families of Koradi TPS were resettled in New Koradi village about two km from the affected site (existing power station), and the colony has been provided with all the basic amenities. Koradi TPS has also provided free housing plots and house construction allowance to the project affected people. All these aspects would facilitate reducing poverty. However, it is to be noted that the EE R&M works under this Project led to no displacement of the people.

53. The Project implementing agencies, through implementation of their respective CSR, have contributed towards strengthening of the social-economic status of the people residing in the adjoining areas and of the affected community, which were in line with the Bank's social safeguards strategy. A number of activities with regard to infrastructure development, health, education, etc. such as clean water, sanitation and health care and advance development through the provision of reliable and efficient lighting, transport and telecommunication services were implemented to mitigate the adverse impacts identified through the Rapid Social Assessment (RSA) studies. Results of these activities, which have also been covered through the impact assessment study, indicated positive impacts on the lives of community, especially women.

54. Further, energy efficiency resulting from R&M of thermal power plants would lead to reducing GHG emissions and producing cleaner air, thereby enhancing the quality of life.

III. Key Factors that Affected Implementation and Outcome

A. Key Factors during Preparation

55. **Project Design:** The design was anchored on realistic sequencing order and scaling up approach; and focused on carrying out EE R&M pilots to giving the Government an opportunity to draw lessons for the wider *National R&M Program*, targeting an estimated 27,000 MW of eligible power plants.

56. **Lessons from previous projects:** The Project design considered a number of lessons drawn from previous projects:

a. Providing adequate *support for improvement of environmental performance* of the plants.

[29] Due to displacement

b. Need for *preparation of technical design by reputable consultancy firms* in close collaboration with the power generation companies.

c. The Project ensured detailed review of all technical aspects of the Project design by a *panel of technical experts* with extensive experience in design and implementation of R&M projects in India and abroad enhances the quality of outcome.

d. *Procurement was structured in four packages* with the most critical boiler-turbine-generator (BTG) as a single package allowing an appropriate risk allocation between the client and contractors.

e. *Two-stage bidding for the main BTG package would allow further refinements* in technical design and performance requirements based on concerns highlighted by bidders.

f. *Independent implementation support* and quality assurance consultants need to be appointed for monitoring implementation progress as well as quality.

g. *Need for upfront preparation of a detailed* strategy for handling surprises on opening the machines for R&M implementation.

h. *Phasing implementation of pilots* allow transfer of learning from one pilot to the next.

57. **Risks and Risk Mitigation Measures:** During the Project preparation, the Bank team identified key risks that were three-fold and adopted appropriate mitigation measures. The first risk arose from the technical aspects of the Project – i.e. the difficulty in assessing the exact scope of what physical activities were needed to be carried out, since this could not be fully determined until after the BTG contractor opened up the machine, and the consequent difficulty of accurately defining technical specifications in the bidding documents and assessing Project costs. The second risk pertained to the level of participation in the bidding process and the risk in terms of higher than anticipated price discovery. The third risk revolved around weak client capacity and the inadequate decision-making framework during implementation, especially in view of possible 'surprises' upon opening the machines which may require contract modifications and price increases. The Project team adequately highlighted these and other risks along with mitigation measures.

58. **Adequacy of Government commitment:** The Project was structured to be fully consistent with the GoI's NEP and was designed to ensure maximum ownership by the Government. The Project provided a broad vision, a sequenced strategy, and details on each utility's responsibility.

B. Key Factors during Implementation

59. **Change of priority on R&M.** When the Project was conceived, the GoI was in favor of R&M of old thermal power units and had completed the R&M strategy. By the time the Project became effective, the thrust of the GoI (and of states and its utilities) had started to change from R&M to building new super critical thermal plants resulting in slowing down the momentum of EE R&M activities under the Project.

60. **Technical Factors:**

a. *RLA study* was conducted by an independent consultant much in advance from the start of execution of EE R&M works. Such a study was based on the testing of materials and did not consider practical difficulties involved during execution such as dismantling of old equipment and erection of new equipment. The RLA study consultant had no involvement at execution stage and was not accountable for their recommendations. As a result, the BTG contractor had to carry out more studies subsequently and thus the scope recommended by the RLA study

consultant had to undergo substantial changes. Further, the time lag between RLA study and the actual execution was more than five years in both cases.

b. *Mismatching of old and new equipment parts led to long lead times* as some of the key parts, especially of the BTG package had to be sent back to manufacturing companies (some outside of India).[30]

c. *Technical surprises* that sprung up during execution affected implementation negatively.[31]

61. **Project Management Factors:**

a. *Inadequate planning* on the following aspects contributed to delays in project implementation:

- A dedicated team for R&M on the part of WBPDCL and Mahagenco did not exist. Further, frequent change of management and shifting of the team members involved in the R&M works in WBPDCL and Mahagenco resulted in the lack of continued commitment and ownership.
- Workforce planning was not conducted properly leading to a shortage of adequate labor force.
- The works were not based on a Program Evaluation Review Technique (PERT) chart[32] which would have detailed out all activities needed for the completion of the job and micro planning for activities falling in the critical path was not carried out.
- There was an under estimation of the time and effort needed to complete the EE R&M works at both the sites. For example, tender conditions prepared by Mahagenco for the Koradi TPS Unit-6 had estimated eight months; however, in reality it took more than two years.

b. *Inadequate house-keeping,* such as, clearing out scrap materials and dismantled parts affected the movement of equipment and workforce.

c. *Lack of coordination*. Coordination among different units of the contractor was inadequate. Due to mismatches in equipment, re-work was necessary, and equipment/components had to be transported back to the factory for modifications to meet the requirements. This lack of coordination contributed to implementation delays. There were implementation support consultants in both the pilots, but their role was limited, particularly in case of WBPDCL, in terms of either technical support, quality control, or coordination among the utility, BTG and other equipment contractors.

62. **Financial Factors:**

a. *Underestimation of project costs:* Long lead time due to above mentioned reasons led to overrunning of the costs in both the pilots.

b. *Counterpart funding issues*: There was a persistent delay on the part of the Government of Maharashtra to transfer funds to Mahagenco. No funds were transferred until after July 2012 (30 months since effectiveness of the Project), even though funds had been received from the GoI. Similarly, the Government of West Bengal was also unable to provide the required

[30] For example, generator rotor flange did not fit with turbine barring gear flange. Likewise, reheater tubes were short in length and small pieces of pipes had to be welded to increase the length and enable connections with the header.
[31] For instance, at Koradi TPS, it was pointed out before the start of EE R&M works that the foundation may not be strong enough to support the new turbine. It took about 18 months to analyze and rectify this situation. Similarly, at Bandel TPS, while dismantling turbine it was noticed that foundation bolts were cast along with the main foundation and they had to be removed by boring using special machine.
[32] Program Evaluation Review Technique (PERT) is a project management tool used to schedule, organize, and coordinate tasks within a project.

counterpart funds in a timely fashion, because of which the implementation work remained slow.

63. **Procurement challenges.** Two main factors that affected procurement negatively included: (i) limited capacity within the implementing agencies to handle relatively complex procurement process (two-stage bidding) and managing complex contracts; and (ii) cumbersome internal approval process, particularly where applicable procurement provisions were at variance with the state procurement rules. The Bank team actually ended up providing more hand-holding and guidance (especially for smaller value contracts) than what is generally needed as per the policy.

64. ***Delays in environmental clearances***. There was a delay of more than two years (until mid-2012) for the Bandel TPS Unit 5 to obtain the necessary environmental clearances to proceed with the start of the R&M activities.

65. ***High turnover of the Bank's Task Team Leaders.*** During the first five of the nine years of the Project (that is, 2009 through 2014), there were frequent changes of the Task team Leaders. As a result, the execution work actually picked up only in 2014.

IV. Bank Performance, Compliance Issues, and Risk to Development Outcome

A. Quality of Monitoring and Evaluation (M&E)

66. **M&E Design:** The Project's RF was prepared as per the Bank's Guidelines. The PDO indicators and targets were compatible with the GoI's approach, donor (GEF) inputs, and India's overall policy reform agenda in the power sector. Such approach ensured that the M&E framework was grounded in reality that evolved during implementation. Additional changes in the RF were later introduced through Project restructurings to enhance results monitoring. See Annex 1 for details.

67. **M&E Implementation:** The Project was subject to nine implementation support/supervision missions along with regular monthly technical visits during 2013-2015 to Bandel TPS and during 2016-2018 to Koradi TPS that monitored detailed progress and provided extensive support to both the implementing agencies. The progress and guidance were recorded in the Implementation Status Reports (ISRs) and Aide Memoires. The task team regularly collected detailed progress data, updated current progress against the baseline, and highlighted issues for the Bank management's attention. In addition to the supervision missions, the outcome/results of the Project were monitored through information gathered by the participating generation utilities, CEA and the relevant consultants, as well as during the regular site visits by the Bank. Information provided included quarterly progress and financial management reports, annual audits of Project accounts, and external monitoring reports from consultants. Progress in the implementation of the EE R&M demonstration pilots was monitored based on information from the participating utilities.

68. **M&E Utilization:** The M&E evaluation results provided critical inputs to the Government for decisions on adjustments of national policies and regulations and set up benchmarks and good practices for replication in the rest of the country. The evaluation of results and impacts of the pilot programs were managed by CEA, to ensure ownership and replication.

Justification of Overall Rating of Quality of M&E

69. ***The overall quality of M&E is considered as Substantial.*** The M&E design was flexible, because of which the Project team was able to adequately adjust the indicators and target values during implementation, i.e.: the outcome targets were revised in the RF to accommodate changes in the scope of work under EE R&M Pilots component, where Panipat TPS' Units 3 and 4 (HPGCL) were cancelled. The M&E reports were prepared timely to keep track of Project status at any given time. The "Moderately Satisfactory" rating for M&E in the

ISRs does not reflect the Bank's M&E processes but rather the contribution by the implementing agency and the delays in delivering timely progress reports.

B. Environmental, Social and Fiduciary Compliance

70. **Environmental and social safeguards compliance***:* The Project was assigned "Category B" reflecting limited environmental impacts. Environmental Audit Due Diligence Reports (EADD), acceptable to the Bank, were prepared for Bandel and Koradi TPS. The EADDs included Environmental Management Action Plans for implementation. Relevant public consultations were carried out to address environmental issues associated with the operation of these plants and the in-country disclosure of EADD reports.

71. The Project did not trigger the policy on involuntary resettlement (OP 4.12) as no land acquisition and displacement took place throughout the Project's lifecycle. RSA studies were carried out by all the implementing agencies to: (i) document adverse impacts of the TPS' operations on agricultural fields and habitations; (ii) identify stakeholders and screen social development issues; and (iii) assess the needs of the community and facilities that power station may have resulted in, which also provided input for preparing CSR policy. It is noted that a number of community development activities were undertaken by the implementing agencies, as part of their respective CSR Plans that covered social safeguards aspects of the TPS at Koradi and Bandel.

72. **Fiduciary Compliance:** The Project complied with all fiduciary covenants during implementation. Internal control arrangements were put in place, and adequate financial management, procurement, and disbursement systems were maintained.

73. **Financial Management:** The financial management Manual incorporated necessary internal control guidelines using country finance system. The internal controls of the Project worked as intended. The quarterly interim unaudited financial reports (IUFR) were submitted to the Bank on time. The final audit for the Project was carried out by an internationally affiliated firm, in full compliance with the international standards. The auditors expressed 'unqualified audit opinion' on the financial statements of recent years, which indicated financial statements gave a true and fair view on the financial state of the Project. The Project faced persistent delays at the Government of Maharashtra level to transfer funds to Mahagenco even though funds had been received from the GoI. This was a non-compliance to the legal agreement (transfer of funds within 15 days) signed under the Project.

74. **Procurement:** All procurement packages were completed as per the approved procurement plan, albeit with extensive delays. It should be noted, though, that the 2-stage procurement of the critical BTG packages was complex and had in the case of West Bengal led to a time-consuming rebidding. The procurement was for goods, equipment and services related to the EE R&M of the power stations, consultancy for strengthening O&M practices, and consultancy towards barrier reduction and market development. All procurement under the Project was carried out in accordance with the Bank's procurement guidelines.

C. Bank Performance

75. The overall quality of Bank performance in ensuring quality at entry and quality of supervision is considered as 'Moderately Satisfactory'

Quality at Entry

76. Regarding quality at entry, the Bank took into account the adequacy of the Project design and all major relevant aspects such as technical, financial, economic, and institutional, including procurement and financial management. Potential risks and corresponding mitigation measures were appropriately incorporated into the Project design. It is important to highlight that detailed RLA studies were conducted for both the pilot units but due to changes in the priorities of the government, delays in final placement of the order were noted. This resulted

not only in procurement delays but also in increasing the gap between completion of RLA studies and actual execution of works and hence diminishing the importance of such studies. As the experience of conducting EE R&M was limited in the country, procurement timelines were based on the RLA studies conducted, which as mentioned above became redundant due to time lag in awarding of the contract. Further, due to conflict of interest issues as well as long lead time between completion of study and completion of actual works, the Project design also couldn't allow continuation of the services of the consulting firms that conducted RLA studies. This reduced the accountability of such consulting firms. Hence, the Project design was based on these factors and generated lessons learned for such similar works in the future.

Quality of Supervision

77. The Project supervision ensured detailed review of all technical aspects of the Project by a panel of technical experts with extensive experience in the implementation of R&M projects. The Bank's technical, safeguards, and fiduciary teams provided regular support to the counterparts, which resulted in adjustments in project design, including project restructuring on four occasions and extending the project closing dates in anticipation of implementation progress.

78. During implementation, contractual difficulties continued to plague the Project; nevertheless, the Bank team adequately managed close supervision throughout the course of the Project and conducted regular supervision missions, on average once every year, to take stock of the progress. During the construction period at each of the site, monthly visits were made by the Banks's relevant team members to take stock of things and iron out any coordination or technical issues being faced at the site. ISRs were candid, detailed and well targeted to outline important events and formulate clear and complete picture. The team also produced clear and detailed Aide-Memoires. During the course of implementation, the supervision team assisted the client in resolving some difficult issues, including co-financing problems, limited bidder interest in procurement, and prolonged negotiations with a single bidder.

Justification of Overall Rating of Bank Performance

Rating: Moderately Satisfactory

79. With Moderately Satisfactory ratings for both the quality at entry and the quality of supervision, the overall Bank performance is considered as ***'Moderately Satisfactory'***.

D. Risk to Development Outcome

80. The risk to development outcome is ***Low***. Bandel TPS which was commissioned in October 2015 is already feeding electricity to the electricity grid since then. After commissioning reliability run (completed in January 2019), Koradi TPS is running its rehabilitated unit to the full extent and is expected to continue to perform well. Because of the EE R&M, Unit's rated capacity has increased from 210 to 227 MW as designed, and its life has increased by 15 years. The energy efficiency has increased in terms of reduction in CO_2 emissions.

V. Lessons and Recommendations

81. While technical parameters envisaged at design stage were fully met after completion of rehabilitation work, there were considerable delays in execution of both the projects.

a. EE R&M Approach:

- *Comprehensive rehabilitation of plant after 25-30 years of plant life takes lot of time in re-commissioning of plant*. It is worth considering that instead of a comprehensive R&M after 15 years of operation, the R&M could be broken into small works and phases, say handling turbine improvements, ESP, and boiler area retrofits in separate, and independent shut downs.

- *Existing sites of plant should not be given up in favor of totally new plant because of difficulties experienced in rehabilitation work.* Existing sites are the best because of the availability of all inputs, statutory clearances, tie up of power extraction, supply of fuel, and water, etc. However, if works are attempted with full planning as per observations stated above, better results would be obtainable.
- *O&M should be given priority and appropriately incentivized.* Adequate training should be provided to the employees at regular periods for undertaking periodic O&M.
- *It is important to explore various models where private sector could be engaged and a public-private-partnership approach could be applied in scaling up the implementation of R&M.* Further, *to address the uncertainties and implementation difficulties involved in R&M*, it is important to have an intelligent risk sharing mechanism among various stakeholders, namely the generation utility, design consultant and the equipment supplier.

b. *Technical:*

- *Services of a design consultant to prepare detailed scope of rehabilitation through RLA studies for entire plant are not necessary*. Experience in both units underscore the fact that the scope of replacements/modifications should be decided by the BTG contractor and not the RLA studies (by design consultants), in consultation with the implementing agency. Time gap between finalisation of scope of work and start of execution of EE R&M works should be minimum.
- *Technical surprises in rehabilitation of old plant are inevitable*. Dedicated teams should be constituted to find solutions to handle surprises and these should be documented well in order to address the problems of frequent change in management and teams which could be beyond control.

c. *Procurement:*

- *Adequacy of time required to implement complex procurement packages:* A major lesson learned is the need to realistically assess the time required for procurement and contract implementation for complex and large value packages, particularly in case of implementing agencies with limited capacity and slow decision-making process. It was also experienced that after exceeding maximum liquidated damage limit for delays, the contractor lost interest in expediting the completion of the left-over works and hence it is important to think through possible measures that could continue to incentivize the contractors to successfully execute the works.
- *While selecting a contractor, more care should be exercised on verifying their competence* in executing similar works. It is critical to ascertain that the contractor had previous experience with specific reference to the complexities involved in the R&M works of TPS and in a timely manner. Furthermore, the main contractor must have selected all subcontractors well in advance before starting works at site.

d. Project Management:

- *It is important to prepare at the outset, details like PERT chart, manpower requirement* during all stages of Project execution, charts showing movement of scrap material, and requirement of erection machinery and erection tools and consumables, new material, erection equipment, etc. during execution. The contractor's strategy for movement of material, storage of old material, housekeeping, and safety aspects should also be amply demonstrated.
- *There should be a dedicated Project team for rehabilitation work for the entire duration of the Project. Further, continuity of the teams working on the Project is very important* both for the Bank and the counterpart. The Project was adversely affected by the frequent change of officials in the

implementing agencies and project teams in Koradi and Bandel TPS. Likewise, frequent changes of the Bank's Task Team Leaders created a certain lack of continuity and ownership, as well as different approaches to supervision. On the other hand, continuity of the task team, would engender consistency, depth and follow-up in the dialogue with the government and provided expertise to help implementing agencies analyze issues and implement actions as they emerge during implementation. Provision of incentive to contractor for early completion of the Project can be considered. Similarly, an incentive can be considered for Project staff for sticking to schedule.

- *Monitoring the progress of works at regular intervals is essential during implementation*. In particular, it is important to have an effective implementation support consultant who plays the role of coordination, monitoring and quality control and ensures that monthly meetings with various contractors are held to keep track of project activities. In addition, commitment and involvement of top management of the utility itself is necessary for the success of a project of this nature. Safety during project execution deserves top most priority. Any accident can mean lot of delays. Housekeeping during execution is also important. Scrap material as and when generated at site must be cleared on daily basis. This will enable faster and safe movement of new material, machinery and men.

b.

Annex 1: Results Framework and Key Outputs

A. RESULTS INDICATORS

A.1 PDO Indicators

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Unit-5, Bandel TPS, West Bengal: Reduction in Specific Coal Consumption	Kg/kWh	0.684	0.602 (12%)	0.602 (12%)	0.58 in 2016-17 0.56 in 2017-18 (At GCV 3694 kcal/kg) 0.84 (up to Jan 2019) at GCV of 3437 kcal/kg
	22-May-2009	22-May-2009	22-May-2009	22-May-2009	29-Nov-2017

Comments (achievements against targets): Coal Rate target is achieved.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Unit-5, Bandel TPS, West Bengal: Reduction in Specific Oil Consumption	ml/kWh	2.5	2 (20%)	2 (20%)	3.47 in 2016-17_ 4.21 in 2016-18 4.57 (up to Jan 2019)
	22-May-2009	22-May-2009	22-May-2009	22-May-2009	29-Nov-2017

Comments (achievements against targets): Oil Rate target is not achieved

Reason 1: Boiler tube leakage – Erosion in certain portion of Primary Re-heater Tube, Furnace water wall, cage wall, RHS Economizer side wall tube.
Reason 2: More number of startups – high oil consumption for light up & stabilization of unit.

Measures taken to achieve targeted oil rate

1. To reduce erosion of 2nd pass Reheat coil at top & bottom bank; perforated plate is fitted at rear wall 6” above of coil. Rear wall Erosion survey has to be done by de-metering and visual inspection during upcoming O/H. At O/H, tube guard will be fitted at Economizer side coils bend.
2. Coal feeding strategy optimized keeping high VM. GCV coal at the lower elevation
3. Review of past unit tripping events for corrective action.

4. Procurement of Burner from OEM.
5. Oil burner tip is being replaced.

Observation after taking measures in January 2018: Oil consumption in February 2018 was 2.39 ml/kWh.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Unit-6, Koradi TPS, Maharashtra: Reduction in Specific Coal Consumption	Kg/kWh	0.703	0.605 (14%)	0.605 (14%)	0.730
Comments (achievements against targets):	22-May-2009	22-May-2009	22-May-2009	22-May-2009	29-Nov-2017
Unit-6, Koradi TPS, Maharashtra, Reduction in Specific Oil consumption	ml/kWh 22-May-2009	2.27 22-May-2009	2 (12%) 22-May-2009	2 (12%) 22-May-2009	1.215 29-Nov-2017
Comments (achievements against targets): To be available after PG Test					

A.2 Intermediate Results Indicators

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Component 1: Number of contracts awarded	Value	0.00 22-May 2009	9.00 22-May 2009	7.00 29-Sep-2014	7.00 29-Nov-2017
Comments (achievements against targets):					

Indicator Name	Unit of	Baseline	Original Target	Formally Revised	Actual Achieved at

	Measure			Target	Completion
Component 1: Capacity rehabilitated and modernized with focus on energy efficiency, financed under this project	Number	0.00 22-May 2009	640.00 22-May 2009	420.00 29-Sep-2014	420.00 29-Nov-2017
Comments (achievements against targets):					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Component 2: Cumulative number of Units for which R&M procurement process is initiated at the National Level	Value	0.00 22-May 2009	8.00 22-May 2009	2.00 29-Sep-2014	2.00 29-Nov-2017
Comments (achievements against targets):					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Component 2: Cumulative number of energy audit reports with baseline performance information	Value	0.00 22-May 2009	8.00 22-May 2009	8.00 22-May-2009	8.00 29-Nov-2017
Comments (achievements against targets):					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Component 2: Cumulative number of R&M detailed project reports (DPRs) with investment plans optimized for energy	Value	0.00 22-May 2009	8.00 22-May 2009	8.00 22-May-2009	4.00 29-Nov-2017

Comments (achievements against targets):

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Component 2: Cumulative number of barrier reduction studies/technical assistance interventions undertaken by CEA under Bank project	Value	0.00 22-May 2009	4.00 22-May 2009	4.00 22-May-2009	4.00 29-Nov-2017
Comments (achievements against targets):					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Component 2: Cumulative number of utilities in which implementation of agreed O&M and Institutional Strengthening Programs is completed	Value	0.00 22-May 2009	3.00 22-May 2009	3.00 22-May 2009	3.00 29 Nov. 2017
Comments (achievements against targets):					

GEO Indicators

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Reduction in CO_2 emission intensity for each of the generation units after completion of R&M (%)	Percentage	0.00	10.00	10.00	Bandel = 15.39% Koradi = 17.89%
		22-May-2009	22-May-2009	22-May-2009	29-Nov-2017

Comments (achievements against targets):

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Reduction in CO_2 emissions as a result of energy efficient R&M - in plants financed under Project - other plants	 Million TCO_2 Million TCO_2	 0 0	 0.43 0.30	 0.45 0.00	0.31 (this is for 5 months for Koradi and full year for Bandel. Considering a full year for Koradi it would be **0.46**)
		22-May-2009	22-May-2009	29-Sep-2014	29-Nov-2017

Comments (achievements against targets):

B. KEY OUTPUTS BY COMPONENT

Objective/Outcome: To improve energy efficiency of selected coal-fired power generation units through R&M and improved O&M.

Outcome Indicators	Reduction in fuel (coal and oil) consumption per unit of power generation after completion of R&M
Intermediate Results Indicators	5 packages have been awarded.
Key Outputs by Components	**Component 1: EE R&M Pilots** Sub-component-1: Unit-5, Bandel TPS, West Bengal (210 MW) There are 5 supply and installation packages:

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Main Plant Package	M/s Doosan (Doosan Heavy Industries & Construction Co. Ltd., South Korea	29-2-12 / 14-3-12	31-10-2017

	[DHIC] for Off Shore Supply Contract & Doosan Power System India Private Limited [DPSI] as associate of DHIC for On Shore Supply Contract & Service Contract)		
Coal Handling Plant (CHP) Package	M/s Vinar Systems Private Limited	03-1-2013/30-1-13	29-11-2017
Electrical Package	M/s GE-T&D erstwhile M/s ALSTOM T&D India Limited	28-12-12/ 21-1-13	29-11-2017
Ash Handling Plant (AHP) Package	M/s Macawber Beekay Pvt Limited	29-04-13/ 07-07-13	29-11-2017
Air Conditioning System	M/s Voltas Limited	31-12-2015	29-11-2017

Key Results:

a. After completion of EE R&M works, the Unit is running at 215 MW.
b. Unit Heat rate achieved in PG test is 2284 kCal/kWh (PG test date 24.11.2016). Average Heat Rate in 2017-18 (April'17 – Dec'17) is 2406 kCal/kWh.
c. Auxiliary consumption of major load bearing equipment selected in Contract is 11.803 MWh. (PG test result)
d. ESP outlet emission 74.5 mg/Nm3. (PG test result). ESP outlet emission in 2017-18 (April'17 – Dec'17) is 91.27 mg/Nm^3.
e. Reason of higher heat rate is due to operation at partial load.

Component 2: TA

Sub-component-1: Support for Design of EE R&M

Under Policy & Human Resource Development (PHRD) grant, WBPDCL had engaged following consultancy services for design of EE R&M:

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Consultancy Services for EE R&M of Bandel TPS Unit 5 (210MW)	M/s Steag encotec (India) Pvt. Limited	12.07.2007	12.07.2008
Consultancy for EADD Study	M/s SGS India Private Limited	04.06.2007	31.03.2008
Consultancy for RSA Study	M/s South Asian Foundation for Human Initiatives, Kolkata	03.09.2007	28.02.2008

Consultancy Services for EE R&M of Bandel TPS Unit 5 (210MW): Following services were under this scope of work:

a. Energy Audit (Report submitted on 22-02-2008)
b. DPR (Final Report submitted on 22-07-2008)
c. Technical specification of four sub packages (Main Plant Package, CHP Package, Electrical Package, Ash Handling and Balance of Plant [BOP] package) of the Project.
d. Evaluation of the technical part of bids.
e. EADD Study – Carrying out Environmental Audit.
f. RSA Study – Carrying out Social Assessment Study

Sub-component-2: Support for Implementation of Pilot EE R&M Investments
There are 3 consultancy service packages under TA:

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Implementation Support and Quality Assurance Consultancy Services for "EE R&M of Bandel TPS Unit 5 (210MW)	Development Consultants Pvt. Ltd [DCPL]	10.04.2012	29.11.2017
Consultancy Services for Feasibility study of Stage1 Bandel TPS, WBPDCL along with RLA study of BTG, Critical Piping of one Unit followed by Performance Study of the Unit of 60 MW (De-rated Capacity) against original installed Capacity of 82.5 MW	TUV SUD South Asia Pvt. Ltd.	18.07.2016	29.11.2017
Impact assessment study on CSR activity	M/s Webcon	15.05.2017	31.08.2017

a. Implementation Support and Quality Assurance Consultant broadly has a mandate of reviewing engineering designs for all the 4 supply and installation packages, reviewing Quality Plans, performing quality inspection at shop under On-shore packages and at field, reviewing PG Test Procedure, and, witnessed and reviewed PG Test result.
b. RLA study and feasibility study of 1 no. 60 MW unit of Bandel TPS included performing RLA study of BTG, conducting performance test of major equipment, and studying space availability at Bandel TPS to lay down Cooling Tower to make the system closed cycle as per Environmental Norms.

	c. Impact assessment study on CSR activity broadly included performing survey on nearby inhabitants to understand impact of CSR activity carried out by Bandel TPS at present and after studying demand of inhabitants, suggested areas to be addressed in future. Sub-component-3: Support for Addressing Barriers to EE R&M Projects Not applicable to WBPDCL Sub-component-4: Support for Strengthening Institutional Capacities of Utilities WBPDCL informed the World Bank on 15.07.2010 that WBPDCL has already engaged M/s NTPC and M/s PwC for 'improving O&M performance' and 'Organizational Culture and Climate' respectively for all the plants including Bandel TPS. Activities envisaged for 'O&M Capacity Building Consultancy Services' in 'Project Implementation Plan, February 2009' is fully addressed in the scope of already engaged consultancy firms - NTPC and PWC. WBPDCL proposed to allow the WBPDCL to merge the procurement of 'Implementation Support Services' and 'Quality Assurance Services' into one Consultancy Service and cancel the 'O&M Capacity Building Consultancy Services'. In response to WBPDCL proposal, the Bank on July 23, 2010 stated their 'no objection' to WBPDCL's proposal to merge into one the procurement of Implementation Support Services and Quality Assurance Services and to increase the combined budget. They also stated that the budget increase is made possible by reducing the size of future procurement of Operation & Maintenance (O&M) capacity building support. Hence, no further consultancy service has been engaged for Operation & Maintenance (O&M) capacity building support under this Project.

Annex 2. Bank Lending and Implementation Support/Supervision

A. TASK TEAM MEMBERS

Name	Role
Preparation	
Supervision/ICR	
Ashok Sarkar, Surbhi Goyal	Task Team Leader(s)
Shanker Lal	Procurement Specialist
Supriti Dua	Financial Management Specialist
Boonsri Prasertwaree Kim	Program Assistant
Sita Ramakrishna Addepalli	Environmental Safeguards Specialist
Surbhi Dhingra	Social Safeguards Specialist
Rishi Kumar Jain	Technical Expert
Shalini Agrawal	Program Assistant
Shaukat Javed	Program Assistant

B. STAFF TIME AND COST

Stage of Project Cycle	Staff Time and Cost	
	No. of staff weeks	US$ (including travel and consultant costs)
Preparation		
FY06	17.263	43,364.86
FY07	37.238	98,131.87
FY08	53.342	182,269.85
FY09	59.258	207,145.43
FY10	0	0.00
FY11	0	0.00
Total	**167.10**	**530,912.01**
Supervision/ICR		

FY09	0	350.25
FY10	41.927	155,194.69
FY11	49.116	143,608.44
FY12	31.972	138,390.83
FY13	30.843	115,684.48
FY14	24.618	80,140.16
FY15	13.612	64,158.95
FY16	25.355	145,140.30
FY17	14.425	78,485.46
FY18	5.800	27,749.64
Total	**237.67**	**948,903.20**

Annex 3. Project Cost by Component

Components	Amount at Approval (US$M)	Amount after Restructuring (US$M)	Actual at Project Closing (US$M)	Percentage of Approval (%)
Component 1: EE R&M Pilots – World Bank	180.00	136.16	104.14	57.8
Component 1: EE R&M Pilots - GEF	37.90	37.90	24.28	64.0
Component 2: TA - GEF	7.50	7.50	3.67	48.9
Total	**225.40**	**181.56**	**132.09**	**58.6**

Annex 4. Efficiency Analysis

1. The project level economic and financial analyses for: (i) Bandel TPS (Unit 5), and (ii) Koradi TPS (Unit 6) for the ICR are based on data provided by WBPDCL and MSPGCL, some parameters from the DPRs, and some of the assumptions from the analysis carried out for the PAD. The base period considered here is 2009-10. The economic and financial analyses presented in the PAD pertained to Bandel TPS (Unit 5) only. The same methodology adopted in the PAD has been followed here to calculate internal rates of return based on the project level economic and financial analyses of both Bandel TPS (Unit 5) and Koradi TPS (Unit 6).

A. Bandel (Unit 5):

2. Key parameters considered in the economic and financial analyses for the "without project" scenario, the "with project" scenario as expected in the PAD, and the estimated post-R&M parameters from the project site are detailed in table 4.1.

Table 4.1: Key Parameters for Bandel TPS (Unit 5)

Head	Without Project	With Project – Expected (PAD)	With Project - Actual (ICR)
Residual Plant Life	7 years	15 years	15 years
Capacity	210 MW	215 MW	215 MW
Shutdown Period	-	6 months	Approximately 24 months (December 2, 2013 – November 24, 2015)
Other key dates	-		Contract sign: February 29, 2012 Full load run: November 24, 2015 PG Test: November 24, 2016
Plant Load Factor (PLF)	67%	85%	80%
Heat Rate (in kcal / kWh)	2872	2456	2430
Auxiliary consumption	10.86%	8.50%	9.00%
Secondary oil Consumption (SOC) (in ml/kWh)	2.5	1.5	From WBPDCL: 3.47 (2016-17) 3.81 (2017-18) 4.57 (up to Jan'19) Assumed: 3.47 in 2015-16; 4.57 in 2019-20 and 1.75[33] in 2020-21
Capacity Deterioration Factor	0.00%	0.00%	0.00%
PLF Deterioration	4.00%	0.10%	0.10%

[33] 1.75 is the WBERC approved figure. WBPDCL would need to undertake measures at an additional cost of INR 600 million to bring down the SOC.

Head	Without Project	With Project – Expected (PAD)	With Project - Actual (ICR)
Factor			
Heat Rate Escalation Factor	0.40%	0.20%	0.20%
Specific Consumption of Oil escalation factor	2%	1%	1%
Auxiliary Consumption Escalation Factor	0.30%	0.15%	0.15%
Average GCV of oil	*(same figure as "with project" figures considered in the PAD and ICR)*	9334 Kcal/lit	9150.68 Kcal/lit
Average UHV/GCV of coal	*(same figure as "with project" figures considered in the PAD and ICR)*	4050 Kcal/kg	3694.5[34] Kcal/kg

3. Table 4.2 presents actual generation figures for Bandel TPS (Unit 5)reported by WBPDCL for 2015-16 to 2017-18. These figures have been incorporated in the economic and financial analyses.

Table 4.2: Actual electricity generation figures for Bandel TPS (Unit 5) post-R&M (2015-16 to 2017-18)

Year	Generation (MU)
2015-16	394.291
2016-17	1084.408
2017-18	1234.826

Economic Analysis:

4. **Benefit from Reduction in Fuel Cost:** To value the coal savings due to increased energy efficiency, we calculate the value of coal saved under R&M. In the PAD, these savings were valued based on the prevailing international coal prices (adjusted for differences in quality between foreign and Indian coal), yielding a price of INR 1,890/MT. In the ICR, these savings have been valued using the FY 2017-18 audited figure of INR 4220.23/MT provided by the client, adjusted to 2009-10 terms assuming an annual increase in coal price of 5% (yielding a price of about INR 2856/MT in 2009-10). There is a lower fuel cost per kWh of generation with R&M: in the first seven years (residual plant life without R&M) the fuel cost is INR 2.61 per kWh in the Without Project case and around INR 2.55 per kWh with R&M during the 1st 7 years (2009-10 to 2015-16 with a shutdown period with R&M from Dec. 2013-Nov. 2015), and INR 2.26 per kWh with R&M (2009-10 to 2030-31) considering the entire useful life of 15 years post-R&M (starting from December 2015).

5. **Benefit from Increased Generation:** Increased capacity, improved PLF, reduced auxiliary consumption and increased unit life all contribute to increased generation with R&M. The value of

[34] GCV provided by client for 2017-18 assumed equal to UHV

additional generation is considered to be equal to the average cost of alternate supply from gas based thermal power generation - INR 3.62 per kWh, which was considered in the PAD. The total estimated extra net generation over the period under consideration (2009-10 to 2030-31) compared to the without R&M scenario is 17,665.98 MU.

6. **Benefit from reduced carbon emissions:** Consistent with the approach followed in the PAD, the estimated carbon reduction benefit has not been considered in the calculation of the economic IRR.

7. **Project cost:** Actual investment costs reported by the client for each year add up to INR 6148.71. The total capex amount reported by the client is INR 6522 million. To be conservative, the balance amount has been considered as a cost in FY 2018-19. WBPDCL would also need to undertake measures at an additional cost of INR 600 million to bring down the SOC. These expected costs have been considered in FY 2019-20.

Table 4.3: Phasing of investment

Year	Investment (INR million)
FY 2011-12	496.4
FY 2012-13	92.71
FY 2013-14	3112.21
FY 2014-15	1420.14
FY 2015-16	242.39
FY 2016-17	121.12
FY 2017-18	663.74
FY 2018-19	373.29
FY 2019-20 (expected)	600
Total	**7122**

8. **Incremental fuel cost:** Incremental fuel (coal and oil) costs with R&M have been considered using:

- *For coal:* the FY 2017-18 audited figure of INR 4,220.23/MT provided by the client, adjusted to 2009-10 terms assuming an annual increase in coal price of 5 percent (yielding a price of about INR 2,856/MT in 2009-10).
- *For oil:* the FY 2017-18 audited figure of INR 42,590.18/KL provided by the client, adjusted to 2009-10 terms assuming an annual increase in oil price of 5 percent (yielding a price of about INR 28,827/KL in 2009-10).

9. **O&M costs:** The economic analysis for the PAD does not seem to have considered O&M costs. Incremental O&M costs with R&M have been considered in the present analysis by taking the value of the total O&M cost in the "without R&M" scenario considered in the financial analysis for the PAD (INR 228.9 million in the base period with an annual escalation factor of four percent). The overall O&M cost "with R&M" (INR 1527.71 million inclusive of units 1 to 5) reported by the client for FY 2017-18 was considered in the "with R&M" scenario in the post-R&M years (with an annual escalation factor of four percent), with the cost pertaining to unit 5 estimated on the basis of the proportion of total capacity that unit 5 accounted for in 2017-18[35] (no apportionment was done for the "without R&M" estimates discussed above – it is assumed that these figures already pertained to unit 5). Estimated O&M costs for each year were then

[35] 47.25% = 215 MW/(4*60 MW + 215 MW)

adjusted to 2009-10 price terms for the economic analysis assuming annual inflation of O&M costs equal to four percent. O&M costs were assumed to be zero during the shutdown period in the "with R&M" scenario, and it is assumed, for simplicity, that any staff costs during the shutdown period are charged to other units.

10. **Discount Rate:** A discount rate of 11.07 percent[36] is considered (over 2009-2031).

11. **Results:** The economic IRR is presented in table 4.4 for:
- The base case considered in the PAD
- The ICR analysis without O&M costs
- The ICR analysis with O&M costs

Table 4.4: Internal Rate of Return (IRR)

PAD (Base Case)	ICR (Without O&M costs)	ICR (With O&M costs)
29.09%	16.73%	11.94%

12. **Conclusion:** The economic IRR is 11.94 percent when we consider O&M costs, and 16.73 percent excluding O&M costs, both of which are above the discount rate of 11.07 percent, demonstrating the economic viability of the project. One of the key factors impacting the economic IRR based on the analysis for the ICR as compared to the analysis for the PAD is the difference in the coal price assumption – the estimated base period coal price considered for the ICR analysis (based on the FY 2017-18 figure provided by the client) is higher than the base period price that was assumed in the economic analysis for the PAD.

Financial Analysis:

13. The financial benefit of the investment is increased revenue from additional energy sales. The estimated tariffs considered in each year are detailed in Table 4.5. For 2017-18, the tariff is calculated based on the tariff order of WBPDCL for the year 2017-18 (and tariffs for all other years are estimated based on an assumed annual increase of four percent for the fixed charge and five percent for the variable charge):

- *Fixed Charge:* the determined annual capacity charge for Bandel in 2017-18 is INR 19732.10 lakh (INR 1973.21 million). A fixed charge of INR 1.31 per kWh was calculated for Bandel on the basis of this, a capacity of 215 MW and PLF of 80 percent. The fixed charge pertaining to unit 5 was then estimated on the basis of the proportion of total capacity that unit 5 accounted for in 2017-18 (as discussed for O&M costs).

- *Variable Charge:* the energy charge for Bandel in 2017-18 is 270.27 paise/kWh (INR 2.7027 per kWh). The variable charge pertaining to unit 5 was then estimated on the basis of the proportion of total capacity that unit 5 accounted for in 2017-18 (as discussed for O&M costs).

Table 4.5: Tariff assumptions

	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Fixed Charge (INR/kWh)	0.45	0.47	0.49	0.51	0.53	0.55	0.57	0.60	0.62	0.65	0.67
Variable Charge (INR/kWh)	0.86	0.91	0.95	1.00	1.05	1.10	1.16	1.22	1.28	1.34	1.41
	2020-	**2021-**	**2022-**	**2023-**	**2024-**	**2025-**	**2026-**	**2027-**	**2028-**	**2029-**	**2030-**

[36] Based on the Technical Note on Discounting Costs and Benefits in Economic Analysis of World Bank Projects (2/18/2016) available at: *worldbankgroup.sharepoint.com/sites/ggs/SitePages/Detail.aspx/Blogs/mode=view?_Id=2892&SiteURL=/sites/ggs*. An average per capita real GDP growth rate of approximately 5.53 percent is expected (over 2009-2031), based on forecasts by the Economist Intelligence Unit.

	21	22	23	24	25	26	27	28	29	30	31
Fixed Charge (INR/kWh)	0.70	0.73	0.75	0.78	0.82	0.85	0.88	0.92	0.96	0.99	1.03
Variable Charge (INR/kWh)	1.48	1.55	1.63	1.71	1.80	1.89	1.98	2.08	2.18	2.29	2.41

14. **Results:** Net incremental cash flows in each year are predominantly negative, and the financial IRR was not calculable. In the base case considered in the PAD (considering the existing tariff would continue), it was 16.60 percent. One of the key factors impacting the financial IRR is the difference in the coal price – the estimated base period coal price considered in the analysis for the ICR (based on the FY 2017-18 figure provided by the client) is more than double the base period price (INR 1,400/MT) that was assumed in the financial analysis for the PAD.

B. Koradi TPS (Unit 6):

15. Key parameters considered in the economic and financial analyses for the "without project" scenario, and the estimated post-R&M parameters from the project site are detailed in table 4.6.

Table 4.6: Key Parameters for Koradi TPS (Unit 6)

Head	Without Project	With Project - Actual (ICR)
Residual Plant Life	8 years	15 years
Capacity	210 MW	228 MW
Key Dates	-	Start of shutdown: August 24, 2015 Unit synchronized on: July 16, 2018 Full load achieved on: October 19, 2018 Reliability run: January 9, 2019 to January 24, 2019 PG Test: April 26, 2019 (however the results from this test will be available after a month)
Plant Load Factor (PLF)	72.2%	85%
Heat Rate (in kcal / kWh)	2953[37]	2423
Auxiliary consumption	10.65%	9.05%
Secondary oil Consumption (in ml/kWh)	2.27	1.215
Capacity Deterioration Factor	0.00%	0.00%
PLF Deterioration Factor	3.00%	0.10%
Heat Rate Escalation Factor	0.40%	0.20%
Specific Consumption of Oil escalation factor	2%	1%
Auxiliary Consumption Escalation Factor	0.30%	0.15%
Average GCV of oil	10373 Kcal/lit	10373 Kcal/lit
Average UHV of coal	3170 Kcal/kg	3170 Kcal/kg

[37] As per the DPR

Economic Analysis:

16. **Benefit from Reduction in Fuel Cost:** To value the coal savings due to increased energy efficiency, we calculate the value of coal saved under R&M. These savings have been valued using the January 2019 figure of INR 2271 /MT provided by the client, adjusted to 2009-10 terms assuming an annual increase in coal price of five percent (yielding a price of about INR 1464/MT in 2009-10). There is a lower fuel cost per kWh of generation with R&M: In the first eight years (residual plant life without R&M) the fuel cost is INR 1.63 per kWh in the Without Project case and around INR 1.62 per kWh with R&M during the 1st 8 years (2009-10 to 2015-2016 with a shutdown period with R&M starting from Aug. 24 2015), and INR 1.37 per kWh with R&M (2009-10 to 2033-34) including the entire useful life of 15 years post-R&M (starting from November 2018).

17. **Benefit from Increased Generation:** Increased capacity, improved PLF, reduced auxiliary consumption and increased unit life all contribute to increased generation with R&M. The value of additional generation is considered to be equal to the average cost of alternate supply from gas based thermal power generation - INR 3.62 per kWh (consistent with the assumption above for Bandel TPS). The total estimated extra net generation over the period under consideration (2009-10 to 2033-34) compared to the without R&M scenario is 21,336.85 MU.

18. **Benefit from reduced carbon emissions:** Consistent with the approach followed in the PAD, the estimated carbon reduction benefit has not been considered in the calculation of the economic IRR.

19. **Project cost:** Actual investment costs reported by the client for each year have been considered, along with estimated additional costs in 2018-19 and 2019-20.

Table 4.7: Phasing of investment

Year	Investment (INR million)
FY 2011-12	3.63
FY 2012-13	19.61
FY 2013-14	408.59
FY 2014-15	64.62
FY 2015-16	1175.56
FY 2016-17	1315.11
FY 2017-18	637.64
FY 2018-19	1595.24
FY 2019-20	411.20
Total	**5631.20**

20. **Incremental fuel cost:** Incremental fuel (coal & oil) costs with R&M were considered using:

- *For coal:* the January 2019 figure of INR 2271 /MT provided by the client, adjusted to 2009 terms assuming an annual increase in coal price of 5 percent (yielding a price of about INR 1464 /MT in 2009-10).
- *For oil:* the January 2019 figure of INR 44420 /KL provided by the client, adjusted to 2009 terms assuming an annual increase in oil price of 5 percent (yielding a price of about INR 28634/KL in 2009-10).

21. **O&M costs:** Incremental O&M costs with R&M have been considered in the present analysis following a conservative approach, based on O&M cost information for 2009-10 to 2019-20 provided by the client and apportioned to unit 6 based on the proportion of total capacity that unit 6 accounted for in each year[38]. Estimated O&M costs for each year were then adjusted to 2009-10 price terms for the economic analysis assuming annual inflation for O&M costs equal to the average of the O&M escalation factors provided by the client for 2010-11 to 2012-13 (approximately 7.89 percent) up to 2015-16, and equal to the escalation factor of 4.27 percent provided by the client starting from 2016-17. O&M costs were assumed to be zero during the shutdown period in the "with R&M" scenario, and it is assumed, for simplicity, that any staff costs during the shutdown period are charged to other units.

22. **Discount Rate:** A discount rate of 10.75 percent[39] is considered (over 2009-2034).

23. **Result:** The economic IRR is 25.62 percent, which is well above the discount rate of 10.75 percent, demonstrating the economic viability of the Project.

Financial Analysis:

24. The financial benefit of the investment is increased revenue from additional energy sales. The tariffs considered in each year are detailed in table 4.8. These figures are based on tariff information for 2009-10 to 2019-20 provided by the client and apportioned to unit 6 based on the proportion of total capacity that unit 6 accounts for, for both fixed and variable charges. An annual increase of 5 percent for both fixed and variable charges is considered for all future years. Fixed charges per kWh for each year were calculated based on the capacity and PLF of unit 6, and the estimated annual fixed charge pertaining to unit 6.

Table 4.8: Tariff assumptions

Charges (INR/kWh)	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Fixed Charge	0.47	0.64	0.68	0.80	0.90	0.41	0.61	0.95	1.03	0.91	1.44	1.51	1.58
Variable Charge	0.32	0.55	0.94	1.21	1.28	1.24	1.22	1.20	1.66	1.39	1.34	1.41	1.48
	2022-23	2023-24	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33	2033-34	-
Fixed Charge	1.66	1.75	1.83	1.92	2.02	2.12	2.23	2.34	2.46	2.58	2.71	2.84	
Variable Charge	1.55	1.63	1.71	1.80	1.89	1.98	2.08	2.18	2.29	2.41	2.53	2.65	

25. **Results:** Net incremental cash flows for a number of years are negative, and the financial IRR was not calculable.

[38] It is assumed that the FY 2018-19 O&M cost provided by the client is a full-year estimate, and only 5/12 of the proportion pertaining to unit 6 is considered in 2018-19 as the O&M cost (in the "with project" scenario), to reflect that unit 6 was in operation for only about 5 months in FY 2018-19. For simplicity, it is conservatively assumed that the FY 2015-16 O&M cost provided by the client is the same both with and without the project, although in the "with project" scenario, unit 6 was shut down for part of FY 2015-16.

[39] Based on the Technical Note on Discounting Costs and Benefits in Economic Analysis of World Bank Projects (2/18/2016) available at: worldbankgroup.sharepoint.com/sites/ggs/SitePages/Detail.aspx/Blogs/mode=view?_Id=2892&SiteURL=/sites/ggs. An average per capita real GDP growth rate of approximately 5.38 percent is expected (over 2009-2034), based on forecasts by the Economist Intelligence Unit.

Annex 5. Supporting Documents

1. Project Information Document, Report No.: AB2430
2. Project Appraisal Document, Report No.: 43378-IN
3. Project Restructuring Paper, dated September 24, 2014, Report No.: RES16149
4. Project Restructuring Paper, dated November 24, 2017, Report No.: RES30550
5. Project Restructuring Paper, dated November 24, 2016, Report No.: RES----
6. Loan Agreement, dated December 17, 2009, Report No.: Loan 7687-IN
7. Implementation Status & Results Reports (ISRs): Sequence 1 through 16 – from November 2009 through July 2017
8. Aide-Memoires:
   a. April 2010
   b. May 2011
   c. July 2012
   d. Jan 2013
   e. April 2014
   f. March 2015
   g. September 2015
   h. June 2016
   i. May 2017
9. Informal Missions Reports:

a. December 2017
b. January 2018
c. February 2018

10. Mid-Term Review Report, July 9-18, 2012
11. Memos regarding amendments to the Project Agreement
12. Presentation Report on ‘Round Table Discussion on EE and R&M’ for Bandel TPS, dated February 12, 2018
13. Borrower’s Evaluation Report

Annex 6. Outputs Under GEF Grant Funded Activities of HPGCL

1. The table below provides details of the various activities that were undertaken by HPGCL through allocated GEF grants under the Project.

Table 6.1: TA Activities of HPGCL

S. No.	Name of Assignment	Description of Assignment	Name of firm	Completion status/ Remarks
1.	Design Consultancy for R&M of unit 3&4 of Panipat TPS	An advisory role to assist HPGCL for the R&M and Life Extension works of Units 3 & 4 (110 MW each) of Panipat TPS for the unit / subsystems (e.g. Boiler, Turbine, Generator and its auxiliaries, C&I system, Electrical Systems, Coal and Fuel Handling systems, Ash Handling system, etc.) of units / replacement of the units	M/s Energo Engineering Projects Limited, New Delhi.	Contract was short closed on mutually agreed basis in November 2015 after HPGCL concluded that EE R&M works may be financially unviable as per sensitivity analysis (with regard to station heat rate).
2.	EADD	Major activities were as under: a. Regulatory Compliance Assessment. b. Pollution Prevention & Control Assessment. c. Resource Efficiency Assessment. d. Occupational Health, Safety Assessment.	M/s. Enzen Global Solutions, Bangalore.	Completed in March 2011
3.	RSA	a. To carry out socio-economic and cultural analysis to identify potential impacts of the Thermal Power Plant on the immediate habitations. b. To identify stakeholders and screen social development issues. c. To ensure that the results of the Social Impact Assessment provides inputs and enables formulation of indicators for monitoring and evaluation of the project outcomes at the completion.	M/s. SMEC India, Gurgaon.	Completed in September-2010
4.	Implementation Support Consultant for R&M of unit 3&4 of Panipat TPS	Not Applicable (NA)	NA	Grant not utilized as work of EE R&M of Unit 3 & 4 of Panipat TPS was dropped.
5.	Quality Assurance Consultant for R&M of unit 3&4 of Panipat TPS	Not Applicable (NA)	NA	Grant not utilized as work of EE R&M of Unit 3 & 4 of Panipat TPS was dropped.
6.	Assessment of O&M Practices at	Assessment of current O&M Practices at HPGCL and to compare these with the best practices followed in other Power Stations in India/Abroad	M/s Steag Energy Services,	Completed in May 2015. Details provided further in this Annex.

S. No.	Name of Assignment	Description of Assignment	Name of firm	Completion status/ Remarks
	Power Stations of HPGCL.	and to submit an action plan for improvement in O&M and management practices.	Noida.	
7.	Strengthening O&M Practices at Power Stations of HPGCL.	To carry out following activities: 1. Development of Standard Operating Procedures (SOP), Standard Maintenance Procedure (SMP) and training thereof" 2. Audit of auxiliary power consumption, Condenser vacuum and consumption of demineralization water. 3. Water Balance/Optimization Study. 4. Strengthening of the Fire Fighting System of Coal Handling Plant-II (CHP-II) 5. Consultancy for feasibility study for installation of FGD at Rajiv Gandhi Thermal Power Plant (RGTPP) Hisar	M/s PwC (for S. no 1 & 2). M/s NTPC (for S. no 3,4 &5)	1. Completed in Nov - 2017 2. Completed in July - 2017 3. Completed in July - 2017 4. Completed in May - 2017 5. Completed in Nov - 2017

Assessment of O&M Practices at Power Stations of HPGCL

2. *Objectives of the assignment* were:

a. Carryout an assessment of O&M practices as well as O&M management practices.
b. Based on the detailed assessment identify options for improvement in operations and maintenance practices leading to improved performance of the power plants.
c. Jointly with the O&M staff at the power plant develop an action plan for improving Operational maintenance practices of the plants.

Table 6.2: TA Activities of HPGCL

S. No	Major Recommendations / Gaps	Action Taken / Implementation
1.	The permit to work system is manual. System of safety permits like hot permit, etc., and lock-out-tag-out system not followed. This is potentially unsafe work practice.	Lock-out-tag-out system has been implemented. Computerized permit to work system will be covered in Enterprise Resource Planning (ERP).
2.	System of scheduled equipment changeover is not practiced regularly, which can result in imbalance in equipment running. This could affect the preventive maintenance schedules and may lead to equipment forced breakdown.	The change-over schedule is being followed & reviewed in operation review team meetings.
3.	System of checking interlocks and protections in place, but protocols of checks are not maintained systematically.	The interlocks & protections of Turbine & boilers are being checked in association with operation engineers and record is maintained.
4.	Regular and structured O&M reviews are done on weekly basis chaired by Chief Engineer along with Superintendent Engineers and Executive Engineers.	Daily plant meeting chaired by respective Chief Engineer is in place.
5.	Maintaining history of critical equipment has the scope for further improvement for systematic	The history of equipment breakdown & annual overhauling is being maintained and will be put in

	analysis of the faults and corrective action taken.	practice after installation of ERP system.
6.	Heat rate improvement programs, equipment performance testing is yet to be initiated.	Monitoring of important parameters carried out twice in a day and being discussed in daily plant meeting. Energy Audit of the plant is being carried out regularly and discussed in operation review team meeting.
7.	System of creating a special overhaul team for overhaul coordination and re-commissioning ensures for completeness of the work carried out, by charging the system and taking trial run of the equipment, checking protections and interlocks, thereby ensuring the readiness of the equipment / system for operation. Presently the system of creating a special overhaul team is not practice.	HPGCL has constituted boiler knowledge team, turbine knowledge team, C&I knowledge team to check overhaul effectiveness in these area, major outage study & recommendations/ suggestions.
8.	Ash Handling Plant: Check lists, maintenance instruction sheet, emergency operating instructions and other systems not developed. The plant does not have computerized inventory monitoring and control system.	• Preparation of check lists, maintenance instruction sheet, emergency operating instructions and other systems covered in development of SOPs. • To be covered in ERP.
9.	The maintenance planning function at HPGCL requires Computerized maintenance management system in order to fulfill its role effectively.	To be covered in ERP.
10.	Equipment condition monitoring needs to be reviewed. Though the system is under practice, condition monitoring techniques such as vibration analysis, oil analysis, motor current signature analysis are to be strengthened for improving equipment reliability and reduced forced outages.	Running hours for change of equipment is being frequently monitored and preventive maintenance are being implemented accordingly. These issues are being monitored and reviewed in ORT meeting.
11.	The system of Mean Time to Repair (MTTR) and Mean Time Between Failures (MTBF) is not followed. This will lead to unplanned outage of equipment / systems, lack of planning for spares, and man power, and also results in generation loss	System of Mean Time to Repair (MTTR) and Mean Time Between Failures (MTBF) be ensured at the time of implementation of ERP system.
12.	Periodic efficiency testing of systems and equipment is not in place	Audit for auxiliary power condenser vacuum and consumption of DM water is implemented.
13.	System of pre-overhaul survey for identification of leakages is not in place.	Pre overhaul survey for identification of leakages i.e. steam water, coal, flue gas in the respective area were got identified by the concerned maintenance agencies and were got attended during the annual overhaul of the units & the performance of the units is being monitored by conducting regular performance test and discussed in every ORT along with Ex-NTPC experts.
14.	A dedicated EHS department is not in place. This may sometimes lead to lack of coordination and follow up.	Health and safety related issues are being monitored by safety officer cum Factory Manager. HPGCL is already ISO 9001, ISO 14001, ISO 18001 certified company.
15.	At HPGCL, almost all purchase and stores activities	E-Procurement, E-Auction and ABC analysis will be

	are carried out manually through filing system. This is leading to high cycle time and huge manual efforts	ensured at the time of implementation of ERP system.

Strengthening O&M Practices at Power Stations of HPGCL.

Development of SOPs, SMPs and training thereof of HPGCL TPS (awarded to M/s PwC):

3. *Objectives of the assignment:* SOPs are vital documents for bringing consistency, efficiency, safety in operation of the plant and averting equipment failures because Operation department is responsible for safe & efficient operation of plants. The term operation mainly includes start-ups, shutdowns, and routine operation, handling of emergencies, monitoring of critical parameters that affect the process and ultimately the power generation. Operation's responsibility includes testing of various protective devices and protections of principle equipment, regular changeover of standby auxiliaries to ensure their availability & functionality. Further operation is also responsible for proper isolation of equipment/auxiliary/system to facilitate preventive maintenance/ breakdown/ planned shutdown as per the schedule.

4. SMPs are the vital documents developed to ensure efficient and reliable operation of the equipment/system/Unit so as to achieve high availability. Maintenance can be considered as a combination of actions carried out in order to replace, repair, and service (modify) the components of an equipment/system/Unit so that it will continue to operate for a specified time. Maintenance not only raises the level of equipment performance and availability but also adds to running costs. Hence, the maintenance objective should be to achieve the optimum balance between these effects, i.e. the balance which maximize the department's contribution to profitability

5. M/s PwC deputed specific field experts i.e. boiler, turbine, control and instrumentation (C&I) electrical, ash handling, coal handling, water chemistry, etc. at each Power Station. Specialized task force at each power station were got constituted. Both the teams developed the identified SOPs and SMPs in close co-ordination with each other.

6. Following SOPs and SMPs (refer table 7.3) were developed at respective power plants and same have been circulated for implementation at respective power station.

Table 6.3: SOP and SMP Developed for HPGCL

S. No.	Station	SOPs	SMPs	Training Mandays
1.	RGTPP	166	212	52
2.	Deenbandhu Chotu Ram Thermal Power plant (DCRTPP)	136	156	49
3.	Panipat TPS Units 6,7,8	260	305	43

7. Assignment was Completed in November 2018.

Audit for Auxiliary Power, Condenser vacuum and consumption of De-Mineralization water for all the three Power Stations of HPGCL (awarded to M/s PwC):

8. *Objectives of the assignment:* The energy audit study focused on all major energy consuming equipment and the evaluation of operational efficiency/performance of such equipment from the energy conservation point of viewpoint. The study focused on all energy-consuming areas and identified opportunities for energy savings at the plant. Special attention was given towards conducting the Helium

test and Flood test for the condenser to improve its performance. During the audit, there was continuous interaction between the audit team and the plant personnel to ensure that the recommendations made are realistic, practical and implementable. Specifically, it included the below:

a. To conduct a comprehensive Auxiliary Power Consumption audit of HPGCL Power Stations to monitor Auxiliary Power Consumption, identify avenues for auxiliary power saving and optimization.
b. Audit of Condenser Vacuum for RGTPP, Hisar; DCRTPP, Yamunanagar; and Panipat TPS (only Unit 6 to 8).
c. To conduct a comprehensive DM Water audit of HPGCL Power Stations to evaluate DM water use, identify avenues for water conservation and enhance DM water use efficiency.

9. *Recommendations and Achievements:* Following were the results of the study:

a. Auxiliary Power Consumption Audit: Study revealed break up of energy consumption in plant (e.g. Boiler, Turbine, ESP, De-Mineralization plant, AHP, CHP, raw water system) besides potential power saving areas in different location in the plants, maximization of power saving and least power consumption.
b. Audit of Condenser Vacuum: During the study, various tests including Condenser flood test, Helium Test of the condenser, etc. were carried out. The various leakage points identified during the study have already been attended except for those that require long shut down. Such leftover recommendations will be attended at the soonest available opportunity.

10. The study was completed in July 2017.

Water Balance/ Optimization study for Unit 6-8, Panipat TPS and Unit 1-2, RGTPP, Khedar (awarded to M/s NTPC):

11. *Objectives of the assignment:* The study was carried out covering the estimation of water consumption at each stage of water systems, identification of water saving potential at various stages of water systems by reduce, recycle and reuse of water as well as implementation of latest technologies. From the study expected benefits are outlined for reduction of overall water consumption for the station, improving pump efficiency, identification of various losses and to reduce the same. This ultimately helps in reduction of water and energy costs. Specifically, the objective was to conduct a comprehensive Water audit of HPGCL power stations to evaluate water use, identify avenues for water conservation and enhance water use efficiency. Water audit is to be done to identify various options for efficient water use and conservation opportunity

12. *Recommendations and Achievements:* Following were the results of the study:

a. Logging Running Hours: The system of logging running hours of pumps at water consumption nodes were not there at TPS of HPGCL. A typical measurement diagram has been provided in the final report. Online flow meter or pump running hour integrator may be installed as per feasibility.
b. Use of Firewater in place of Service Water: There is sporadic use of firewater to meet service water requirement inside the plant. This was noted as a wastage of high-pressure water, which compromises reliability of firewater system. It has been recommended to substitute use of firewater with service water in CHP and other areas.
c. Maximize reverse osmosis water production by maintaining the drains oil contamination free.

d. Ash water recovery: Ash water recovery from ash pond to be maximized.
e. Raw Water for Horticulture Use of raw water for Horticulture should be substituted with waste water generated inside the plant. In this regard, a scheme to use the water in rain harvesting pond has been constructed.

13. The above recommendations have already been implemented at Panipat TPS and RGTPP (Hisar). Improvements in Specific Water Consumption has been noted at both the sites.

14. The study was completed in July 2017.

Strengthening of the Fire Fighting System of Coal Handling Plant (CHP-II), Panipat TPS (awarded to M/s NTPC):

15. *Objectives of the assignment:* The study focused on preparation of a technical feasibility report and pre-award activities for revival/new installation of fire-fighting system in CHP for Units 5&6 (210 MW each) at Panipat TPS, Haryana. The report was prepared for the following major activities:

a. Technical feasibility.
b. Basic system design/scheme.
c. Bill of quantity/material
d. Cost estimations
e. Preparation of Biding/Tender documents and drawings
f. Preparation of Technical specifications

16. The matter has been deliberated during the Operation Review Team meeting reviews at Panipat TPS wherein steps for need based revival have been initiated and in the first phase, revival of fire fighting in conveyor has begun. The second phase will cover Rotary Discharge Machine area.

17. M/s NTPC completed the above assignment in May 2017.

Consultancy for feasibility study for installation of FGD at RGTPP Hisar (awarded to M/s NTPC):

18. *Objective of the assignment:* It was to assess feasibility of installing FGD systems/equipment required to meet with new environmental norms, especially removal of Sulphur dioxide from flue gases at RGTPP. Identified technology to control Sulphur dioxide was to be described. Type of FGD proposed with merits and demerits of various systems were also to be described along with typical layout of proposed FGD system.

19. *Recommendations and Achievements:* The study found that the installation of FGD system is feasible in this station. The subsequent action of installation of FGD system has already been initiated.

20. Assignment was completed in November 2017.

Annex 7. Borrower's ICR

I. MSPGCL: Borrower's ICR

Project Background

1. MSPGCL planned to carryout R&M and Life Extension (LE) of 210 MW Unit #6 at Koradi TPS in the 11th Plan (2007-2012). Govt. of India approached the World Bank and the Global Environmental Facility (GEF) for financing this initiative under their "INDIA: Coal Fired Generation Rehabilitation Project". The Project is proposed to be an energy efficiency window within the Partnership for Excellence Program. It is intended to demonstrate the efficacy of using energy efficiency as one of the primary criteria along with PLF enhancement and life extension in R&M project design.

2. MSPGCL appointed M/s. EVONIK Energy Services (formerly STEAG encotec India Limited) to conduct RLA Study, Energy Audit and prepare the Detailed Feasibility Report (DPR) & bid specifications for R&M of Koradi U-6.

3. The R&M of Unit 6 is aimed at:
- Improved Availability and Load Factor of the Generation Unit
- Improved Heat Rate (efficiency) up to original design value or even better
- Enable the unit to be operated using available quality of coal
- Reduction in Auxiliary consumption
- Ensure emission level (SPM) is sustained level below 100 mg/Nm^3

4. The Energy Audit and DPR for Koradi U-6 have been prepared and based on these studies the technical specifications have also been finalized. As mentioned above, improvement of energy efficiency and environment standard are the clear objectives of the R&M exercise and the GEF grants would be utilized towards these ends.

Project Components

5. There are two components –
- Component -1: Renovation & Modernization (R&M) and Life Extension (LE) of 210 MW Unit #6 at Koradi TPS
- Component -2: Technical Assistance (TA)

  - Sub-Component 1 - R&M work is divided into four packages:

6. BTG Main Plant, Electrical, BOP & Coal Handling Plant. Out of this the Coal Handling Package is cancelled.

7. BOP Package was comprising of Cooling Tower & Cooling Water System, Raw Water System, DM Plant & Pre-treatment System, Ash Handling System, Compressed air System & Fire Detection, Protection & Inert Gas System.

8. During retendering of BOP package, Raw Water System & Compressed air System were deleted. During ordering, DM Plant & Pre-treatment System tender was cancelled & need based refurbishment of 2 streams of DM Plant is taken up.

Table 7.1: Details of Packages

Name of Package	Agency Engaged	Contract Sign. Date/ Package Start Date	Package End Date
Main Plant	M/s Bharat Heavy Electricals Ltd. (BHEL)	18.12.2013 / 03.03.2014	20.08.2016 (still in progress)
Electrical	M/s Asia Brown Boveri (ABB)	25.05.2012/ 07.09.2012	20.08.2016 (still in progress)
Cooling Tower Plant	M/s. Hamon Shriram Cottrell Pvt. Ltd	20.09.2016 & 23.09.2016/ 19.11.2016	06.06.2017 (still in progress)
Ash Handling System	M/s. The Indure Pvt. Ltd., New Delhi	26.10.2016/ 20.02.2017	07.09.2017 (still in progress)
Fire Detection, Protection & inert Gas System	M/s. Nitin Fire Protection Industries Ltd.	05.11.2016/ 02.01.2017	21.07.2017 (still in progress)
Demineralization Plant Package	Tender cancelled in Jan.2017 due to higher cost than estimated. The need-based work of DM Plant is being carried out separately by O&M section through various agencies as per requirement.		

9. Amount of Loan/ GEF Grant allocated (expressed in USD)-

Sub-Component 1:

Table 7.2: Original Allocation (in USD)

Amount of Loan allocated (expressed in USD)	Amount of Grant allocated (expressed in USD)	Percentage of expenditure to be financed (inclusive of taxes)
58852500	12450000	74%

10. Source of remaining 20 percent is equity fund of Govt. of Maharashtra & 6 percent funds from internal resources of MSPGCL.

Sub-Component 2 – Following Consultancy services were engaged under TA

A. Support for Design of EE R&M –

Under PHRD grant MSPGCL engaged following consultancy services for Design of Energy Efficiency Renovation & Modernization (EER&M) are utilized:

Table 7.3: Packages under Support for Design of EE R&M

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Consultancy Services for EER&M of Koradi TPS Unit No.6 (210MW) RLA Study, Energy Audit, DPR, Bid specs.	M/s. Evonik Energy Services (formerly STEAG encotec India Limited)	13.11.2007	23.12.2013 (short closure)
Consultancy for Environmental Audit and due Diligence Assessment Study	M/s. Ernst and Young Ltd. Hyderabad	26.06.2007	26.08.2008
Consultancy for Rapid Social Assessment Study	M/s. AC Nielsen ORG Marg Ltd. New Delhi	3-12-2007	26.06.2008

B. Support for Implementation of Pilot EE R&M Investments: The following consultancy services are utilized under GEF -TA Grant:

Table 7.4: Packages under Support for Implementation of EE R&M Investments

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Project Implementation Support Services for EER&M of Koradi TPS Unit No. 6 (210MW)	M/s. Tata Consulting Engineers Ltd. Bangalore	01.06.2012 / 13.12.2013	01.09.2015 (still in progress but now being funded by MSGPCL)
Quality Assurance Consultancy Services for "EER&M of Koradi TPS Unit No. 6 (210MW)	M/s Tata Consulting Engineers Ltd. Bangalore	14.10.2015	25.02.2018 (still in progress but now being funded by MSGPCL)
Cost Estimate Consultancy for Cooling Tower and De-Mineralization Plant tenders	M/s. Mecon	21.04.2016/ 09.06.2016	15.07.2016
Health assessment of Coal Bunker structure	M/s. Structwel Designers & Consultants Pvt. Ltd.	07.02.2017	April-2017
Assessment of structural stability of existing foundations of Bottom Ash Hopper at 0.00 Level	M/s. Structwel Designers & Consultants Pvt. Ltd.	07.03.2017	July-2017

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Impact assessment study on CSR activity	M/s. Surya Enviro Tech	11.02.2016	11.05.2016

Table 7.5: Amount of GEF TA Grant Allocated

Amount of Grant allocated (expressed in USD)	Percentage of expenditure to be financed (inclusive of taxes)
3300000	100%

PROJECT RESTRUCTURING

11. Balance of Plant (BOP) package was awarded to M/s. Tecpro. The contract was signed on 20.02.2012 & zero date was 25.02.2014 as BTG package was delayed. M/s. Tecpro could not execute the contract due the financial crisis in their company. The contract was terminated in March 2015.

12. The plant study was done in the 2009, tender was floated in 2011 and contract was terminated in 2015. During this time many major changes occurred in plant condition and hence while refloating the tender some changes were made. To save the time in single order execution the DM, AHP, CT and FF package tenders were floated on 23.09.2015 at NIC's portal for e-procurement. World Bank extended the support for Techno- commercial terms finalization & clearance for placing the orders to concerned bidders with lowest offer.

13. Letter of Award (LOA) for Cooling Tower Plant Package, Ash Handling Plant package and Fire Detection, Protection & Inert Gas System Package were issued and contracts were signed on 23.09.2016, 26.10.2016 & 05.11.2016 respectively.

PROJECT OBJECTIVES

- Life of unit will be extended at least by 15 years. With Periodic overhauling life may be extended further for another 10 years.
- Post R&M, Unit Capacity will be 215 MW & PLF to average 85 percent.
- Availability Factor will be above 90 percent. This means quantum of Electricity Generation will increase as well as become more reliable as compared to the present status.
- Target Unit heat rate of this EER&M Project is 2350 Kcal/Kwh. This will help to reduce coal requirement per unit electricity generation. Levelised Generation Cost – Rs. 3.50 per Kwh as per DPR.
- The Unit will be capable to operate with inferior grade coal (Retrofitted boiler to cope up with the existing coal quality (3400 to 3800 Kcal/Kg against design of 5000 Kcal/Kg) which will reduce the Generation cost.
- Auxiliary power consumption will be lowered. Net Power sent out will increase.
- Replacement of Turbine, Condenser tubes , Boiler Pressure Parts, Renovation of APH etc. will help to overcome followings:-
- Aging of critical components (leading to lower reliability and shorter residual life)
- Non-availability of critical spares due to obsolescence

- Renovation of ESP, replacement of burner assembly, etc will help to comply with latest Environmental Norms and reduction in emission.
- Incorporation of advanced, state of the art, Control & Instrumentation (C&I) technology will improve operational reliability and efficiency.
- Increase in reliability and efficiency by reduction in forced outages

Finally achieved functional guarantees:

PG test was successfully concluded on April 26, 2019. The raw data collected on various parameters reflected significant improvement and were within targets, however the final report will be submitted within a month by the contractor (M/s BHEL). Hence the functional guarantee parameters are not available at this stage. The reliability run was carried out from 09.01.2019 to 24.01.2019 as per available inputs. The average parameters recorded during the unit run from 21.01.2019 to 24.01.2019 are furnished below for reference. However, final parameters will be available only after PG test.

Table 7.6: Parameters as per Reliability Run

S.No.	Parameters	Units	Value
1	Unit Load	MW	Max: 230 MW (21.01.2019 to 24.01.2019)
2	Unit Heat Rate	Kcal/Kwh	As Performance Analysis and Optimization module (PAO) is not functional as yet, Heat rate value will be available after PG test.
3	Specific Coal Consumption	Kg/Kwh	0.730
4	Specific Oil Consumption	ml/ Kwh	1.215
5	Auxiliary Power consumption (BTG)	% of output	0.305 (6.237%)
6	Auxiliary Power consumption(Complete)	% of output	0.409 (8.364%)
7	Demineralised water consumption	M^3	523 (@3.6% considering average feed flow of 596 TPH on 22.01.2019.)
8	Steam Parameters (MS)	^oC Kg/cm^2	535 115
9	Steam Parameters (HRH)	^oC	542 (Ave Value) 22.01.19
10	Condenser Vacuum	Kg/cm^2	(-) 0.870
11	SPM		Data not available through DCS during the trial run of the unit. Will be measured during the PG test.
12	Oxygen content & carbon mono oxide content in flue gases		
13	No. of Mills in operation	No.	5
14	Load at which oil support is withdrawn	MW	Around 130 MW
15	Furnace vacuum	mmWC	-10

Project Scope

The major scope of R&M works under various packages –

Main Plant Package

i) Boiler –

- Boiler to be Uprated – from 700 TPH to 721 TPH
- Replacement of pressure parts, flue gas ducting, expansion joints, dampers, Induced Draught (ID) Fans, Primary Air (PA) Fans, Air Pre Heater (APH), New Gravimetric Feeder, Hangers & Supports of Critical Piping
- Refurbishment of Forced Draught (FD) Fan
- Replacement of existing Bag Filters with new design retrofitted ESP for all 4 passes to achieve guaranteed SPM of 70 mg/NM3 with one field out of service.
- Refurbishment of Coal Mills XRP 803

ii) Turbine & Generator –

- TG to be Uprated - 228 MW
- New HP & IP turbines, LP turbine rotor and diaphragms for LP casing, new barring gear assembly
- Replacement of condenser tubes, BFP cartridge assembling & BFP recirculation valve, Tube bundles for LP Heaters & GC.
- New HP Heaters
- HP & LP bypass valves, Turbo supervisory system and Electro hydraulic governing system
- New Generator and its bus duct
- New Generator Transformer
- Static excitation system with DAVR and Auto synchronization.

iii) C&I:

- Unified Distributed Digital Control Monitoring & Information System (DDCMIS) of the following systems:
- Steam Generator Controls
- Steam Turbine Controls
- Station C&I and Electrical Control System
- Man Machine Interface and Plant Information System
- Steam & Water Analyser System
- Flue Gas Analyser

iv) BOP:

a) Cooling Tower Plant Package

Existing Five (5) Main Cooling tower (30 cells) to be renovated and modified so as to achieve cooling water temperature range of 9ºC and approach 5 Deg. with WBT 28ºC.
Replacement of CT fans complete with efficient design FRP hollow blades, with motor, shaft, coupling, gear box etc. for optimum performance of the cooling tower and enhanced cooling range.
Replacement of aluminium fan blades of four (4) nos. CT fans of Axillary Cooling Tower with efficient design FRP hollow blades of auxiliary cooling tower for optimum performance of the cooling tower.

Associated Civil and electrical works.

b) **Ash Handling System**:

Removal/ Dismantling of existing equipment
Supply and installation of complete wet fly & coarse ash evacuation system below each ESP, Economizer, Air Pre-heater and Duct hoppers. Replacement of suction and discharge knife Gate valves of ash slurry pumps and to make the system complete in all respect for safe reliable, efficient and trouble free operation.

c) DM Plant & Pre-treatment System:

Replacement of following items for two DM streams:
Degasser blowers complete with energy efficient motors & other accessories, Mixed Bed Air Blower, DM inlet pumps, Degasser transfer pumps, Alkali-unloading pumps complete with motor and other accessories (Near Alkali tanks), Acid-unloading pumps complete with motor and other accessories (Near Acid tanks), Gravity filter air blowers with motor, Rubber lining of SAC, WBA, SBA, MB vessels of One stream.

d) Fire Detection, Protection & Inert Gas System:

To renovate the fire detection system in the cable galleries of Unit # 6 replacing by advance multi sensor detectors suitable for the duty conditions along with the control cables and the control panel.

Addition of Inert Gas System for the enhance fire protection of the PCR. Plant control Room comprises central control room, engineering room, control equipment room, UPS, battery room and charger room
Associated Electrical, C&I & civil work.

v) Electrical –

- Replacement of UAT, CEP motor, LT motors
- New Energy Management system and energy meters for HT and LT drives
- Microprocessor based Bus transfer system
- Retrofit of HT & LT Breakers
- Illumination
- Retrofit HT and LT Switchgear for control and monitoring from DCS

MSPGCL Views on Performance of the World Bank

1) The World Bank extended their support to make this pilot project successful.
2) The World Bank allocated funds from GEF Grant to engage consultant for following:

i) To prepare Detailed Project Report along with environment impact assessment
ii) Project Implementation Support
iii) Quality Assurance
iv) Cost Estimate Consultancy for CT & DM Plant tenders
v) Health assessment of Coal Bunker structure

vi) Assessment of structural stability of existing foundations of Bottom Ash Hopper at 0.00 Level
vii) Impact assessment study on CSR activity.

3) Techno-commercial and Administrative guidelines from the World Bank received during tendering process and preparation of contract document etc.
4) World Bank loan helped to maintain steady cash flow throughout the project.
5) The World Bank team monitored the project through regular visits & implementation support mission during project execution.
6) WBPDCL arranged roundtable in Kolkata on 04.04.2016 with the support of World Bank team. MSPGCL representative attended the meeting in which the implementation experience from Bandel TPS was shared and brain storming session on issues around the potential for scaling up R&M of similar TPS units in India was held.
7) No Objection Letters required for procurement of some of the items to meet the contingencies are issued considering the situation.
8) World Bank consistently suggested Mahagenco/BHEL to prepare micro Schedule of the balance activities with achievements thereon.
9) World Bank suggested to ensure safety practices to avoid accidents
10. During TG foundation issue, World Bank proactively discussed the matter with MSPGCL, TCE along with their commercial expert.
11. The World Bank extended their support from time to time during procurement process.
12. The overall involvement of the World Bank is satisfactory

Assessment of Institutional and Financial sustainability of activities initiated under the project after project closure.

Benefits achieved through implementation of the R&M project at U#6, Koradi T.P.S. shall be available after conductance of PG test & thereafter the continuous running of the unit for considerable period.
The project estimated cost at this stage is @Rs.563.12 Cr. against the DPR estimate of Rs.486.07 Cr. The final project cost will be available at the time of project closure.
MSPGCL will approach the Regulatory Commission during Final True up of FY 2017-18 in November 2019. As such revised tariff of the Koradi TPS is not yet fixed.
Further as per the new guideline of MoEF & CC, necessity of FGD installation need to be reviewed financially and technically.
Proper assessment of Institutional and Financial sustainability of activities is not possible at this stage. The experience from Bandel & Koradi U-6 EER&M projects shall help in targeting other similar R&M projects.

Outcome of R&M

The unit is still under stabilization period. PG test is yet to be conducted. Outcome of R&M in terms of specific coal consumption, specific oil consumption etc. can be available only after continuous running of the unit for a considerable period after R&M activities completion.

Problems Faced During Implementation

Civil area:

1) TG foundation health assessment & strengthening.

2) Bottom Ash Hopper foundation reconstruction.
3) Execution of civil works required to be carried out along route for transportation of Gen. Stator movement inside plant.
4) Coal bunker structure health assessment & repairs.
5) TG floor '0' meter slab health assessment & repairs.
6) Floor tiling and wall cladding of Plant control Room.
7) False ceiling of PCR.

Space constraints:

1) Dismantling and removal of Coal mill reject system in order to provide space for seal air fans.
2) FO (Fuel Oil) lines rerouting.
3) Rerouting of Unit-5 & 7 pipelines and cables.
4) Rerouting of pipelines (Underground) fouling at construction of ESP control room.
5) Scrap storage, removal & transportation of scrap.

TG Area:

1) ATRS (Automatic Turbine Run-up System) Valves replacement.
2) LPH-4 & GC tubes damaged during transportation hence new sets brought by BHEL.
3) LP turbine casing strengthening required due to uprated capacity of the turbine.
4) The barring gear was fouling with Generator rotor shaft flange; hence the Generator rotor was threaded out and taken to Haridwar by BHEL for modification of the flange. Generator shaft modification carried out and returned to site & restored at location.
5) Newly introduced Jacking oil system encountered troubles during initial start-up. After trial & error, the cut- in/ cut- off speed is finalised.
6) HP rotor was sent to BHEL-Haridwar for rectification and full speed balancing. After rectification, all above components of TG received at site on 22.05.2018 and Re-assembly of TG was done.
7) Rising trend in babbit temperatures of TG Bearing 4, 5 and 6 were noticed during coasting down. Loading of bearings reviewed & attended.
8) Tripping on high babbit temperature of Brg. No.2, 4 (RTD failure). Bearing No.4 DPT/UT done. No abnormality found. RTD replaced, bearing boxed up & Set synchronized.

Boiler Area:

1) Boiler Tube Leakage (BTL) on 09.09.2018. Thorough inspection of all Furnace Water Walls was taken up by M/s. BHEL. On the basis of inspection, tubes at @ 50 locations involving @ 100 joints are replaced from 09.09.18 to 10.10.2018.
2) Boiler tube leakage at Final Super Heater on 20.10.2018. Leakages attended and set synchronized on 10.11.2018.
3) Bottom ash hopper replacement done instead of refurbishment as the structure was deteriorated.
4) Coal feeder belts failure & replacement.
5) Coal feeder & central pipe alignment.
6) Mismatch in Boiler tubes (RH Header stubs and coils)
7) Isolated Phase Bus Ducts (IPBD) – Rework due to manufacturing issues.
8) Additional Works/ spares in replacement of Coal Mill Gear Box as the old one were deteriorated.

9) Procurement & replacement of Coal Mill Separator Body/ Scrapper body.
10) FD fans spares procurement done on urgency basis.
11) PA Fan, ID fan hoists replacement due to relocation & capacity constraints.
12) Bottom ash handling system problems taking long time for evacuation.

ESP Area:

1) Hopper Orientation mismatch between approved drawing and erection (noticed during erection) Corrections carried out at site and relevant drawings revised (@ 13 Nos)
2) Mismatch in ESP Outlet to Chimney Duct – Rectification carried out at site.
3) ESP to ESP Control Room Cable route design finalization and implementation
4) ESP transformer overhaul required and carried out.

Electrical Area & C&I:

1) LT MCC control circuit modification - Non integral Motor Operated Valve (MOV) were retained in the system. There were approx. 70 such valves whose feeders on GVDC has to be refurbished as per new scheme of MOV and to be controlled from DCS. Feeder readiness for these MOV's was in MSPGCL scope under LTMCC head.
2) 24V battery relocation required-No space was allocated for erection of 2X 24 VDC battery banks in the scheme. Hence space was searched in co-ordination with BHEL and O&M towards unit 5 near old station battery bank. 24vdc battery banks and UPS battery banks were erected and commissioned at this new location by refurbishment of old existing room.
3) GVDC valves –non- integrated type -- spares required for servicing- As per the existing scheme, non - integral type MOV to be retained in the system. These valves are of 1) OLD (Z) MODAC 2) ROTORK 3) AUMA and 4) EMS make. Being obsolete nature of design, spares for servicing of these valves were not available in user section. Hence it was proposed to make spares available from various closed units like TPS Parli, CSTPS, and old Unit 5 of Koradi TPS. Manpower was hired to prepare limit switch assembly and other usable spares from these resources to be used for unit#6.
4) 220V DC battery sizing issue- Existing station battery capacity for unit 6 is 220VDC/1250 AH. With addition of DCJOP -45KW & DC Scanner air fan -5.5KW in new system, capacity of battery bank has to be uprated to 220VDC/1800AH. Since this would have taken more time , it is proposed that unit 5 battery to be utilised to cater the added load of highest capacity motor i.e. of DC JOP. Intermediate SFU Feeder is erected in u#6 which is fed from unit #5 DCDB/battery bank.
5) Replacement of 1000KVA boiler Auxiliary Transformer by existing ESP transformer of 1600KVA- Load studies shows that due to uprated motors and newly added equipments by BHEL, source rating was not adequate to cater the new load. Existing transformers of 1000KVA were replaced by 1600 KVA transformers. These transformers were taken out from closed unit of Koradi U#5 transformers commissioned by MSPGCL, since power source arrangement was in MSPGCL scope.
6) DG 375 KVA U-5 used for U-6 emergency MCC- Due to added load of AC JOP, UPS , 24V chargers, Hydraulic coupling of IDF, ID LOP etc. , existing single DG of 375 KVA was not sufficient to cater the load in case of emergencies like A.C. failure. Hence individual section of emergency board is now charged from separate DG sets of 375 KVA each. U#5 DG set is used for this purpose. Cabling and separate control panel commissioning was carried out for this purpose.

7) BHEL never gave consolidated LT load and kept on varying on each occasion (e.g. ID coupling, Lub. oil heaters, Feeders for integrated MOVs.) - BHEL while engineering considered less load for newly added load /uprating of auxiliaries. BHEL kept on adding the load in system. Feeders on LT board and GVDC were in limited numbers and source capacity was also limited. Hence trolleys allocation for refurbishment imposed a problem. Original demand was almost doubled in revised demand.
8) Illumination- Area below turbine floor was not considered by ABB for illumination while engineering stage. Illumination scope was not clear. Some portion of Boiler side, A.C. room outside part, HT room, SWAS room, cable galleries, area near chimney and ID fan, were found escaped. All these remaining portions are now under consideration.

BOP Area:

1) Common cooling towers for U-6 & U-7 and as Unit -7 was running, there was delay in handing over of towers to M/s. Hamon.
2) Replacement of Drift eliminators of Aux. CT as the fills could not be replaced without removal of old concrete drift eliminators.
3) Water seepage/leakage at main header of CT resulting in hold up of work & thereby delay .
4) Delay in availability of fronts to AHP contractor.
5) Overflow of slurry boxes during fly ash evacuation. Modification taken up.
6) PCR Layout modification causing relocation of Inert gas system outlets.
7) Refurbishment of AC (Air Conditioning) Plant as the old one was deteriorated.

Commercial Issues

1) Price escalation issue with M/s. ABB.
2) Termination of contract of M/s. Tecpro in March 2015 & awarding three separate contracts for Cooling Tower Plant Package, Ash Handling Plant package and Fire Detection, Protection & Inert Gas System Package are issued and contract is signed on 23.09.2016, 26.10.2016 & 05.11.2016 respectively.
3) Consultancy awarded to M/s. MECON for cost estimates of DM plant and CT (Cooling Tower) as original estimate and Bidder's offers were not matching.
4) Cancellation of DM Plant tender due to higher offer prices & need based refurbishment of 2 streams of DM Plant taken up.
5) GST implementation resulting in delay in supply.
6) FO/LDO utilized not covered in DPR.
7) Increase in the ordering cost of various packages due to time lapse from DPR to ordering.

Overall slow progress in implementation phase is due to delay in awarding sub contracts by M/s. BHEL, delay in supply of material, termination of BOP contract & awarding three separate contracts, inadequate manpower deployment by contractors, interfacing issues etc.

Lessons Learned

1. Time interval between DPR preparation & Project Implementation should be minimum.
2. Scope of the work should be well defined to avoid techno commercial implications during execution.

3. The work orders of sub-contractors should be issued by Main contractor before actual commencement of shutdown.
4. R&M should be taken up for the units whose completed life is @ 20 years. This will result in minimum surprises during execution which will ultimately help to avoid time & cost overrun.
5. R&M work may be planned in phase manner instead of comprehensive R&M at a time.
6. Completion of project within schedule period needs to be achieved to avoid financial loss on account of time & cost overrun. The Grant portion & low interest loan could not be utilized fully due to time overrun.

II. WBPDCL – Borrower's ICR

Project Background

14. WBPDCL has planned to carryout R&M and Life Extension (LE) of 210 MW Unit #5 at Bandel TPS in the 11th Plan (2007-2012). The GoI approached the World Bank and the GEF for financing this initiative under their "India: Coal Fired Generation Rehabilitation Project". The Project is proposed to be an energy efficiency window within the PiE Program. It is intended to demonstrate the efficacy of using energy efficiency as one of the primary criteria along with PLF enhancement and life extension through EE R&M project design.

15. WBPDCL appointed M/s EVONIK Energy Services (formerly, STEAG encotec India Limited) to conduct Energy Audit and prepare the DPR for R&M of Bandel Unit 5.

16. The R&M of Bandel Unit 5 was aimed at:
- Improved Availability and PLF of the Generation Unit
- Improved Heat Rate (efficiency) up to original design value or even better
- Enable the unit to be operated using available quality of coal
- Reduction in Auxiliary consumption
- Ensure emission level (SPM) is sustained level below 100 mg/Nm^3

17. The Energy Audit and DPR for Bandel Unit 5 were prepared and based on these studies the technical specifications were finalized. As mentioned above, improvement of energy efficiency and environmental standards were the clear objectives of the EE R&M exercise and the GEF grants would be utilized towards this end.

Project Components

18. There were two project components:
- Component-1: EE R&M and LE of 210 MW Unit 5 at Bandel TPS
- Component-2: TA

Component 1:

19. Package: EE R&M work was divided into five packages:

Table 7.7: Packages under Project's Component 1

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Main Plant Package	M/s Doosan (Doosan Heavy Industries & Construction Co. Ltd., South Korea [DHIC] for Off Shore Supply Contract & Doosan Power System India Private Limited [DPSI] as associate of DHIC for On Shore Supply Contract & Service Contract)	29.02.2012 /14.03.2012	31.10.2017
CHP Package	M/s Vinar Systems Private Limited	03.01.2013/30.01.2013	29.11.2017
Electrical Package	M/s GE-T&D erstwhile M/s ALSTOM T&D India Limited	28.12.2012/ 21.01.2013	29.11.2017
AHP Package	M/s Macawber Beekay Pvt Limited	29.04.2013/ 07.07.2013	29.11.2017
Air Conditioning System	M/s Voltas Limited	31.12.2015	29.11.2017

20. Project Funding: Amounts of Loan/ GEF allocated – original and revised - are in below table (expressed in USD). Source of remaining 26 percent is equity fund of WBPDCL.

Table 7.8: Original Allocation (in US$)

Amount of Loan allocated (expressed in USD)	Amount of Grant allocated (in USD)	Percentage of expenditure to be financed (including taxes)
58,852,500	12,450,000	74%

Table 7.9: Revised Allocation (in US$)

Amount of Loan allocated (expressed in USD)	Amount of Grant allocated (in USD)	Percentage of expenditure to be financed (including taxes)
76,860,000	16,280,000	74%

Component 2: TA

21. Following consultancy services were undertaken under TA.

22. Activity 1: Support for Design of EE R&M: Under PHRD grant, WBPDCL had engaged following consultancy services for Design of EE R&M.

Table 7.10: Details of Activities under Support for Design of EE R&M

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Consultancy Services for Energy Efficiency Renovation & Modernisation of Bandel TPS Unit 5 (210MW)	M/s EVONIK Energy Services (formerly STEAG encotec India Limited)	12.07.2007	12.07.2008
Consultancy for EADD Study	M/s SGS India Private Limited	04.06.2007	31.03.2008
Consultancy for RSA Study	M/s South Asian Foundation for Human Initiatives, Kolkata	03.09.2007	28.02.2008

23. Activity 2: Support for Implementation of Pilot EE R&M Investments: There are 3 consultancy service packages under TA:

Table 7.11: Details of Activities under Support for Design of EE R&M

Name of Package	Agency Engaged	Contract Sign Date/ Package Start Date	Package End Date
Implementation Support and Quality Assurance Consultancy Services for "Energy Efficiency Renovation & Modernisation of Bandel TPS Unit No. 5(210MW)	Development Consultants Pvt. Ltd [DCPL]	10.04.2012	29.11.2017
Consultancy Services for Feasibility study of Stage1 Bandel TPS, WBPDCL along with RLA study of Boiler, Turbine & Generator, Critical Piping of one Unit followed by Performance Study of the Unit of 60 MW (De-rated Capacity) against original installed Capacity of 82.5 MW	TUV SUD South Asia Pvt. Ltd.	18.07.2016	29.11.2017
Impact assessment study on CSR activity	M/s Webcon	15.05.2017	31.08.2017

Table 7.12: GEF Funds Allocation to TA Activities (in US$)

Amount of Grant allocated (expressed in USD)	Percentage of expenditure to be financed (inclusive of taxes)
1,300,000	100%

Project Restructuring

24. NIT for 1st Stage of Two Stage ICB was floated for Main Plant Package on 23rd February, 2009.

25. During evaluation of bids only one bidder was found qualified for Second-stage bid; WBPDCL proposed to cancel the bids and requested for re-tendering. Accordingly, proposal was placed before the World Bank. On 02.06.2010, the World Bank agreed to cancel the entire bid processing and advised for re-tendering at an early date.

26. At this stage WBPDCL intimated the World Bank about a specific proposal. The excellence of the proposal is as follows:

- Re-orientation of scope of work among the packages. This would help de-link the packages which in turn would ease the project management.
- Bidding Process for Main Plant Package in Single Stage ICB instead of Two Stage ICB. This will minimize delay in project execution as the closing date of the loan agreement is November 30, 2014.

27. The World Bank agreed with the proposal. Accordingly, WBPDCL modified the procurement plan.

Project objectives

1) Life of unit will be extended at least by 15 years. With Periodic overhauling life may be extended further for another 10 years.
2) Post R&M, Unit Capacity will be 215 MW and Availability will be 85 percent. This means quantum of Electricity Generation will increase as well as become more reliable as compared to the present status.
3) Target Unit heat rate of this EER&M Project is 2456 kcal/kWh. This will help to reduce coal requirement per unit electricity generation.
4) The Unit will be capable to operate with inferior grade coal which will reduce the Generation cost.
5) Auxiliary power consumption will be lowered. Net Power sent out will increase.
6) Replacement of Turbine, Condenser tubes, Boiler Pressure Parts, Renovation of APH etc. will help to overcome followings:

   - Aging of critical components (leading to lower reliability and shorter residual life)
   - Non-availability of critical spares due to obsolescence

7) Renovation of ESP, replacement of burner assembly, etc will help to comply with latest Environmental Norms and reduction in emission.
8) Incorporation of advanced, state of the art, C&I technology will improve operational reliability and efficiency

Table 7.13: Finally achieved functional guarantees

Sl. No.	Required functional Guarantees	Required Guaranteed parameter	PG Test result on 21-24.11.2016*	
			Test 1	Test 2
1.	Unit Heat Rate	2345 Kcal/kWh	2284 Kcal/kWh	2287 Kcal/kWh
2.	Power Output	215 MW	217.693MW	220.519MW
3.	Auxiliary Power Consumption	13000 KW	11803 KW	11322 KW
4.	Bids offering without ammonia / chemical injection: ESP outlet dust concentration with one out of first four (4) fields out of service in each gas path with worst coal firing under 100% BMCR.	≤ 90 mg/Nm3	74.5 mg/Nm3	

Project Scope:

28. Major scope of EE R&M Works under various packages are as below:

i] **Boiler –**

1. Complete replacement of Platen SH, Final SH, Primary SH (Horizontal Bank), Economiser, Front side Water Wall, S Panel, etc.
2. Installation of new Coal & Oil Burner System, New Mill (8.5E9), PA Fan, ID Fan, SA Fan, Coal Feeder.
3. Complete replacement of Wind box, and Damper, Expansion Joint & Ducts in FG as well as

Air path, Soot Blowing system.
4. Installation of one new APH bank. Complete Tube change of existing APH.
5. Modification of ESP to achieve 90 mg/Nm3 emission level at ESP outlet with worst coal firing of 3300 kcal/kg.
6. Repair / replacement of major valves.
7. Replacement of refractory and Insulation.

ii] **Turbine –**

1. Complete replacement of Turbine and its auxiliaries.
2. Installation of digital electro hydraulic (DEH) governing system in place of Hydraulic governing System.
3. Complete Tube replacement of LP Heaters, Condenser.
4. Retubing of HP Heaters, New Deaerator, new Auxiliary PRDS, new Ejectors, Gland Steam Condenser & Vent Steam Condenser, new HP-LP Bypass.
5. Repair / replacement of major valves.
6. Replacement of BFP cartridge, installation of new CEPs, overhauling of Drip Pump, CW and RCW pump

iii] **Generator –**

1. Complete replacement of existing Generator by a new 215MW Generator having 0.85pf lag, 3000 rpm, terminal voltage 15.75KV, Stator winding directly cooled by water, Rotor winding & Stator Core indirectly cooled by Hydrogen matching with other relevant parameter of existing Generator with Bearings including Bearing Pedestal
2. Replacement of Generator Auxiliary system.
3. Complete replacement of existing Generator/Generator Transformer protection system by dual redundant Numeric Relay based protection system including necessary replacement of CT & PT of desired accuracy.
4. Change of location of Generator Relay Panel from ECR to UCR

iv] **Balance of Plant –**

1. Replacement of Idlers and its Associated Brackets of 23 nos. Conveyor Belts
2. Flap Gates - Supply &delivery at site and installation of 22 nos. (Twenty two) pneumatically operated flap gates with all necessary accessories for remote /manual operation of existing manually operated flap gates in various bifurcating chutes.
3. Complete replacement of two (2) nos. cross belt magnetic separator by in -line magnetic separator (ILMS) iron chutes, bins and electrical accessories etc.
4. Complete replacement of existing Eighteen (18) nos. old Vibrating Feeders by unbalanced motor type Vibrating Feeders of capacity 250TPH.
5. Design, supply and installation of eighteen (18) nos. double Rack and Pinion Gates
6. Replacement of fast speed couplings between motors and gear box and slow speed coupling between drive pulleys and gear boxes for fifteen (15) nos. conveyors
7. Complete replacement of eleven (11) nos. drive gear boxes of conveyors
8. Replacement of Chutes in Existing Transfer Point
9. Condition based replacement of Defective structures/sheeting of galleries, transfer houses

and conveyor galleries/stringer supports
10. Design, Supply & Installation of Dust Extraction System for Crusher House
11. Design, Supply & Installation of Dry fog type Dust Suppression System at all transfer Chutes & plain water sprinkler type Dust Suppression system for stock pile.
12. Supply & Installation of new LT Switchgear for CHP equipments, Shifting of Existing MCC and associated control to New CHP Control Room
13. Supply & installation of a PLC based control system in place of relay based system for Coal feeding system for Unit -5.
14. Construction of New CHP Control Room
15. Fire Fighting System modification work.
16. Modification of existing Wet and Dry Fly ash evacuation system.
17. Installation of 4X50% (2W+2S) capacity motor operated mechanical vacuum pumps of liquid ring design, 2 no (1W+1S) continuous duty dry type non lubricated oil free screw compressor
18. 2X100% (1W+1S) Induced Draft cross/counter flow type Cooling Towers for cooling of water
19. 2X100% (1W+1S) Cooling Water Pumps

v] **Electrical –**

1. Complete replacements of 24 sets (each set comprises of 3 nos. Isolators) motor operated 132 kV isolators in the existing operating switchyard.
2. Complete replacement of existing electromagnetic relay based protection systems of 25 MVA, 132 KV / 6.6 KV station transformer at ECR by numerical relay.
3. New marshalling box cum Cooler Control Panel for two nos. 16 MVA, 15.75/6.6 KV Unit Auxiliary Transformer and 25 MVA, 132 KV / 6.6 KV station transformer containing cooler controls & local temperature indications and remote indication of Oil Temperature Indicator & Winding Temperature Indicator at ECR.
4. Repair of OLTC of two nos. 16 MVA, 15.75/6.6 KV Unit Auxiliary Transformer and 25 MVA, 132 KV / 6.6 KV station transformers which are inoperative since long and putting it into operation.
5. 4 nos. ZIG-ZAG Transformers along with neutral resistors for changing existing un-earth 6.6 KV System to semi-grounded 6.6 KV systems. These ZIG-ZAG Transformers shall be installed at the outlets of 02 nos. Reserve Transformers (25 MVA, 132 KV / 6.6 KV, 35 MVA, 132 KV / 6.6 KV /03 KV) and 02 nos. Unit Auxiliary Transformer (16 MVA 15.75 KV/6.6 KV) of Unit -5.
6. Neutral Grounding Resistor at secondary side of 1 no. 12.5 MVA, 33KV/6.6 KV Station Transformer.
7. Battery bank, battery charger, DCDB, DC fuse board as second source of DC system of Switchyard and Unit-5. Bus Tie connection between new and existing DCDB.
8. Extension of existing 6.6KV Reserve Bus R2 to accommodate three (03) additional breaker –two (02)for 2 MVA capacity transformer feeders and one spare feeder-one (1) on main entrance door side and two (02) on other side.
9. 2nos. 2 MVA dry type 6.6 KV / 415 V transformers
10. 415 V PMCC to be fed from above dry type transformers required for switching of the equipments of ash handling plant, new MCC for ESP & power supply to different areas.
11. Replacement of 3 Nos. TATA-Marlin make manual LT breaker at existing lighting bus of unit –V power house by air circuit breaker with in-built micro-processor based release.

12. Replacement of total illumination system of Boiler Gallery with ID/FD & Hopper, Burner Front and Coal Mill Area of Unit -5 with energy efficient light. Replacement of Lighting distribution Boards of Boiler area.
13. Supply, erection and commissioning of one no. MLDB with Lighting Transformer at of New AHP Building. The MLDB should be designed considering illumination of New AHP Building, New Cooling Tower, New Vacuum pump area etc. illumination of New AHP Building is under the scope of bidder.
14. Earthing of all equipment & the connection to the station grid
15. Supply of Electrical Lab & Testing Equipment.
16. Complete replacement of existing protection system of Generator, 2Nos. UAT (Unit Auxiliary Transformer), Incomer & Bus Coupler Breakers of Unit Bus & Reserve Bus, Transformer Feeders, Motor Feeder of 6.6KV & 415 V level by Numeric Relay based protection system including necessary replacement of CT & PT as per specified accuracy class and Installation of Energy Meters.
17. Re-designing/augment/modify some of the existing 415V Power Control Centre (PCCs), Power-Cum-Motor Control Centre (PMCCs), motor Control Centre (MCCs), ACDB to accommodate new/additional drives
18. Electrical Actuators for all the existing as well as newly supplied MOVs.
19. Supply, Installation of DG Set

vi] **C&I:**

1. Total replacement of existing Relay logic & Analog Controlled open & close loop automation System by new set of Distributed digital control & management information system (DDCMIS)
2. Replacement of existing Flow elements, Installation of new Flow elements, Venturi for PA Flow to Mills.

Outcome of EE R&M at Bandel Unit 5 - PDO Indicators

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Reduction in Specific Coal Consumption	Kg/kWh	0.684	0.602 (12%)	0.602 (12%)	0.58 in 2016-17 0.56 in 2017-18 (09 months)
	22-May-2009	22-May-2009	22-May-2009	22-May-2009	24-Nov-2015
Comments (achievements against targets) – Coal Rate target is achieved					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Reduction in Specific Oil Consumption	ml/kWh	2.5	2 (20%)	2 (20%)	3.47 in 2016-17 4.21 in 2017-18 (09 months)
	22-May-2009	22-May-2009	22-May-2009	22-May-2009	24-Nov-2015
Comments (achievements against targets): Oil Rate target is not achieved					

Reasons:

1. Boiler tube leakage – Erosion noticed in certain portion of Primary Reheater Tube, Furnace water wall, cage wall, RHS Economiser side wall tube.
2. More number of start-ups – high oil consumption for light up & stabilization of unit.

Measures taken to achieve targeted oil rate –

1. To reduce erosion of 2nd pass Reheat coil at top & bottom bank; perforated plate is fitted at rear wall 6” above of coil. Rear wall Erosion survey has to be done by demetering and visual inspection during upcoming O/H. At O/H, tube guard will be fitted at Economiser side coils bend.
2. Coal feeding strategy optimized keeping high VM. GCV coal at the lower elevation
3. Review of past unit tripping events for corrective action.
4. Procurement of Burner from OEM.
5. Oil burner tip is being replaced

Problems faced during Implementation

29. Surprise/ problem during execution of the Project are as follows -

- Constraint of space for storing the dismantled scrap – removal of some scrap twice had happened.
- Supports of the connected pipes of Attemperator stage-II found dislodged after shutdown. – Rectified during shut down. It had affected Boiler Hydro Test.
- After removal of Drum internals, a few parts like Vortex Breaker, Bridge Bars of Baffle etc. found missing / damaged – New Material procurement was done.
- HP heater tube replacement was mentioned in Technical Specification whereas due to Non availability of spiral tube, total HP Heater replacement was done. –lead time was considerable for procuring HP Heater.
- Total replacement of Diamond spring due to damage of existing springs.
- Reheater pendent outlet bank coil was fouling with gooseneck in boiler – rectified at site.
- Existing TG bolts were rigidly grouted with concrete which is not likely at present days. Removing of full length grouted TG Foundation Bolt required 'special' length cutting tools.
- Expansion bellow at condenser area found damaged - lead time was considerable for procuring new expansion bellow.
- Ash evacuation lines of APH hopper to Main Branch Line were found fouling with existing structure – reengineering was done to change layout
- Space constraint for accommodating new structure of flue gas duct to chimney as ESP design was changed- Dyke wall of oil tank area & piping shifting was done
- Underground oil & water pipe lines were found at location of new ID Fan - Old pipe lines were rerouted
- Underground oil pipe/steam pipe/cable trench found in ESP/ AHP Control room foundation area - removed with help of WBPDCL.
- Change in Piping Layout of Hydrant and spray water system at Misc. area causing additional work for fire hydrant line
- Insulation of Critical Pipe Line and Turbine delayed due to Labor problem of TG area sub vendor
- TG area problems faced during commissioning stage-

  (1) Generator Trunion hole mismatch problem – rectified at site.
  (2) Problem in Bearing No. 6- Oil clearance between journal of the generator rotor and the bearing supporting the rotor journal was more than recommended - Bearing no. 6 was replaced by spare.
  (3) Mismatch of PCD of Turbine & Generator coupling holes - Re-alignment is done and two coupling bolts are replaced by new one brought from SKODA.
  (4) Poor performance of Main Ejector supplied by Doosan - Spare ejector from Koradi TPS was used. Doosan attended the problem later.
  (5) Barring Gear damaged due to overload during starting at zero rpm - Damaged barring gear has been replaced
  (6) Insufficient Gap in nozzle of IP Gland pipe & Bearing pedestal no.2 – rectified at site
  (7) Restraint Support for critical piping needs design change - new restraint supports were fabricated at site

- Boiler & Aux area problems faced during commissioning stage-

  (1) Mill Dynamic Classifier vane orientation was faulty - Rectified at site by OEM
  (2) Damaged old grouting Bolt of PA Fan - Rectified at site
  (3) Defective Bearing Fittings of PA Fan B, C & D - Corrected at vendor's workshop
  (4) Problem of Lube oil pump of Mill

Lessons Learned

1. Time interval between DPR preparation & Project Implementation shall be minimum.
2. R&M Project shall be monitored by a dedicated team throughout the completion time span.
3. Be prepared for surprise factors & monitoring in advance to reduce bottlenecks.
4. Monitoring of critical spares with stringent quality measures.
5. Proper FQAP checking & maintain of Protocol jointly with party & project chief consultant.
6. Maintain everyday job plan & achieving updated job status.
7. Daily coordination meeting with the contractor & supplier.
8. Proper Safety Measure during erection work can make zero man-day loss due to accident – M/s Doosan has created this instance.
9. Arrangement for proper re-commissioning of the unit.