Study Report

Developing Markets for Implementation of R&M Schemes in Thermal Power Stations in India

Prepared by:

Mercados Energy Markets India Pvt. Ltd.

Under

India: Coal Fired Generation Rehabilitation Project

(13 November 2013)

Central Electricity Authority

Disclaimer

The information, statements, statistics and observations (together the 'Information') contained in this Report have been prepared by AF Mercados EMI from publicly available material, discussions held and information provided by the Client and its related parties. AF Mercados EMI does not express an opinion as to the accuracy or completeness of the information provided, the assumptions made by the Client or related parties that provided the information or any conclusions reached by the Client and its related parties. AF Mercados EMI disclaims all liability and responsibility of errors or omissions in the content contained in this report.

Table of Contents

List of Tables

List of Figures

List of Boxes

Abbreviations

AHP	Ash Handling Plant	**D/E**	Debt to Equity
Aux.	Auxiliary	**DFR**	Detailed Feasibility Report
Avg.	Average	**DM Plant**	Demineralization Plant
BoP	Balance of Plant	**DoC**	Date of Commissioning
BHEL	Bharat Heavy Electricals Limited	**DPR**	Detailed Project Report
BSEB	Bihar State Electricity Board	**ERC**	Electricity Regulatory Commission
BTG	Boiler-Turbine-Generator	**ESP**	Electrostatic Precipitator
BAU	Business As Usual	**EE R&M**	Energy Efficiency Rehabilitation & Modernization
CAPEX	Capital expenditure	**EPC**	Engineering Procurement and Construction
CEA	Central Electricity Authority	**FY**	Financial Year
CERC	Central Electricity Regulatory Commission	**FYP**	Five Year Plan
CPRI	Central Power Research Institute	**GENCO**	Generation Company
CDM	Clean Development Mechanism	**GW**	GigaWatt
CHP	Coal Handling Plant	**GEF**	Global Environment Facility
CIL	Coal India Limited	**GoI**	Government of India
CAGR	Compound Annual Growth Rate	**GHG**	Green House Gas
CA	Condition Assessment	**GCV**	Gross Calorific Value
C&I	Control and Instrumentation	**GSECL**	Gujarat State Electricity Corporation Limited

HPGCL	Haryana Power Generation Corporation Limited
IDC	Interest During Construction
IEPC	Indo Engineering Projects Corporation
ISC	Implementation Support Consultants
JV	Joint Venture
KBUNL	Kanti Bijlee Utpadan Nigam Limited
KPI	Key Performance Index
kCal	Kilocalorie
kWh	Kilowatt Hour
LROT	Lease, Rehabilitate, Operate and Transfer
LE	Life Extension
MW	Megawatt
MT	Metric Tonne
MU	Million Unit
NTPC	National Thermal Power Corporation
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
PET	Performance Evaluation Test
PG Test	Performance Guarantee Test
PLF	Plant Load Factor
PP	Private Promoter
R&M	Renovation and Modernization
RLA	Residual Life Assessment
SCCL	Singareni Collieries Company Ltd.
SHR	Station Heat Rate
SPA	Steam Path Audit
TCE	Tata Consulting Engineers Limited
TPP	Thermal Power Plant
TPS	Thermal Power Station
WBPDCL	West Bengal Power Development Corporation Limited

Executive Summary

High capital expenditure related to new capacity augmentation, poor financial health of the utilities and emerging fuel constraints necessitate efficiency improvement of the existing power stations in the country. Renovation and Modernization (R&M) of thermal power plants plays a critical role in restoring the power station's rated capacity and reducing coal consumption, and is one of the most cost effective options to achieve additional generation in a short gestation period. Despite numerous benefits, the pace of implementation of R&M in the country has been slow. The purpose of this report is to communicate the R&M potential in the country (based on certain assumptions), estimate the overall market size and develop strategies to improve stakeholder interest. The report undertakes analysis of trends in the critical operational plant parameters viz. Heat rate, Auxiliary power consumption, plant availability and force outage for coal plants in India which emphatically indicates the need of R&M in order to tap the huge potential for energy efficiency improvement in the coal generation mix.

As assessed in the report the R&M potential (including LE) in India under high case is estimated at 28,900 MW for 12th plan and 14,570 MW 13th Five Year plan. The table presented below provides the sector-wise breakup of the R&M (including LE) potential in the 12th and 13th Plan as assessed in the report.

Table ES-1: R&M and LE Potential in 12th and 13th Plan under High Case

Sector	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
12th Five Year Plan						
State Sector	6,250	27	7,940	38	14,190	65
Central Sector	11,070	32	3,640	15	14,710	47
Total 12th Plan	**17,320**	**59**	**11,580**	**53**	**28,900**	**112**
13th Five Year Plan						
State Sector	3,770	16	5,120	23	8,890	39
Central Sector	4,430	14	1,250	6	5,680	20
Total 13th Plan	**8,200**	**30**	**6,370**	**29**	**14,570**	**59**

Further, the report also presents a low case wherein a conservative approach for estimation of R&M potential is adopted considering the poor R&M achievement record and limited capabilities of utilities. As assessed, the R&M potential (including LE) in India under low case is estimated at 18,730 MW for 12th plan and 20,460 MW 13th Five Year plan. The table presented below provides the Sector wise breakup of the R&M (including LE) potential in the 12th and 13th plan under low case as assessed in the report

Table ES-2: R&M and LE Potential in 12th and 13th Plan under Low Case

	R&M		LE		Total	
	Capacity (MW)	**No. of Units**	**Capacity (MW)**	**No. of Units**	**Capacity (MW)**	**No. of Units**
12th Five Year Plan						
State Sector	6,250	27	3,950	19	10,200	46
Central Sector	4,890	15	3,640	15	8,530	30
Total 12th Plan	**11,140**	**42**	**7,590**	**34**	**18,730**	**76**
13th Five Year Plan						
State Sector	3,770	16	4,830	23	8,600	39
Central Sector	4,430	14	7,430	23	11,860	37
Total 13th Plan	**8,200**	**30**	**12,260**	**46**	**20,460**	**76**

The potential presented above clearly indicates that the size of R&M market is reasonably large. The assessment also indicates that in most cases R&M works out to be a viable alternative for utilities that are faced with various alternatives (operate, retire, R&M, LE etc).

Accordingly, the total market size of the R&M/LE is estimated to be in the range of Rs. 26,649 to 40,986 Crores for the 12th plan and Rs. 21,202 to 33,129 Crores for the 13th plan period. Thus, it can be seen that the estimated R&M potential translates into a business opportunity of Rs. 47,851 - 74,115 Crores

over the 12th and 13th plan period. Further, at the estimated potential, a total commercial loan of ~ Rs. 333 billion would be required to finance the R&M projects planned during the 12th plan period and Rs. 172 billion during the 13th plan.

The market assessment also indicates that there is a huge market opportunity for both suppliers and technical consultants present across the R&M value chain. The report elaborates on the extensive assessment through stakeholder consultation of the R&M market players i.e. Boiler, Turbine and Generator (BTG), Balance of Players (BoP) and Technical Consultants. The key findings of the assessment are summarised below.

Boiler-Turbine-Generator

- The BTG market is capital and technology intensive industry dominated by large players and can be categorised into three segments:
    - Suppliers with integrated offerings like BHEL, NASL, Doosan, Dongfang etc.
    - Suppliers dealing in Turbo-generator like GE, Toshiba etc. and
    - Suppliers dealing in boilers and related auxiliaries
- The overall BTG market in R&M sphere has good mix of national and international players with few players like BHEL and NASL having deep Indian R&M experience and others having rich global experience but limited Indian experience like Doosan, Dongfang, Toshiba, Ansaldo, Siemens etc.
- Though OEMs, has generally been the first point of contacts and jobs were awarded on nomination basis, the recent trend indicates competitive bidding is being pursued which encourages several international and national players.

Balance of Players

- The Balance of Plant (BoP) market is fragmented characterised by low entry barrier and several unorganised local players. BoP players can be categorised into three segments
    - Forward Integrated Suppliers which comprises large players present in BTG and BOP both viz. BHEL, NASL, Dongfang, & L&T etc.
    - Component Suppliers which comprises suppliers dealing with single or multiple BOP components viz. Techpro, MC Nally & SPML etc.
    - EPC or Turnkey Suppliers which comprises players that offer

entire BOP package/ suite viz. Punj Lloyd & UB engineering etc.

- It was also observed that integrated players have high bargaining power since opportunity origination in most cases happens through OEMs. Thus, market access for others till recently has been indirect.

Technical Consultants

- There are large number of national and international players exists providing technical consultancy services and the market can be categorised into two parts depending upon the nature of the players:
  - **Technical Consultancy as the core area**: It consist of players whose core area is consultancy and are present not in the business of main plant equipment. These are purely technical or management consulting companies.
  - **Equipment Supply as the core area**: It consist of players whose core area is equipment supply but also provide design consulting services.
- While there are significant numbers of technical consultants with ability to service the R&M sector, only few players have strong experience in R&M projects in India
- Earlier there was limited appreciation of technical roles but recent tenders indicate new roles like Environment Impact Audit, Rapid Social Assessment and Quality Assurance for technical consultant.

The assessment of the R&M market players clearly indicates that there are several players who are genuinely interested in R&M but are not able to commit due to low market visibility. The R&M market continues to witness a variety of challenges and issues that have impeded growth and scale up plans. The table below presents the key challenges and action plan for strengthening the interest of the R&M stakeholders.

Table ES-3: Key Challenges and Action Plan for Strengthening the Interest of R&M Market players

S. No	Key Challenges	AF-Mercados EMI Recommendations	Responsibility
1.	Market related challenges • Limited Opportunities entering the	R&M Roadmap to be developed and adopted at the State level with frequency similar to the plan periods	State Utilities/State Governments
		Regulatory Incentives and	Regulators

S. No	Key Challenges	AF-Mercados EMI Recommendations	Responsibility
	Open market • Award of contracts through Nomination • Non-existence of market for technical consultants	Enforcement Mechanisms to be designed to enable adoption of R&M on a timely basis	(Central/ State ERCs or Forum of regulators) through appropriate regulations
		R&M work to be awarded through competitive bidding route only	Utilities/ Gencos
		Preparation of standard bid documents. These should potentially also cover terms and conditions for introducing various private sector participation models already identified by the CEA	CEA
		Delay in obtaining requisite environmental and other clearances for R&M needs to be examined further and appropriate changes as required should be considered.	Ministry of Environment and Forests (MoEF)
		Stringent compliance of timelines for selection/ award of contractor	Central/ State ERCs
		Independent technical assessment of R&M projects by design consultants (Separate from OEM/ Suppliers)	Lenders (enforce as pre-condition to financing)
		Bulk Tendering (wherever possible and applicable)	Utilities/ Gencos
		Creation of National R&M Repository by undertaking feasibility studies for plants identified by CEA under its National Perspective Plan	• Funding support by Ministry of Power • Implementation through CEA through the

S. No	Key Challenges	AF-Mercados EMI Recommendations	Responsibility
			empanelled consultants
2.	Funding related challenges • Limited ability of utilities to infuse equity investment in R&M projects • Credit exposure to power sector is likely to hit limits set by many commercial banks	Standard bid documents for private sector financing models viz. private-public partnership (PPP) and Joint venture (JV) models	CEA
		Pilot projects for demonstration of model of private sector involvement to be undertaken	Lenders (IFIs)/ Utilities
3.	Regulatory related challenges • Lack of appropriate incentive sharing mechanism for Gencos • Limit to R&M Investment • Provision of O&M special allowance	Gencos to be allowed to retain part of benefits achieved through R&M	Central/ State ERCs
		No benchmark to be set for R&M projects or alternatively, the capital cost should be capitalised based on cost-benefit analysis than the benchmark costs.	Central/ State ERCs
4.	O&M related challenges • Poor O&M Practices leading to accelerated deterioration of plant performance	Preparation and implementation of O&M action plan by utilities to ensure long-term sustainability of R&M benefits	Lenders and Central/ State ERCs to enforce O&M action plan as a pre-condition to approval of R&M project
		Assistance from specialised technical agencies for O&M	Utilities/ Gencos

S. No	Key Challenges	AF-Mercados EMI Recommendations	Responsibility
		support	
5.	Contracting related challenges • Unfair and skewed balance of risk and reward among utilities and contractor • Delays in bid evaluation and award of contract • Inappropriate packaging strategy	Preparation of scope and technical specification of contract by independent technical consultant	Lenders and Central/ State ERCs
		Standard bid documents	CEA
		Packaging strategy to be based on implementation capabilities of utilities	Utilities/ Gencos
6.	Institutional related challenges • Limited capacity of utilities in undertaking R&M • Weak implementation support from utilities during R&M work	Formation of dedicated R&M cell by the utilities	Utilities
		Mechanism to capture learning/ experience during implementation of R&M projects at state level	Utilities
		Knowledge sharing platform at central level. The case study should specifically include the experience in implementing R&M, description of experience at various stages, outcomes achieved, and performance after R&M (over a period of time).	CEA supported by respective state utilities

Chapter - 1

Introduction

1. Concept of R&M and Life Extension Programme Of Coal Fired Thermal Power Stations

1.1. Renovation and Modernisation Programme

The main objective of R&M of power generating units is to make the operating units equipped with modified / augmented latest technology equipment/components/ systems with a view to improve their performance in terms of output, reliability and availability to the original design values, reduction in maintenance requirements, ease of maintenance and enhanced efficiency.

However, R&M is not a substitute for regular annual or capital maintenance/overhaul which forms a part of Operation and Maintenance (O&M) activity. Need for Mid-life R&M come up generally after 1,00,000 hrs of operation.

The R&M programme is primarily aimed at generation sustenance and overcoming problems due to:

a) Generic defects

b) Design deficiencies /modifications

c) Avoidance of inefficient operation

d) Non-availability of spares because of obsolescence of equipment/components.

e) Poor quality of coal

f) Major replacements of equipment arising due to unforeseen failures and /or generation sustenance not covered under regular O&M

g) Stringent environmental regulation

h) Safety requirements etc.

1.2. R&M Programme with Life Extension (LE) & Uprating

The equipment subjected to fatigue stresses and creep due to high temperatures such as turbine rotor and casings, HP piping, boiler headers, boiler drum, main steam piping and valves, feed discharge lines etc. are designed for a given fatigue life of about 25-30 years of operation. However, many

equipment/components might become prematurely weak metallurgically due to various operational stresses like frequent temperature and pressure excursions, full load tripping, frequent start and stops etc. and accordingly there is need to check the remaining life of these components after 20 years of life or 1,60,000 hours of operation lest it may result into serious failures. A systematic study called the Residual Life Assessment (RLA) study involving non-destructive and destructive tests would reveal the remaining life of various critical components of plants and equipment so as to take steps to extend the life of the plant by a further period of about 15-20 years by appropriate repairs/replacements. A RLA study may be carried out earlier, say after 15 years or 1,00,000 hrs of operation if the plant condition so necessitates and as stipulated in Indian Boiler Regulation (IBR) 391 A.

The LE programme is a major event in the thermal power station's history, as it envisages extension of life over a considerable period of time beyond its designed life. At this time it is a good practice to examine whether a plant requires a viable modernisation which has not been carried out earlier so that during the extended life the plant operates efficiently and delivers the rated or higher capacity with improved heat rate. Adoption of improved and proven technology can play an important role in plant upgraded output & higher efficiency. There are cost effective options to up-rate the machines for higher output and improved efficiencies thus making it economically viable to integrate life extension programme with uprating.

1.3. Works Not Relating to R&M / LE

In general, works usually done under routine maintenance and annual or capital maintenance do not fall under the purview of R&M Programme. The repetitive nature of activities having the frequency once in five year or less is covered under O&M. The following works should not be included as a part of R&M / LE programme:

a) Infrastructural development work such as township, welfare measures etc., general civil works within the plant such as boundary wall, roads, drainages etc. However, technological structure works required for equipments / structure based on RLA done as per design criteria (such as turbine deck, foundation etc.) shall be part of LE.

b) Procurement of spare equipments.

c) Routine repairs/replacements during annual/capital overhauls.

The expenditure on such works which are O&M in nature is to be met from O&M charges recovered through tariff for sale of electricity as notified by the regulatory commission(s). O&M ought to be attended on a regular basis lest the condition of the unit should deteriorate to such an extent resulting in major breakdowns requiring huge expenditure.

2. Background of the Assignment

The World Bank has financed the "Coal-Fired Generation Rehabilitation Project-India" for demonstrating Energy Efficiency Rehabilitation & Modernization (EE R&M) at coal fired generating units through rehabilitation of 640 MW of capacity across three States - West Bengal, Haryana and Maharashtra. The above project has two components:-

i. Component-1: Energy Efficiency R&M at Pilot Projects

This component would fund implementation of EE R&M of 640 MW capacity comprising Bandel TPS Unit-5 (210 MW) of WBPDCL, Koradi TPS Unit-6 (210 MW) of Mahagenco and Panipat TPS Unit-3 & 4 (2x110 MW) of HPGCL. The World Bank has earmarked US $180 million of IBRD loan and US $ 37.9 million of GEF grants for the Component-1.

ii. Component-2: Technical Assistance to CEA and Utilities

The Technical Assistance component of the project is aimed at providing support in implementation of EE R&M pilots, developing a pipeline of EE R&M interventions, addressing barriers to EE R&M projects and strengthening institutional capacities of implementing agencies for improved operation and maintenance practices. The World Bank has earmarked US $ 7.5 million GEF grant for the Component-2.

Under Component 2, The World Bank is providing technical assistance of US $ 1.1 million as a part of GEF grant to CEA under "Coal Fired Generation Rehabilitation Project-India" for addressing the barriers to Energy Efficient R&M of coal fired generating units in India. The project is being implemented by CEA through appointment of consultants for carrying out following four studies:

a) Review of institutional capacity and capacity strengthening interventions at CEA.

b) Study on reduction of barriers to R&M interventions in thermal power stations in India.

c) Study on developing markets for implementation of R&M in thermal power stations in India.

d) Review of experience from Pilot R&M interventions in thermal power stations in India.

Accordingly, CEA has engaged M/S Mercados Energy Markets India Pvt. Ltd. (AF-Mercados EMI), for undertaking study on "Developing Markets for Implementation of R&M in Thermal Power Stations in India".

3. Scope and Objective of the Study

The key objectives of the study are as follows:

a) **Task 1:** Estimate the overall R&M potential of coal based thermal power plants in India during the 12th and 13th Five Year Plan (2012-22) considering the key drivers influencing the R&M Market.

b) **Task 2:** Assessment of the Interest and Capabilities of the suppliers and technical consultants in the R&M space.

   i. Assess the capability and interest of the existing/ potential suppliers in serving the R&M market in India;

   ii. Study the interest of technical consultants involved in providing quality services for the project design report of R&M projects and for supporting utilities during implementation of R&M activities;

   iii. Interview key market players (Equipment suppliers and technical consultants) to understand the drivers behind their interest in participating in the R&M market in India;

   iv. Suggest ways of strengthening the interest of key players (bidders/suppliers, consultants and generation companies) in the R&M. Also, recommend ways to attract new entrants;

b) Organize two Road shows, one each in Delhi and Mumbai, in order to disseminate the finding of the above tasks and create awareness about the R&M market to enhance the interest of all stakeholders (Task 3)

The detailed scope of work is provided in Annexure I.

It is worthwhile to mention that the objective of the Task-I is to assess the overall R&M potential in the country. This report does not aim to be guidelines notified by the CEA or R&M plan to be adopted and followed by the state utilities. **The analysis presented in this report is to communicate the R&M potential in the country (based on certain assumptions), estimate the overall market size and develop strategies to improve stakeholder interest**. The actual identification of units for EE R&M & LE would largely depend on the priorities and the management strategy of the respective utility.

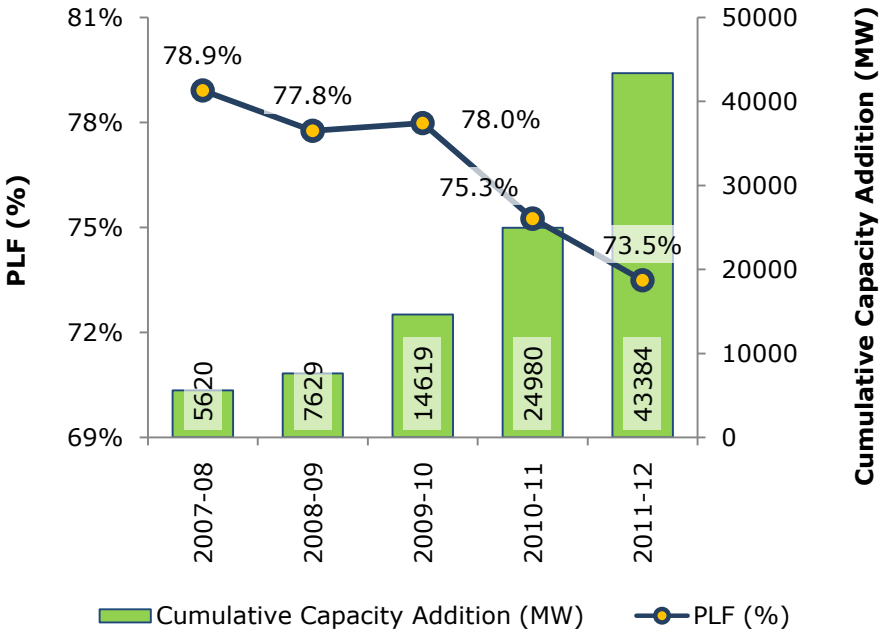
4. Context and Rationale

Recent years have witnessed India's energy consumption increasing at one of the fastest rates in the World on account of several reasons including rapid economic development, urbanization, rising consumer aspirations and growth in the population. The power sector is imperative for sustained and inclusive economic growth. India has added ~ 76,145 MW of generation capacity in last

two Five Year Plans with private sector contributing 33.8%. While the sector in India has witnessed a few success stories in the last 4-5 years, the road that lies ahead of us is dotted with innumerable challenges that result from the gap that exists between rate of resource augmentation/ growth in energy supply and the rate of increasing demand. Hence, India continues to face severe energy shortages.

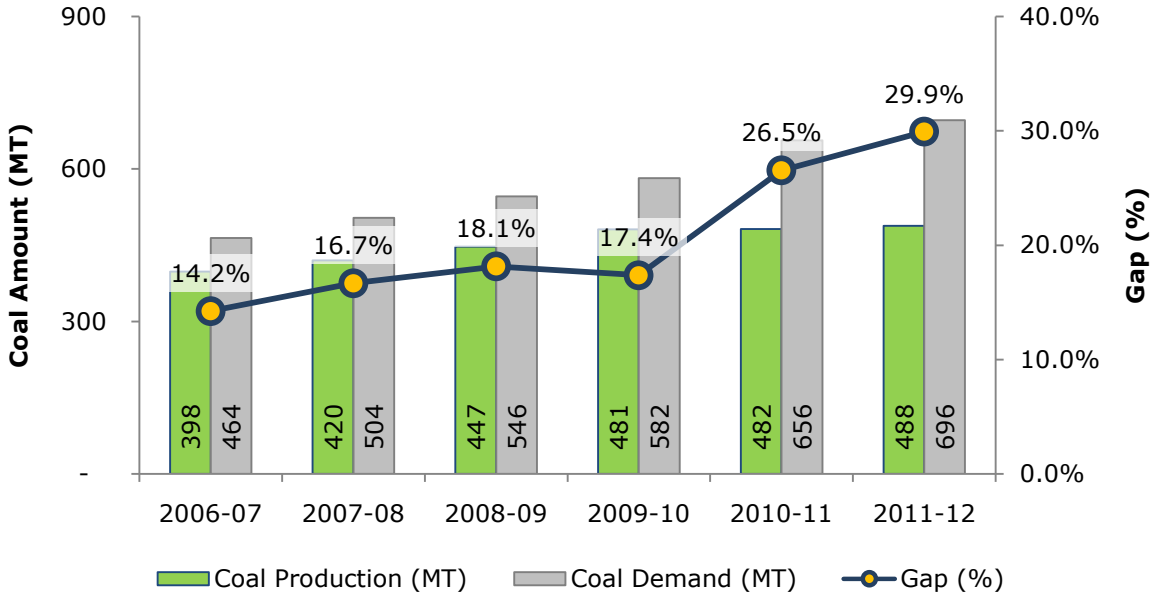
India witnessed its highest ever capacity addition of ~54,967 MW in the 11th Plan, of this around 43,384 MW of capacity was contributed by coal based plants. It is worthwhile to note that despite significant capacity addition, the PLF of coal based plants witnessed a declining trend (i.e. dropping from 78.9% in 2007-08 to 73.5% in 2011-12) primarily on account of severe domestic coal shortages. Figure above indicates the thermal capacity addition achieved during 11th plan. Over the years, the rate of growth of coal production (shown in the graph below) has not kept pace with the demand. The figure below shows the change in total coal production (including CIL and SCCL) vis-à-vis the total coal demand (for all sectors) over last five years.

Figure 1-1: Thermal Capacity Addition Target achieved during 11th Plan



Source: CEA & AF Mercados EMI Analysis

Figure-1-2: Trends in coal demand and production, and the growth rates

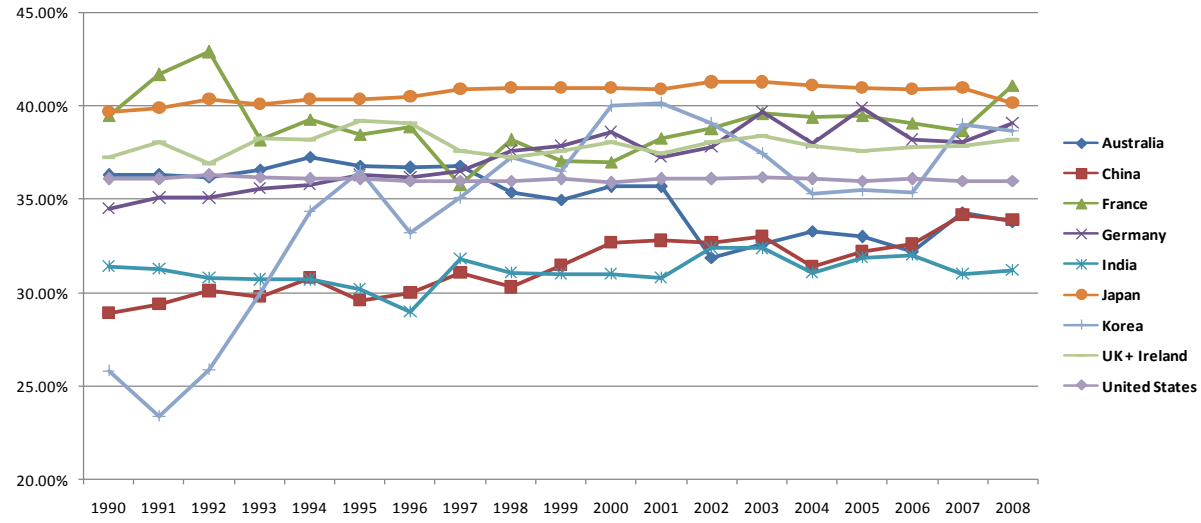


Source: Ministry of Coal

As observed, the growth in coal demand growing at a CAGR of 8.3% is much higher than the coal production that has grown at a CAGR of only 3.8% over the five year period. Inability to introduce modern technology and mining practices has limited the growth in output. Further, environmental and forest clearances, land acquisition and rehabilitation and resettlement has delayed new mine development. Significant hike in coal demand in recent years owing to commissioning of new coal-fired generation capacity and the imbalance between the coal requirement and availability has led to a chronic power deficit situation in the country.

With the high CAPEX of new capacities, poor financial health of the utilities and emerging fuel constraints it is essential to maximize generation from the existing power stations by restoring their rated capacity and reduce the scarce fuel more efficiently. This calls for Renovation & Modernisation (R&M) of existing old power plants, which is one of the most cost effective option to achieve additional generation from existing old units at low cost in short time period. The figure below presents the graphical comparison of coal power efficiency in various countries over last two decades.

Figure-1-3: Comparison of coal power efficiency in various countries



Source: Study by ECOFYS for Mitsubishi Research Institute, Japan, 2011, International Comparison of Fossil Power Efficiency and CO2 Intensity.

The above figure clearly indicates that there exist a significant potential for efficiency improvement of thermal power plants in the country (the world average of coal power efficiency is ~35.1%[1] as compared to ~31% in India) which is largely contingent on the use of advance technology for new capacities and improvement of efficiencies in the existing capacity.

In view of the above, the focus of this assignment is to estimate the R&M requirement and market size for the 12th and 13th Plan period, understand the overall market dynamics, assess key challenges impeding market growth and hence suggest way to strengthen market interest. The report is organised into the following sections:

Chapter 2 specifies the approach and methodology adopted by the team to undertake the study

Chapter 3 summaries the analysis and presents the potential market size for R&M/LE in India during 12th and 13th Plan

Chapter 4 assesses the market capabilities of key equipment suppliers and technical consultants involved in R&M market in India

Chapter 5 presents the key challenges and recommendation to improve the interest of R&M players in India

Chapter 6 concludes the report

[1] IEA and Coal Industry Advisory Board 2010, Power Generation from Coal Measuring and Reporting Efficiency Performance and CO2 Emissions

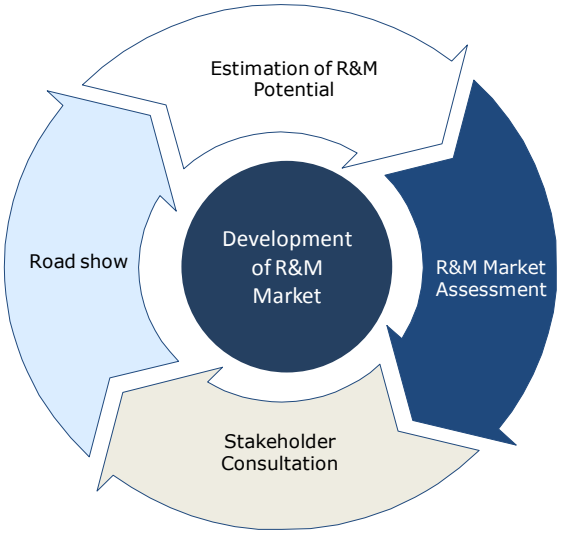
Chapter - 2

Approach and Methodology for the Study

The figure below depicts the broad approach of the study is as follows:

1. Estimation of R&M requirement during 12th and 13th plan in India
2. Assessment of overall market including interest and capabilities of suppliers, vendors and technical consultants.
3. Undertake stakeholder consultation with key equipment suppliers and technical consultants servicing the R&M market in India
4. Organise road-shows for creating awareness and enhancing interest of players involved in R&M space.
5. Suggest strategies of strengthening the interest of the key markets viz. equipment vendors/ suppliers, consultants and generation companies and improving the market as a whole.

Figure 2-1: Approach for the study

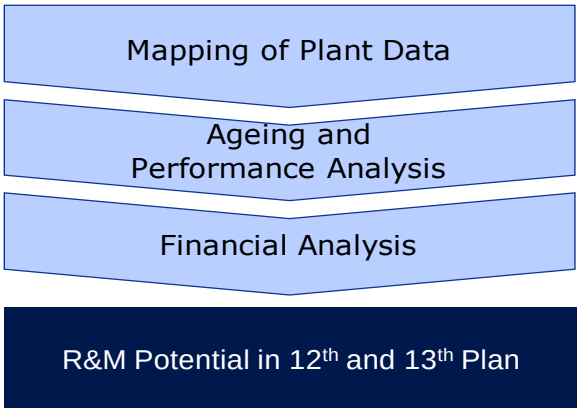


1. Estimation of R&M Requirement during 12th and 13th Five Year Plan in India

The figure below depicts the methodology for assessment of R&M requirement during 12th and 13th Plan:

1. Mapping of the plant characteristics, technical and operational parameters for last three years for all operating coal based thermal units

Figure-2-2: Methodology for estimation of R&M requirement in India



2. Undertake ageing and performance analysis of all the operating coal

based thermal units

3. Understand the economic viability of R&M projects through a excel based model

All of the above collectively contributed towards estimation of potential R&M requirement in the country during the 12th and 13th Five Year Plan. The details of the analytical model including the key assumptions and basis are elaborated in Annexure II.

2. Assessment of the overall market including interest and capabilities of suppliers, vendors and technical consultants

This step involved assessment of overall R&M Market Landscape including utilities/generating companies, technical consultants, EPC contractors, equipment suppliers/manufacturers (further categorized into BTG and BoP), and project financiers. The following steps have been performed for a detailed understanding of the market:

a) Development of capability matrix of the market players (e.g. players in the BTG market, BoP Market and Technical Consultants)

b) Capacity share of the market players in a particular market

c) Breaking down of overall R&M potential estimated in the preceding step into various sub-segments of the market

In addition to the above, the consultant has adopted Porter's five forces model for assessment of attractiveness of R&M market. Porter's model is one of the most widely used and accepted strategic model worldwide for assessment of market attractiveness and strategy development.

3. Stakeholder Consultations

In order to collect the feedback of key market players involved in servicing the R&M market in India, the team also undertook extensive stakeholder consultation to understand perspectives and concerns of various stakeholders. The stakeholder group included the Central/ State electricity regulatory commissions, utilities / generating companies, Equipment Suppliers, Design Consultants, Implementation Support Consultants and the CEA.

4. Road-shows and Dissemination

Further, in order to share the findings of the study and to generate greater supplier and consultant interest, AF-Mercados EMI also conducted two road-shows one each in Mumbai and Delhi. The road-shows drew participations from key suppliers/bidders, technical consultants, key representatives from State Utilities, Central and State Regulators etc.

The table below provides the list of national and international entities consulted during Stakeholder Consultation and during the two Road-shows.

Table 2-1: List of Entities Consulted

S. No.	State	Entities Consulted (State Gencos, SERC, ISC, TC, Suppliers)
1	Punjab	a) Punjab State Electricity Regulatory Commission (PSERC) b) Bathinda Thermal Power Station c) Punjab State Power Corporation Limited
2	Chhattisgarh	a) Chhattisgarh State Power Generation Company Limited (CSPGCL) b) Chhattisgarh State Electricity Regulatory Commission (CSERC) c) Korba (East) Thermal Power Station
3	Haryana	a) Haryana Power Generation Corporation Limited (HPGCL) b) Haryana Electricity Regulatory Commission (HERC) c) Panipat Thermal Power Station
4	Gujarat	a) Gujarat State Electricity Corporation Limited (GSECL) b) Ukai Thermal Power Station
5	Madhya Pradesh	a) Madhya Pradesh Power Generation Company Limited (MPPGCL) b) Amarkantak Thermal Power Station
6	Uttar Pradesh	a) Obra Thermal Power Station b) NTPC (Consultant for Obra TPS) c) BHEL (Vendor)
7	Bihar	a) Bihar State Electricity Board (BSEB) b) Bihar Electricity Regulatory Commission (BERC) c) Barauni Thermal Power Station d) Kanti Bijlee Utpadan Nigam Ltd. e) Muzzaffurpur Thermal Power Station f) NTPC (ISC for Barauni Thermal Power Station)
8	West Bengal	a) West Bengal Power Development Corporation Limited (WBPDCL) b) West Bengal Electricity Regulatory Commission (WBERC) c) Bandel Thermal Power Station

S. No.	State	Entities Consulted (State Gencos, SERC, ISC, TC, Suppliers)
		d) Damodar Valley Corporation Ltd.
9	Maharashtra	a) Maharashtra State Power Generation Company Limited (MSPGCL) b) Koradi Thermal Power Station
10	Delhi, NCR	a) Bharat Heavy Electricals Limited (BHEL) b) NTPC Alstom Power Services Limited (NASL) c) Dongfang Electric (India) Private Limited d) Toshiba e) Siemens f) Development Consultants Private Limited g) Doosan Heavy Industries & Construction h) Alstom India i) Energo Group j) NTPC k) STEAG Energy Services (India) Private Limited l) Lahmeyer India m) Energy Enhancement Centre (EEC) n) L&T-MHI Boilers Private Limited o) GE Energy p) ISGEC John Thompson-Foster Wheeler Limited q) Hitachi India Private Limited r) WAPCOS Limited s) Encotec Energy India Private Limited t) Bureau of Energy Efficiency u) Tata Consulting Engineers Limited v) Shakti Sustainable Energy Foundation w) KfW x) GIZ y) Central Electricity Authority z) Central Electricity Regulatory Commission aa) The World Bank bb) ABPS Infrastructure Advisory Private Limited cc) Excel Engineers & Consultant dd) L&T Power Limited ee) McNally Bharat Engineering Company Limited ff) SPML Engineering Limited gg) Deccan Mechanical & Chemical Industries

S. No.	State	Entities Consulted (State Gencos, SERC, ISC, TC, Suppliers)
		Private Limited hh) Central Power Research Institute ii) Black & Veatch Consulting Private Limited jj) L&T-Sargent & Lundy Limited kk) EM Services India Private Limited ll) Reliance Power Limited mm) Stock Redler India Private Limited nn) Tecpro Systems Limited oo) Techfab System Private Limited
11	Assam	a) Assam Power Generation Corporation Limited

The information and perspectives obtained from all of the above sources were collectively considered to assess the capabilities and interest of entities, identify the key issues and challenges faced by the R&M sector and develop a strategy to appropriately address the concerns to enhance the interest of the market players.

5. Develop Strategies for Strengthening Market Interest

Analysis undertaken in the preceding steps, stakeholder consultation and suggestions received during the road shows provide a holistic view of the market enabling development of strategies/recommendations to strengthen interest of various participants. The development of strategies is based on challenges/ constraints impeding the interest of R&M market.

Towards the end, the Consultant also provides a set of recommendations to strengthen the market interest of R&M players, and a priority setting of the proposed recommendations (including action plan for each of the stakeholder) through assessment of the qualitative/quantitative impact of the measures proposed.

Chapter - 3

Assessment of R&M/LE Potential during 12th and 13th Plan

This section estimates the overall R&M/ LE potential for coal based thermal plants in India during 12th and 13th five year plan period. However, prior to doing so the section analysis the key performance trends of operating thermal plant fleet in the country to understand the existing level of operational efficiency and the quantum of efficiency improvement opportunity.

1. Key Trends in Performance Parameters

This section presents the key emerging trends related to the performance parameters of operating coal based plants[2] in India. The table below indicates the plant parameters that analysed in this section and the rationale for selecting these parameters as the performance indicators.

Table 3-1: Key Plant Parameters

Parameters	Rationale
Age Structure	Indicates the share of ageing plants / technology obsolescence in the total generation mix of the country
Heat Rate	Combined effect of Heat Rate and Auxiliary consumption indicates the net plant efficiency. Lower the combined effect of the two, lower will be the fuel cost/ cost of power generation.
Auxiliary Consumption	
Plant Availability, Forced Outage & PLF	Indicates the quantum and reliability of energy availability. Better the plant availability higher is the generation / reliability of generation.

Each of the above plant parameters are explained below:

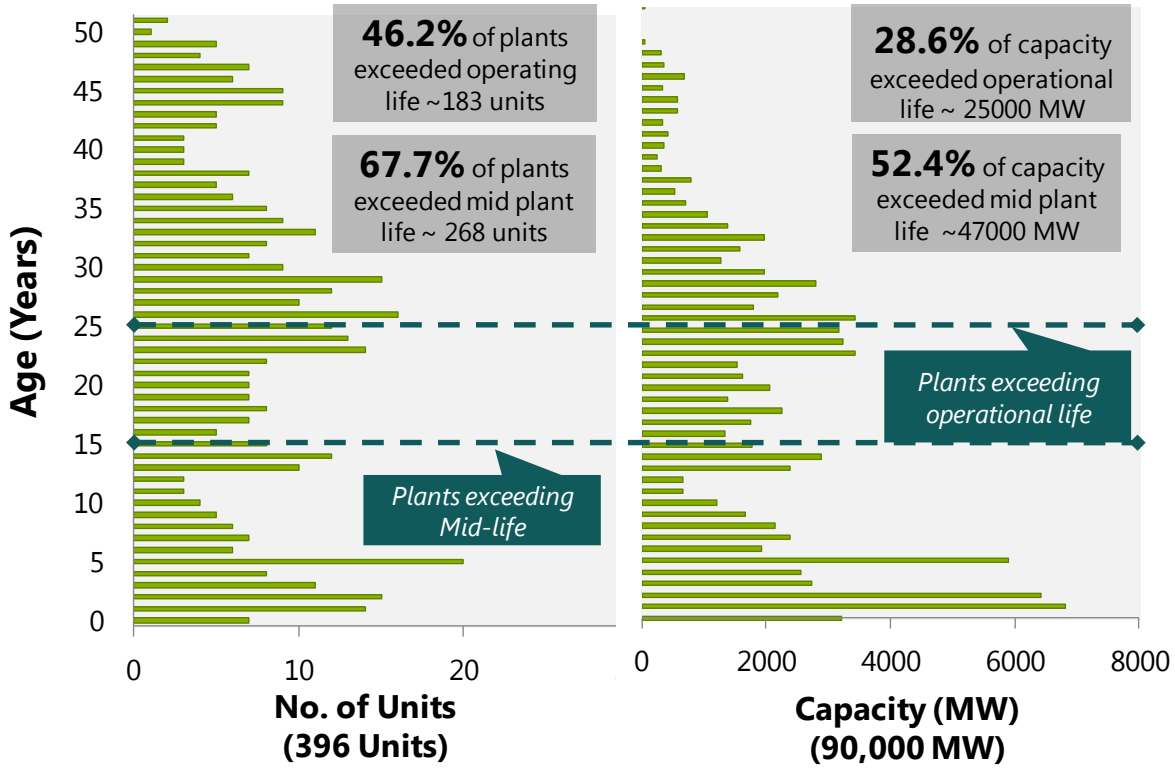
1.1. Age Structure

The design life of power plant equipment is typically 25 years (1,50,000 - 2,00,000 hours of operation) and the health of the plant is expected to be within the reasonable limits during this period subject to the O&M practices/ regular capital overhauling of the equipment as specified by the OEM. Operating plants beyond their economic life generally needs a refurbishment to ensure

[2] The analysis excludes the units with capacity equal to 140 MW and less

compliance to the environmental stipulation, improvement of plant efficiency and safety and reliability of the operation. The figure below presents the age structure of power generation capacity of coal based plants in India.

Figure 3-1: Age Structure of coal based Power Plants in India



Source: AF-Mercados EMI Analysis

The key trends emerging from the above figure is explained below:

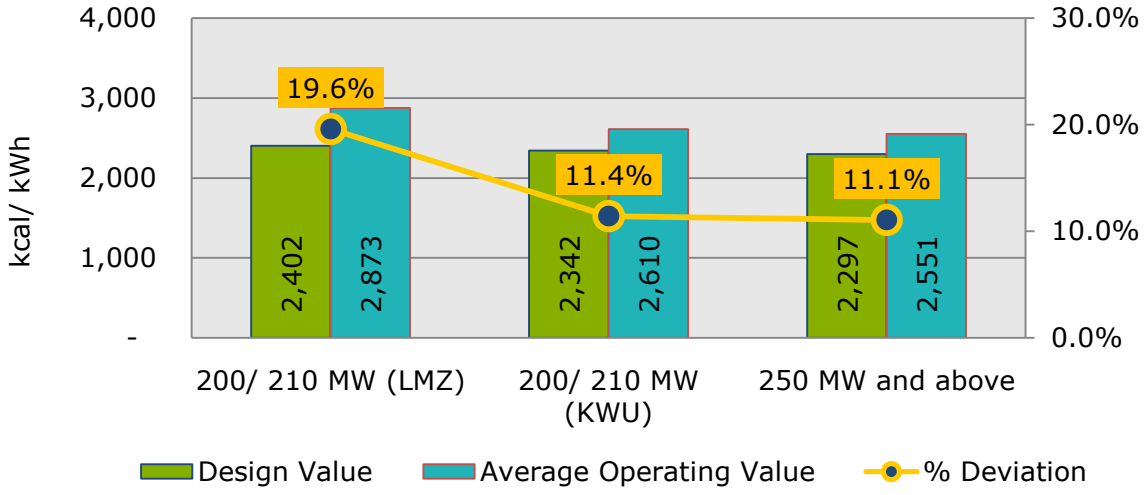
- **67.7% of the total operating coal based thermal units have exceeded their mid-life (> 15 years) while 46.2% have exceeded their operational life (> 25 years)**
- **52.4% of the total capacity (MW) of coal based power has exceeded their mid-life (> 15 years) while 28.6% has exceeded the operational life (> 25 years)**

Above trends clearly indicate a significant proportion of ageing capacity in Indian Power generation mix and hence, necessitate the need for R&M and LE in the ageing capacity.

1.2. Station Heat Rate

The figure below provides the average design, operating heat rate values and percentage deviation for each capacity group.

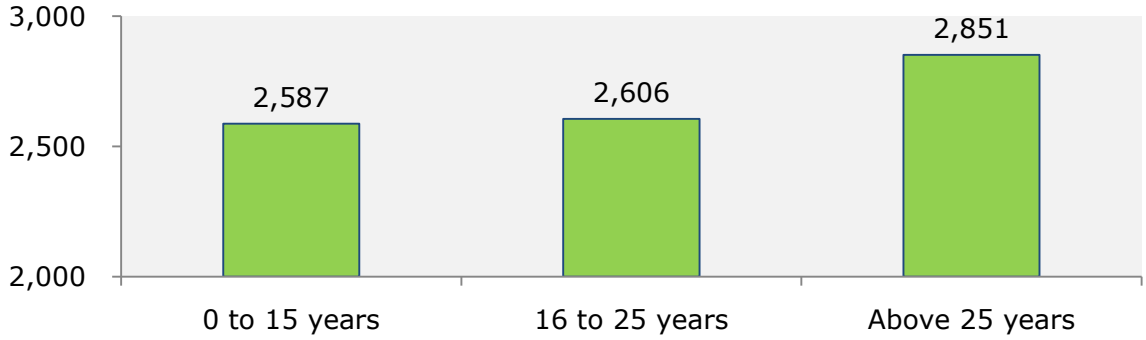
Figure 3-2: Heat Rate Deviations of coal based power plants in various Capacity Groups[3]



Source: AF-Mercados EMI Analysis

The heat rate is an important parameter that impacts the efficiency of the plant. Lower heat rate of plants imply lower specific coal consumption and in turn lower fuel cost and GHG emissions. The figure above clearly indicates that the % deviation of average operating heat rate is significantly varying from its design value between 11-20%. The newer units i.e. 250 MW and above have lower heat rate deviations (operating vis-à-vis design value) in comparison to other categories. Likewise, the figure below presents the average operating heat rate among various age groups of operating coal based plants in India.

Figure 3-3: Average Operating Heat Rate for coal based plants in various Age Groups[4]



Source: AF-Mercados EMI Analysis

[3] This analysis is only undertaken for state sector units as SHR data for NTPC plants is not available in public domain. Also, average operating value of SHR is computed for FY 09-10, FY 10-11 & FY 11-12

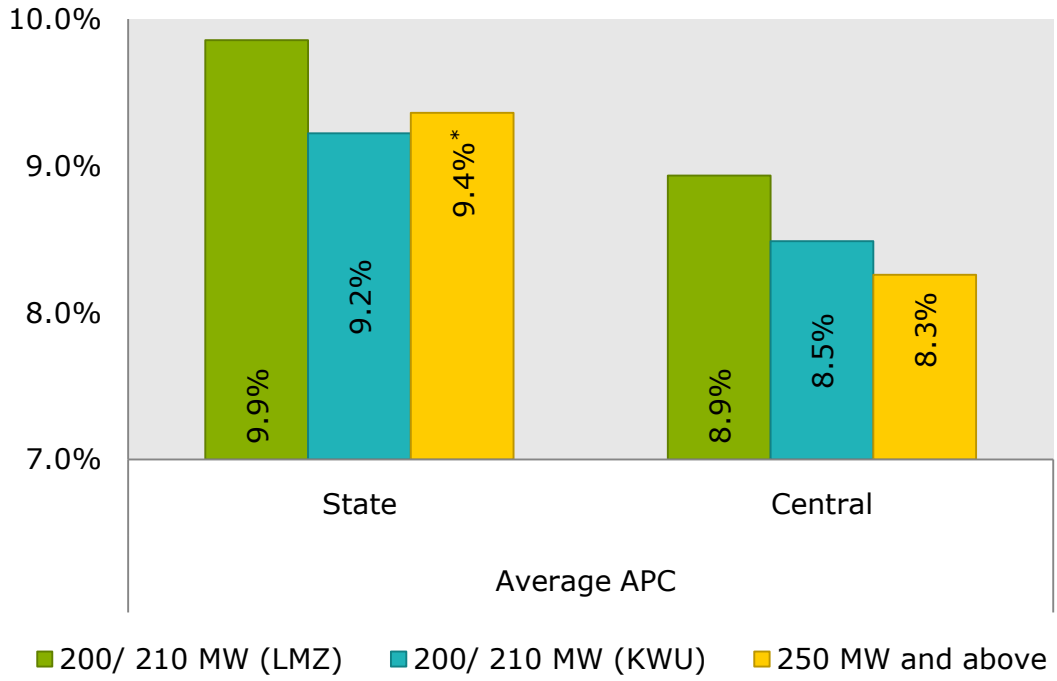
[4] This analysis is only undertaken for state sector units as SHR data for NTPC plants is not available in public domain. Also, average operating value of SHR is computed for FY 09-10, FY 10-11 & FY 11-12

The above indicates that the plants with higher operational age have significantly high heat rate than new plants, corroborating the ageing is a critical factor in deciding candidates for R&M/ LE.

1.3. Auxiliary Power Consumption (APC)

Auxiliary power consumption is another important operational parameter that determines the net efficiency of the plant. Lower auxiliary consumption implies a higher grid electricity availability and lower fuel cost. The figure below provides the average operating auxiliary power consumption for each capacity group.

Figure 3-4: Auxiliary Power Consumption in various Capacity Groups[5]



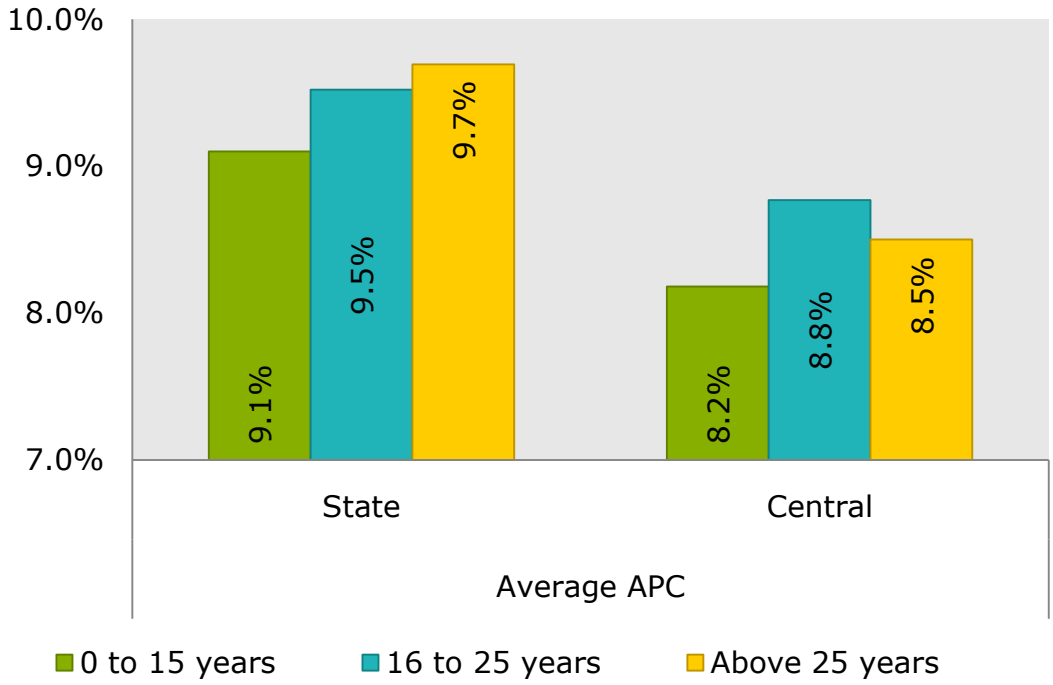
Source: AF-Mercados EMI Analysis

As it is clearly evident from the figure above, the APC of Central sector plants is lower than State sector plants by 0.9-1.1%. Further, the newer capacity group (250 MW & above) have lower APC than the 200/210 MW capacity plants. In case of state sector plants, a slight deviation from the above trend is observed wherein the APC of 250 MW and above capacity is marginal higher than 200/210 MW.

[5] Average operating value of APC is computed for FY 09-10, FY 10-11 & FY 11-12

* Average is higher due to one or two plants outliers, otherwise the group is lower than 9.2%

Figure 3-5: Auxiliary Power Consumption in various Age Groups[6]



Source: AF-Mercados EMI Analysis

Similar analysis of APC for various age groups indicates older plants have higher APC than relatively newer plants with exception of NTPC plants wherein the plants with age 25 years and above having a marginally[7] lower APC than plants with age between 15 to 25 years. One of the potential reasons could be that many of the plants exceeding 25 years have undergone need based R&M whereas; the capacities ageing 15 to 25 years currently are programmed to undergo R&M during 12th Plan.

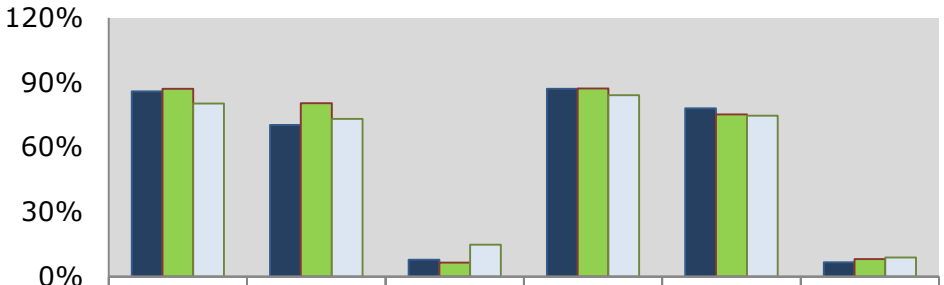
1.4. Plant Availability (PA), Forced Outage (FO) and Plant Load Factor (PLF)

Undertaking R&M not only improves the efficiency of the power generation but also improves the availability and reliability of generation. Thus, the figure below provides the trends of plant availability, forced outage and PLF among various capacity and Age group.

[6] Average operating value of APC is computed for FY 09-10, FY 10-11 & FY 11-12

[7] This also consistent with R&M philosophy of NTPC wherein R&M to the extent possible is undertaken along with annual/ capital overhauls

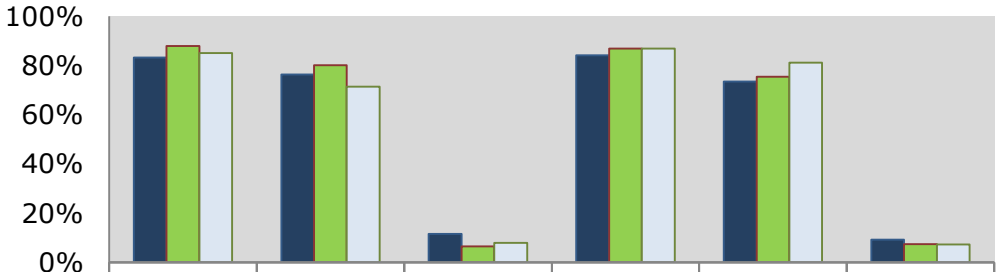
Figure 3-6: Plant Availability, Forced Outage and PLF in various Capacity Groups[8]



	PA	PLF	FO	PA	PLF	FO
	State			Central		
200/ 210 MW (LMZ)	86%	70%	8%	87%	78%	7%
200/ 210 MW (KWU)	87%	80%	7%	87%	75%	8%
250 MW and above	80%	73%	15%	84%	75%	9%

Source: AF-Mercados EMI Analysis

Figure 3-7: Plant Availability, Forced Outage and PLF in various Age Groups[9]



	PA	PLF	FO	PA	PLF	FO
	State			Central		
0 to 15 years	83%	76%	12%	84%	74%	9%
16 to 25 years	88%	80%	7%	87%	75%	7%
Above 25 years	85%	71%	8%	87%	81%	7%

Source: AF-Mercados EMI Analysis

The above figure clearly indicates the following trends:

a) The plant availability of various age and capacity group is observed to be around 85% (except in case of 250 MW and above for state sector). This signifies the potential for increase in generation from operating capacity. Further, Central sector plants have higher availability than State sector plants. This can be attributed to better

[8] Average operating value of Plant availability, PLF and Forced Outage is computed for FY 09-10, FY 10-11 & FY 11-12

[9] Average operating value of Plant availability, PLF and Forced Outage is computed for FY 09-10, FY 10-11 & FY 11-12

O&M practises.

b) High forced outage is observed in state sector plants with capacity 250 MW and above when compared to the lower capacity groups. A similar trend was observed in central sector plant. However, the increase in frequency of outage in 250 MW and higher capacity central sector plants was observed to be marginally high.

c) The outage shows an increasing trend for state sector plants between 15 to 25 years age group to 25 years and above age group. The increase is clearly indicating if the R&M/ LE interventions are not undertaken timely, the reliability of the plant will deteriorate further.

It is worthwhile to mention that the objective of the above analysis is to emphasis on the poor efficiency / plant performance of coal based generation mix in India and on the need for R&M scheme. We acknowledge that the performance parameters vary significantly among individual units which are largely depended on several reasons pertaining to operational environment and technical factors. However, identification of exact reasons for such variation is a matter of detailed technical studies/ scrutiny in each of these units/ plants. **The above trends in the critical plant performance indicators viz. Heat rate, Auxiliary consumption, plant availability and force outage for operating coal plants in India is emphatically indicating the need for R&M and the huge potential for energy efficiency improvement in the coal generation mix.**

2. Financial Analysis

This section of the report presents the results of financial analysis carried out in line with the analytical framework described in the earlier section. The analysis has been carried out to understand the following economic aspects:

a) Comparison of cost of power generation/ levelised tariff under various scenarios namely business-as-usual (BAU), R&M and Greenfield project and determination of least cost option.

b) Assess the minimum range for improvement of plant parameters viz. Heat rate and auxiliary consumption etc. which is to be achieved post R&M to ensure that R&M emerges the least cost option.

Each of the above aspects is examined below:

2.1. Cost Economics of R&M

The table below presents the key outputs of our financial evaluations under the option of BAU, R&M and Greenfield project.

Table 3-2: Key Financial/ Economic Results

The size of the plant assumed for financial/economic analysis is 200 MW.

Parameters	Y1	Y2	Y3	Y4	Y5	Y8	Y15	Y20	Y25
Option A: Business As Usual (BAU)									
Net Generation (MU)	939.2	910.7	883.1	856.3	830.3	757	Residual life of the plant is 8 years and hence, no generation is available from 9th year onwards		
Capacity Charge (Rs./ kWh)	0.94	1.00	1.06	1.13	1.20	1.46			
Energy Charge (Rs./ kWh)	2.27	2.40	2.53	2.66	2.81	3.29			
Cost of Power (Rs./ kWh)	3.21	3.40	3.59	3.79	4.01	4.75			
Levelised tariff (Rs./ kWh)	3.82								
Option B: R&M									
Net Generation (MU)	1362.62	1360.38	1358.15	1355.93	1353.70	1347.05	1331.65	1320.75	Life of the plant undergoing R&M is considered 20 years and
Capacity Charge (Rs./ kWh)	1.00	0.99	0.98	0.97	0.96	0.94	1.04	1.23	
Energy Charge (Rs./ kWh)	1.91	2.01	2.11	2.22	2.34	2.73	3.89	5.02	
Cost of Power (Rs./ kWh)	2.91	3.00	3.09	3.19	3.30	3.66	5.17	6.25	

Parameters	Y1	Y2	Y3	Y4	Y5	Y8	Y15	Y20	Y25
									hence, no generation is available from 21st year onwards
Levelised tariff (Rs./ kWh)	3.72								
Option C: Greenfield Project									
Net Generation (MU)	1458.54	1458.36	1458.18	1458.01	1457.83	1457.29	1455.85	1455.12	1454.21
Capacity Charge (Rs./ kWh)	1.48	1.44	1.41	1.37	1.33	1.23	1.24	1.45	1.63
Energy Charge (Rs./ kWh)	1.89	1.99	2.10	2.20	2.32	2.84	3.86	4.98	6.42
Cost of Power (Rs./ kWh)	3.37	3.44	3.50	3.57	3.65	3.93	5.10	6.39	8.05
Levelised tariff (Rs./ kWh)	4.25								

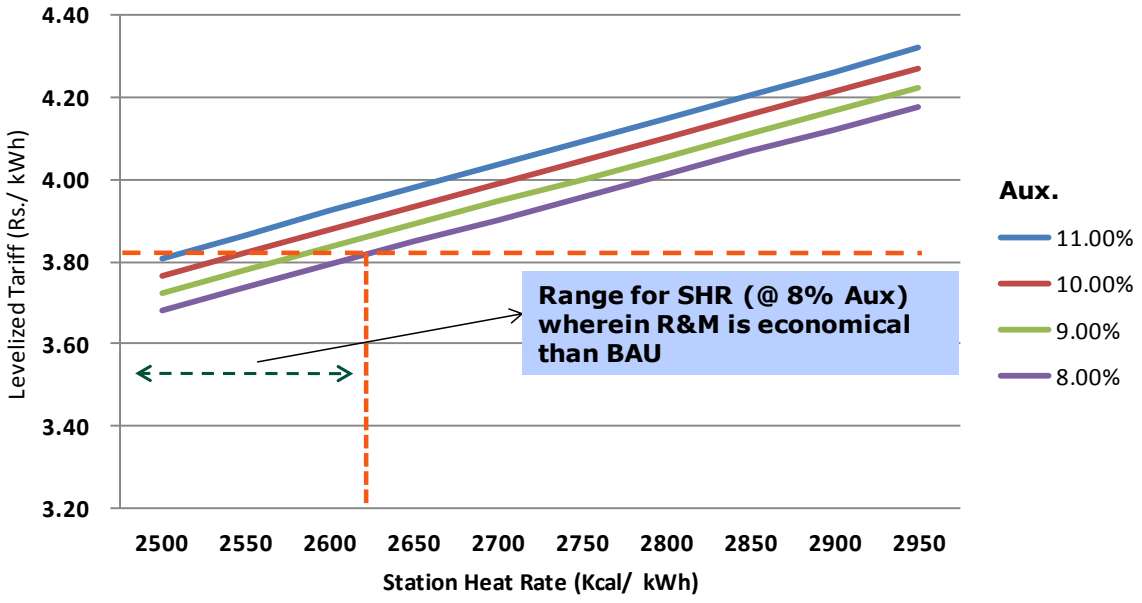
The following key conclusions are emerging from the above financial analysis:

a) The levelised tariff for power generation under Option B (R&M)[10] works out to be the lowest at Rs. 3.72/ kWh followed by Option A (BAU) at Rs. 3.82/ kWh and Option C (Greenfield Project) at Rs. 4.25/ kWh. This clearly indicates that there is significant life cycle cost saving of Rs. 0.10/ kWh in case if R&M is undertaken instead of running the plant with existing operating performance.

b) In addition to the cost saving, undertaking R&M will also benefit in terms of increase in energy availability/ generation from the plant. In this specific case, the total additional power available during a period of 8 years is ~4076 MU vis-à-vis 58 MW or 510 MU annually.

The above results are based on the fact that guaranteed performance parameters are achieved by the plant post R&M. Recognizing the importance of plant performance post R&M in ascertaining the financial viability, a sensitivity of key plant parameters viz. Heat rate and Auxiliary consumption on the levelised tariff is worked out as below:

Figure 3-8: Sensitivity of levelised tariff vis-à-vis heat rate and auxiliary consumption[11]



Source: AF Mercados EMI Analysis

The above figure depicts the sensitivity of levelised tariff under R&M case (option B) with SHR at various levels of Auxiliary consumption. Each line graph is the sensitivity curve of levelised tariff with SHR corresponding to a particular auxiliary consumption level. The levelised tariff under option A (BAU) is Rs.

[10] Assumed SHR @ 2540 kcal/ kWh and Aux. Consumption of 8%

[11] The levelised tariff are corresponding to a R&M CAPEX of Rs. Crore 2.5/ MW

3.82/ kWh and therefore, the R&M option will remain the least cost to the extent that the combination of SHR and Auxiliary consumption post R&M leads results in a levelised tariff which is less than Rs. 3.72/ kWh. In order to understand the range of economic value of SHR and APC, as sensitivity analysis of SHR and APC on levelised tariff at various levels of R&M CAPEX is undertaken and the results are provided in the Annexure VI.

It is worthwhile to note that the current performance commitments provided under R&M by various suppliers are generally observed to be within the economic range, clearly indicating that R&M option is by and large the most economic option available to improve efficiency of the plant among the indicated capacity sizes.

3. R&M Potential of Coal based Thermal Plants in India during 12th and 13th Plan

This section presents the potential for R&M and LE estimated by excel based analytical model discussed in the preceding chapter and Annexure II. The objective of estimation of overall R&M requirement during the 12th and 13th FYP is to provide an indicative market size to incumbent and potential market players interested to participate in opportunities the R&M market in the country.

Even though specific units that form the overall market have been indicated in Annexure IV & V, the estimated market size should not be construed as actual units that will be taken up by the states for R&M, as the actual units will depend on state priorities and management strategy of respective utility/ GENCO.

The key basis for the computation of R&M/ LE potential estimated in this section is reproduced below (details including key inputs and their rationale are provided in Annexure II).

a) Ageing Analysis

- Plants are categorised into various age groups based on their operational life (A1 – 0 to 15 years, A2- 15 to 25 Years & A3 – 25 years & above). This is consistent with the nomenclature currently considered by the CEA.

- Plants under A3 category as on March 2012 are identified as potential for LE under 12th plan while those under A3 category as on March 2017 are identified for LE under 13th Plan

- Plants with capacity less and equal to 140 MW[12] are excluded from the analysis. Further, plants wherein the LE work is

[12] This is in accordance with the discussion and deliberation with the CEA, and subsequently with the Task Force constituted by the CEA for world bank financed project "Coal Fired Generation Rehabilitation Project-India"

completed, ongoing or contracted are also excluded from the analysis

b) Performance Analysis:

- Plants under A2 age category (i.e. plants that will exceed 15 years of operational life during the five year plan) are further segmented into three levels of performance based on their % deviation of Average operating SHR for last three years (FY 09-10, FY 10-11 & FY 11-12) vis-à-vis design value. SHR is the most critical plant parameter that is indicative of the overall plant efficiency and hence, is considered for categorisation of plants into various performance groups (High- 0 to 7.5% deviation, Medium- 7.5% to 15% & Low- 15% & above)

- Plants that are under A2 category as on March 2012 and have low/medium level of plant performance are identified for R&M during under 12th Plan whilst plants that are under A3 category as on March 2017 and have low/medium level of plant performance are identified for R&M during 13th Plan.

- Operational data (viz. SHR) for NTPC plant is not available in public domain and thus, the R&M potential for central sector plants during 12th plan is derived from CEA's National Perspective Plan (revised version).

c) Scenarios for R&M/ LE requirement:

- The overall R&M/ LE potential during 12th and 13th plan is estimated under two scenarios namely High and Low case, as explained below

  - **High Case-** This scenario presents the optimistic estimation of R&M/ LE potential during 12th and 13th plan for coal based thermal power plants in India. The potential projected under this scenario is indicative of the total addressable market (TAM) size of R&M/ LE in India.

  - **Low Case-** This scenario presents a conservative estimation of R&M/ LE potential during 12th and 13th plan for coal based thermal power plants in India. Considering the poor achievement record of R&M / LE projects during past two five year period (10th and 11th plan), the following rationale is used to determine a low case for R&M/ LE potential:

(i) Each state can possibly execute three LE and 5 R&M projects in a five year plan considering the energy deficit and funding limitation,

(ii) Slippage of 17 units (equivalent to 6180 MW) as identified by NTPC for R&M work during 12th plan, to 13th plan as these units are identified for LE under 13th plan based on the ageing analysis

3.1. High Case - R&M and LE potential in 12th and 13th plan

The table below presents the High case for R&M and LE potential during the 12th and state-wise break up for state sector plants. The detailed list of plants (state and central sector) is provided in Annexure III and IV.

Table 3-3: High Case - R&M and LE Potential in 12th Plan (State/ Central Sector Units)

Sector-wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
Chhattisgarh	-	-	840	4	840	4
Gujarat	630	3	1,660	8	2,290	11
Haryana	210	1	-	-	210	1
Jharkhand	210	1	-	-	210	1
Karnataka	420	2	420	2	840	4
Madhya Pradesh	420	2	830	4	1,250	6
Maharashtra	1,630	5	2,720	13	4,350	18
Punjab	840	4	420	2	1,260	6
Rajasthan	630	3	-	-	630	3
Tamil Nadu	420	2	630	3	1,050	5
West Bengal	840	4	420	2	1,260	6
Total State Sector	**6,250**	**27**	**7,940**	**38**	**14,190**	**65**

Sector-wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
Total Central Sector	**11,070**[13]	**32**	**3,640**	**15**	**14,710**	**47**
All India Potential	**17,320**	**59**	**11,580**	**53**	**28,900**	**112**

The total combined potential of R&M and LE during the 12th FYP is estimated ~ 28,900 MW (112 units).

Further, the table below presents the break-up of R&M and LE Potential during the 12th FYP in various capacity groups

Table 3-4: High Case- R&M and LE Potential in 12th Plan (Capacity group wise)

Capacity-wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
200/ 210 MW (LMZ units)	3,360	16	6,440	31	9,800	47
200/ 210 MW (KWU units)	5,460	26	4,140	20	9,600	46
250 MW and above	8,500	17	1,000	2	9,500	19
All India Potential	**17,320**	**59**	**11,580**	**53**	**28,900**	**112**

The above results indicate the following:

- Plants with capacity 200/ 210 MW (LMZ & KWU), constitute 67.1% of the total LE (including R&M) potential in the country during the

[13] Due to limitation of availability of operational data for central sector plants we have derived the R&M potential for central sector from CEA's Revised National Perspective Plan for R&M

12th plan while the remaining potential is contributed by plants with 250 MW & above capacity

- Maharashtra contributes largest share around 30.7% of the total state sector LE (including R&M) potential followed by Gujarat (16.1%), Punjab & West Bengal (8.9% each), Madhya Pradesh (8.8%) and others (19%)

- Most of the units currently taken up in the market are of 200 MW size range, as the experience and outcome from the above will be critical and set basis for successful R&M planning and implementation of 250 MW & above sizes as well.

The table below presents the High case for R&M and LE potential during the 13th and state-wise break up for state sector plants

Table 3-5: High Case – R&M and LE Potential in 13th Plan (State/ Central Sector Units)

Sector wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
Andhra Pradesh	-	-	420	2	420	2
Gujarat	210	1	630	3	840	4
Haryana	210	1	210	1	420	2
Jharkhand	210	1	-	-	210	1
Karnataka	420	2	210	1	630	3
Madhya Pradesh	420	2	-	-	420	2
Maharashtra	920	3	1,130	4	2,050	7
Punjab	-	-	420	2	420	2
Rajasthan	750	3	420	2	1,170	5
Tamil Nadu	-	-	1,260	6	1,260	6
West Bengal	630	3	420	2	1,050	5
Total State Sector	**3,770**	**16**	**5,120**	**23**	**8,890**	**39**
Total Central Sector	**4,430**	**14**	**1,250**	**6**	**5,680**	**20**

Sector wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
All India Potential	**8,200**	**30**	**6,370**	**29**	**14,570**	**59**

The total combined potential of R&M and LE during the 13th FYP is estimated ~ 14,570 MW (59 units).

Further, the table below presents the break-up of LE Potential during the 13th FYP in various capacity groups

Table 3-6: High Case- R&M and LE Potential in 13th Plan (Capacity group wise)

Capacity-wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
200/ 210 MW (LMZ units)	210	1	2,100	10	2,310	11
200/ 210 MW (KWU units)	3,990	19	3,770	18	7,760	37
250 MW and above	4,000	10	500	1	4,500	11
All India Potential	**8,200**	**30**	**6,370**	**29**	**14,570**	**59**

The above results clearly indicates the following,

- Plants with capacity 200/ 210 MW (LMZ & KWU), constitute 92% of the total LE (including R&M) potential in the country during the 13th plan while the remaining potential is contributed by plants with 250 MW & above capacity
- Tamil Nadu contributes largest share around 25% of the total state sector LE (including R&M) potential followed by Maharashtra (22%), Gujarat (12.3%) Punjab, Rajasthan, Andhra Pradesh & West Bengal (8.2% each) and others (8%)

3.2. Low Case - R&M and LE potential in 12th and 13th plan

The table below presents the Low case for R&M and LE potential during the 12th and state-wise break up for state sector plants

Table 3-5: Low Case - R&M and LE Potential in 12th Plan (State/ Central Sector Units)

Sector-wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
Chhattisgarh	-	-	420	2	420	2
Gujarat	630	3	610	3	1,240	6
Haryana	210	1	-	-	210	1
Jharkhand	210	1	-	-	210	1
Karnataka	420	2	420	2	840	4
Madhya Pradesh	420	2	410	2	830	4
Maharashtra	1,630	5	620	3	2,250	8
Punjab	840	4	420	2	1,260	6
Rajasthan	630	3	-	-	630	3
Tamil Nadu	420	2	630	3	1,050	5
West Bengal	840	4	420	2	1,260	6
Total State Sector	**6,250**	**27**	**3,950**	**19**	**10,200**	**46**
Total Central Sector	**4,890**	**15**	**3,640**	**15**	**9,030**	**30**
All India Potential	**11,140**	**42**	**7,590**	**34**	**18,730**	**76**

The total combined potential of R&M and LE during the 12th FYP is estimated ~ 18,730 MW (76 units).

Further, the table below presents the break-up of R&M and LE Potential during the 12th FYP in various capacity groups

Table 3-6: Low Case- R&M and LE Potential in 12th Plan (Capacity group wise)

Capacity-wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
200/ 210 MW (LMZ units)	2,310	11	3,710	18	6,020	29
200/ 210 MW (KWU units)	4,830	23	2,880	14	7,710	37
250 MW and above	4,000	8	1,000	2	5,000	10
All India Potential	**11,140**	**42**	**7,590**	**34**	**18,730**	**76**

The above results clearly indicates the following,

- Plants with capacity 200/ 210 MW (LMZ & KWU), constitute 73.3 % of the total LE (including R&M) potential in the country during the 12th plan while the remaining potential is contributed by plants with 250 MW & above capacity
- Maharashtra contributes largest share around 22.1% of the total state sector LE (including R&M) potential followed by Punjab & West Bengal (12.4%), Gujarat (12.2%), Tamil Nadu (10.3%), Karnataka (8.2%) and others (22.5%)

The table below presents the Low case for R&M and LE potential during the 13th and state-wise break up for state sector plants

Table 3-7: Low Case – R&M and LE Potential in 13th Plan (State/ Central Sector Units)

Sector	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
Andhra Pradesh	-	-	420	2	420	2
Chhattisgarh	-	-	420	2	420	2

Sector	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
Gujarat	210	1	630	3	840	4
Haryana	210	1	210	1	420	2
Jharkhand	210	1	-	-	210	1
Karnataka	420	2	210	1	630	3
Madhya Pradesh	420	2	420	2	840	4
Maharashtra	920	3	630	3	1,550	6
Punjab	-	-	420	2	420	2
Rajasthan	750	3	420	2	1,170	5
Tamil Nadu	-	-	630	3	630	3
West Bengal	630	3	420	2	1,050	5
Total State Sector	**3,770**	**16**	**4,830**	**23**	**8,600**	**39**
Total Central Sector	**4,430**	**14**	**7,430**	**23**	**11,860**	**37**
All India Potential	**8,200**	**30**	**12,260**	**46**	**20,460**	**76**

The total combined potential of R&M and LE during the 13th FYP is estimated ~ 20,460 MW (76 units).

Further, the table below presents the break-up of R&M and LE Potential during the 13th FYP in various capacity groups

Table 3-8: Low Case- LE Potential in 13th Plan (Capacity group wise)

Capacity-wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
200/ 210 MW (LMZ units)	210	1	3,570	17	3,780	18
200/ 210 MW	3,990	19	4,190	20	8,180	39

Capacity-wise	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
(KWU units)						
250 MW and above	4,000	10	4,500	9	8,500	19
All India Potential	**8,200**	**30**	**12,260**	**46**	**20,460**	**76**

The above results clearly indicates the following,

- Plants with capacity 200/ 210 MW (LMZ & KWU), constitute 58.5% of the total LE (including R&M) potential in the country during the 13th plan while the remaining potential is contributed by plants with 250 MW & above capacity
- Maharashtra contributes largest share around 18% of the total state sector LE (including R&M) potential followed by Rajasthan (13.6%), West Bengal (12.2%), Gujarat & Madhya Pradesh(9.8% each) and others (24.4%)

Chapter - 4

R&M Market Assessment (Including Capabilities and Interest of Key Players)

Having understood the overall R&M potential in the country, the focus of this section is to assess the overall attractiveness of the R&M market including the overall market size, size of key sub-segments, stakeholders involved, their capabilities and interest etc.

1. R&M Market Size

Market size is an important determinant for assessing interest and capabilities of different players in serving the R&M requirement of the country. In order to harness the estimated R&M/LE potential, it is important to understand how this potential translates into business opportunities for various R&M market players i.e. suppliers and technical consultants.

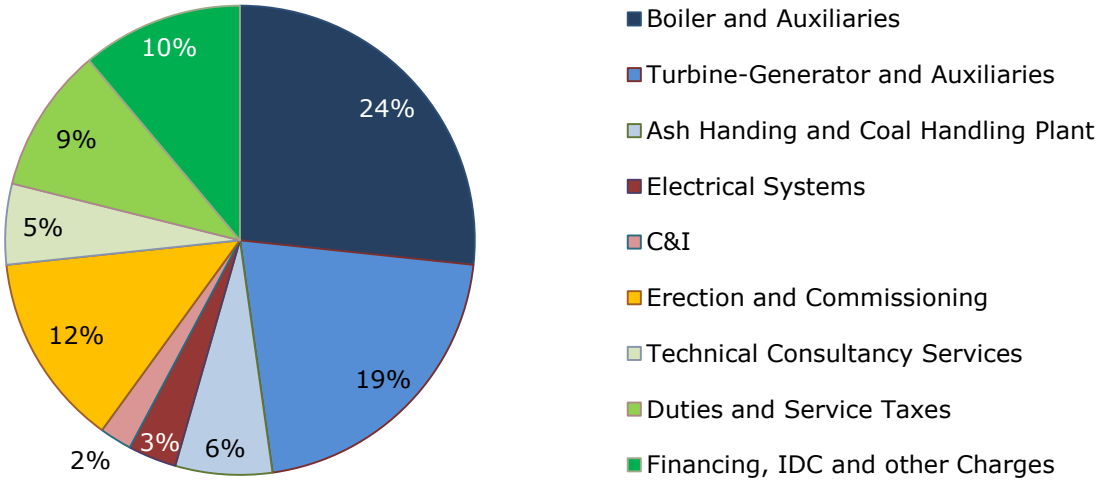
In order to estimate the market size of R&M (including LE) in India during 12th and 13th Plan, following key basis/ assumptions were considered:

- Total R&M potential (including LE) in 12th plan – 18,730 to 28,900 MW
- Total R&M potential (including LE) in 13th plan – 14,570 to 20,460 MW
- Per MW LE (Comprehensive R&M) cost – Rs. 2 Crore per MW (net of taxes and duties)
- Per MW R&M cost – Rs. 1 Crore per MW (net of taxes and duties)

Based on the above assumption, the total market size of the R&M/LE is estimated to be in the range of Rs. 26,649 to 40,986 Crores for the 12th plan and Rs. 21,202 to 33,129 Crores for the 13th plan period. Thus, it can be seen that the estimated R&M potential translates into a business opportunity of Rs. 47,851 - 74,115 Crores over the 12th and 13th plan period.

Further, in order to derive the market size of sub-segments of equipments and services in R&M project, a sample of full scale LE project has been considered to derive the break-up of costs of sub-segments. The cost break-up considered has been derived from the DPR of a few recent projects, inputs received during the stakeholder consultations and review of research reports.

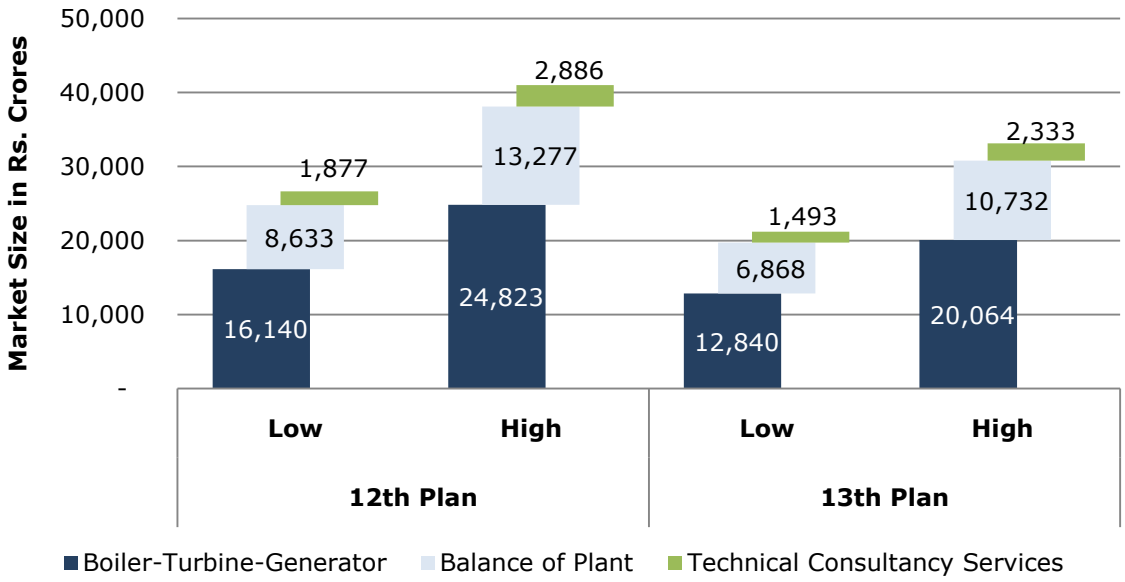
Figure 4-1: Break-up of cost in full-scale LE project[14]



Source: AF-Mercados EMI analysis, Detailed Project Report for Koradi TPS (Unit 6) and Bandel TPS (Unit 5)

Based on the above assumptions an indicative assessment of overall market size of R&M market (including both R&M and LE) in India is presented below.

Figure 4-2: Estimated Market Size for various segments of R&M Market (in Rs. Crores)[15]



Source: AF-Mercados EMI Analysis

[14] The assumption of per MW R&M/LE cost and the respective shares of different equipments/services are only indicative and will vary depending upon the exact scope of the project.

[15] In the estimation of market size for R&M players, Custom and Excise Duties, Service Taxes, Contingency Fund, Financing, IDC and other charges have been excluded as they do not contribute to the market size.

The table below estimates the equity investment and debt requirement for realising the potential R&M market:

Table 4-1: Fund requirement break-up (in Rs. Crores)[16]

Fund requirement break-up (in Rs. Crores)[17]		**12th Plan**	**13th Plan**
Fund Requirement from its own resource (30%)	State	5,010 to 7,703	4,674 to 4,870
	Central	4,291 to 6,608	2,505 to 6,677
Fund Requirement through external resource (70%)	State	11,690 to 17,974	10,906 to 11,363
	Central	10,012 to 15,419	5, 845 to 15,579
Total		**31,003 to 47,705**	**24,583 to 37,835**

Source: AF-Mercados EMI Analysis

The following table provides the break-up of overall market size into different states, particularly mapping the states where the candidate plants (for R&M and LE) are located.

[16] Fund requirement is inclusive of taxes and duties

[17] Range indicates the value under high and low scenarios.

Table 4-2: State level break-up of LE and R&M market size for different R&M players during 12th Plan

States	State wise R&M Potential (MW)	State wise R&M Market Value (Rs. Crore)	State wise LE Potential (MW)	State wise LE Market Value (Rs. Crore)	Total State wise Market Value (Rs. Crore)	Fund Requirement (Rs. Crore)		State wise Market Value (in Rs. Crore) for R&M Players		
						Own Resource (30%)	External Resource (70%)	BTG	BoP	Technical Consultancy Services
Chhattisgarh	0	0	420 to 840	851 to 1,701	851 to 1,701	284 to 567	662 to 1,323	515 to 1,030	276 to 551	60 to 120
Gujarat	630	638	610 to 1,660	1,235 to 3,362	1,873 to 3,999	648 to 1,357	1,512 to 3,166	1,134 to 2,422	607 TO 1,296	132 to 282
Haryana	210	213	0	0	213	79	184	129	69	15
Jharkhand	210	213	0	0	213	79	184	129	69	15
Karnataka	420	425	420	851	1,276	441	1,029	773	413	90
Madhya Pradesh	420	425	410 to 830	830 to 1,681	1,256 to 2,106	434 to 718	1,013 to 1,675	760 to 1,275	407 to 682	88 to 148
Maharashtra	1,630	1,650	620 to 2,720	1,256 to 5,508	2,906 to 7,158	1,030 to 2,447	2,403 to 5,710	1,760 to 4,335	941 to 2,319	205 to 504
Punjab	840	851	420	851	1,701	599	1,397	1,030	551	120
Rajasthan	630	638	0	0	638	236	551	386	207	45
Tamil Nadu	420	425	630	1,276	1,701	583	1,360	1,030	551	120
West Bengal	840	851	420	851	1,701	599	1,397	1,030	551	120
Total State	6,250	6,328	3,950 to	7,999 to	14,327 to	5,010 to	11,690 to	8,677 to	4,641 to	1,009 to

States	State wise R&M Potential (MW)	State wise R&M Market Value (Rs. Crore)	State wise LE Potential (MW)	State wise LE Market Value (Rs. Crore)	Total State wise Market Value (Rs. Crore)	Fund Requirement (Rs. Crore)		State wise Market Value (in Rs. Crore) for R&M Players		
						Own Resource (30%)	External Resource (70%)	BTG	BoP	Technical Consultancy Services
Sector			7,940	16,079	22,407	7,703	17,974	13,570	7,258	1,578
Total Central Sector	4,890 to 11,070	4,951 to 11,208	3,640	7,371	12,322 to 18,579	4,291 to 6,608	10,012 to 15,419	7,463 to 11,252	3,992 to 6,019	868 to 1,308
All India	11,140 to 17,320	11,279 to 17,537	7,590 to 11,580	15,370 to 23,450	26,649 to 40,986	9,301 to 14,312	21,702 to 33,394	16,140 to 24,823	8,633 to 13,277	1,877 to 2,886

Source: AF-Mercados EMI Analysis

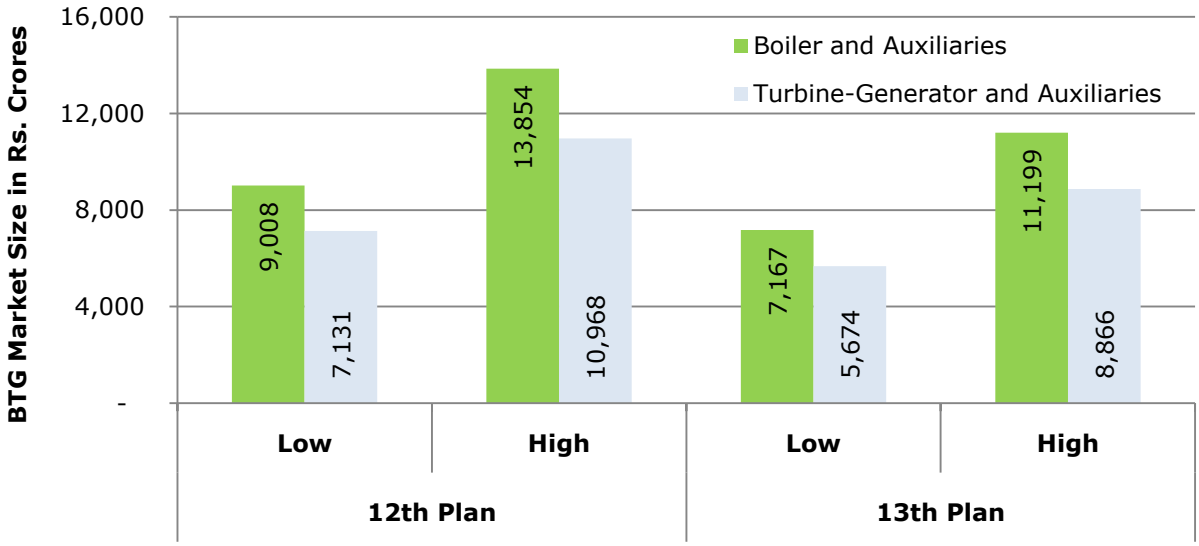
2. Assessment of the capability and interest of R&M Players

This section presents a detailed assessment of different segments of the R&M market i.e. suppliers (BTG and BoP) and technical consultants in terms of number of players, their service offerings and respective capabilities and interests. This section also provides the perspectives of the players and implications for the future development of the market.

2.1. BTG Segment

Boiler, Turbine and Generator (BTG) equipments/products accounts for majority of cost in a power plant. BTG is a capital and technology intensive segment and therefore being dominated by large national and international players. Assessment of R&M market size indicates that the BTG segment has business opportunity to the tune of ~Rs.25,000 Crore in the 12th Plan and ~Rs.20,000 Crore in 13th Plan. The breakup of potential during the 12th and 13th Plan is presented below:

Figure 4-3: Boiler-Turbine-Generator R&M market size in Rs. Crores



Source: AF-Mercados EMI Analysis

Given that there is substantial potential for BTG players, it is imperative to map the capability matrix of the BTG players in order to assess the players involved and their interest and capabilities in the R&M market. The capability matrix aims to capture the ability of the firm in servicing the requirement of R&M sector. The table below maps the key players of the BTG market, their origin (national and international) and service offerings

Table 4-3: Capability Matrix of BTG Players

S. No	Company Name	Origin		Offerings		
		National	International	Boiler	Turbine	Generator
1	L&T	■		■	■	■
2	NTPC Alstom Power Services Pvt Ltd	■		■	■	■
3	BHEL	■		■	■	■
4	Siemens		■	■	■	■
5	Dong Fang		■	■	■	■
6	Sokeo Power Private Ltd		■	■	■	■
7	Alstom India Ltd		■	■	■	■
8	Doosan		■	■	■	■
9	Thermax	■		■		
10	Cethar	■		■		
11	GE		■		■	■
12	Toshiba		■		■	■
13	BGR Energy-Hitachi	■		■	■	■
14	Toshiba JSW Turbine and Generator Pvt. Ltd	■			■	■
15	Gammon (I) Ltd.	■		■	■	
16	Hitachi		■	■	■	■
17	Greenesol Power Systems Pvt. Ltd		■	■	■	
18	Cheema Boilers Ltd	■		■		
19	Ansaldo Caldaie Boilers India Pvt. Ltd.		■	■		
20	Shanghai Electric		■	■	■	■
21	L&T-MHI	■		■	■	■
22	Alstom Bharat Forge Power Ltd	■			■	■
23	Thermax Babcock & Wilcox		■	■		
24	ThyssenKrupp Industries		■	■		
25	ISGEC Heavy Engineering Ltd.	■		■		
26	Veesons Energy Systems Pvt. Ltd	■		■		
27	G B Engineering Enterprise Pvt. Ltd.	■		■		

Source: AF-Mercados EMI Analysis

The capability matrix given above clearly indicate that there is a good mix of national and international players who can cater to R&M requirement during 12th and 13th Plan. It also indicates that the utilities have wide range of options while selecting the supplier for supplying the main plant equipments. The market participation is limited in certain cases wherein BTG is organized as a single package (with only 10-12 vendors, and only 2 with majority of Indian R&M experience).

Due to presence of foreign/private parties, the BTG market is currently witnessing paradigm shift in the market competition and recent years have witnessed several joint ventures established to tap the opportunities in power sector. The next section illustrates the key features of BTG market and

implications for R&M market.

2.1.1. Key Features of the BTG market and implications for R&M Market

The key features of the BTG market along with the implications for R&M market are presented below:

a) **Classification of the BTG market**

BTG market can be categorized into three parts depending upon the service/product offerings of the players' i.e.

i. Suppliers dealing in only Boiler (including auxiliaries) equipments: This includes players such as Ansaldo, Thermax, GB Engineering and ISGEC etc.

ii. Suppliers dealing in Turbine and Generator (including auxiliaries) equipments: This includes players such as GE and Toshiba.

iii. Suppliers offering BTG as a complete package: This includes players such as BHEL, NASL, Dongfang, Doosan etc.

The following observations can be drawn from the above:

- There are 12 players with offering across the spectrum covering boiler, turbine and generator. Of these, only 2 have majority of Indian R&M experience. Others though have limited Indian experience, have strong international experience in the R&M space.

- The above restricts participation of other vendors in the R&M market since packages are mostly organized as a full B, T, G package and guarantees under the contract are organized as per this classification. Further, in certain cases where Indian experience is specifically asked for, the participation is further low. While the later is being overcome to some extent with tendering increasingly being adopted as mode of award that gives adequate weight to international experience as well, the former remains a concern.

- Models that split the Boiler, Turbine and Generator package further, and permit participation of other vendors also would be useful, and are likely to encourage competition. However, in such cases design of contract guarantees becomes a challenge,

which will need to be considered when such models are designed.

b) **Increasing presence of foreign players in the Indian market**

This market is served by large number of foreign players either directly or through joint ventures/ technology transfers with the domestic player. Foreign players include players from China (Dongfang), Korea (Doosan), Germany (Siemens) etc. Presence of large number of foreign players also involves technology partnerships/alliances among different players i.e. player offering all the products in the market might not have their own technology for a particular project but may have a technology agreement with the other supplier. For e.g. BHEL has a technical tie up with Siemens for manufacture of steam turbines and generators. This also implies that although a particular player may not have directly participated in the R&M market but it may have the requisite experience of Indian R&M market owing to technological partnerships.

c) **Slow down in the Greenfield capacity addition**

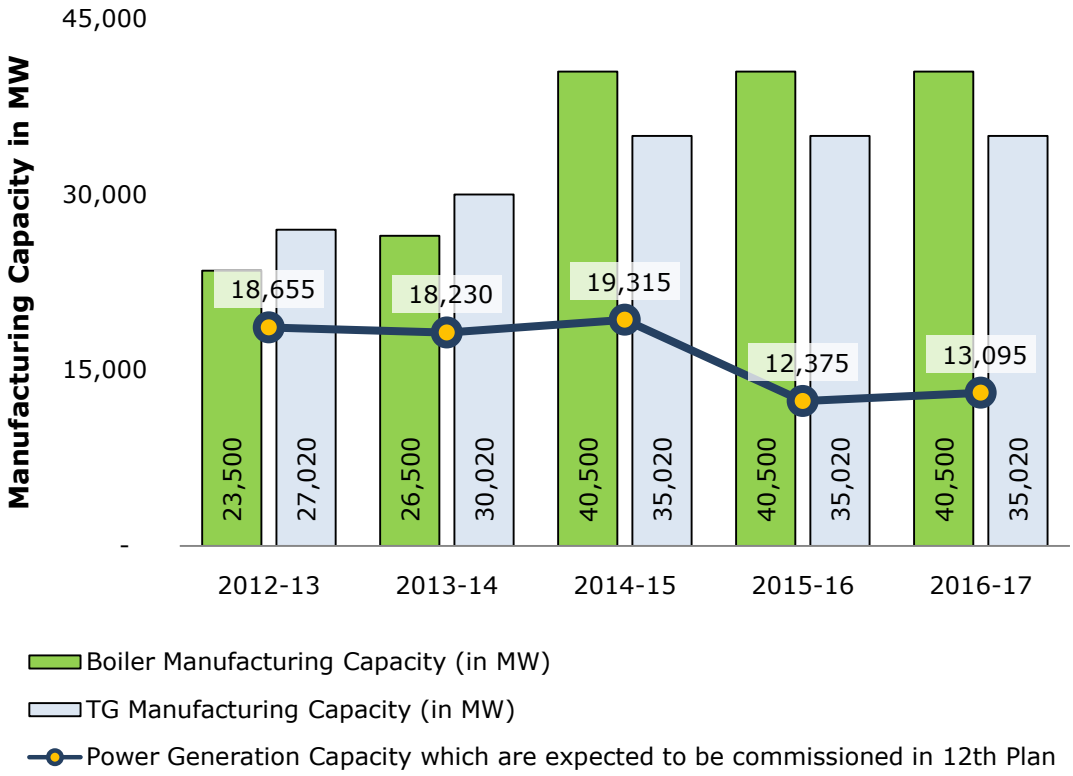
Greater focus/participation of players towards green field capacity addition has been identified as one of the major reasons for slippages in the planned target of R&M works during 10^{th} and 11^{th} plan. However, in the recent past the new thermal capacity addition has been facing unprecedented challenges on account of acute shortage in domestic coal, slow production of coal from the captive coal blocks and huge dependence on imported coal. All of the above coupled with the issues related to environmental clearances and land acquisition have lead to the slowdown in the Greenfield capacity addition in the country, impacting the BTG market for Greenfield projects significantly. The increasing energy requirements of the country coupled with slowdown in green field capacities is expected to provide the initial requisite impetus for the growth of R&M market in the country, as players are likely to diversify into other markets that are natural extensions to the market they have been catering to.

d) **Overcapacity in the BTG segment**

Slow down in the Green field capacity addition coupled with increase in manufacturing capacity addition by the BTG players would lead to significant overcapacity in the BTG market. The figure below highlights the estimated BTG manufacturing capacity addition till FY 2016. It can be observed that capacity of 30,020 MW and 26,500 MW would be available from 2013-14 for TG and Boiler Packages respectively which

is significantly higher than the projected capacity addition in the 12th Plan period (81,670 MW).

Figure 4-4: BTG Manufacturing Capacity in India (2012-2017E)[18]



Source: Industry Input and AF Mercados EMI analysis[19], Report of the Manufacturing Capacity & Construction Agencies for Sub Group 7 of the Working Group on Power for formulation of XII 5 Year Plan

Though many of the manufacturing facilities have been created for only super critical/ ultra-mega projects, stakeholder consultation have revealed that if the player has the design and engineering support, the manufacturing facilities can also be catered for R&M projects. However, it is important to point out that such strategic decision is only possible if R&M market is made more attractive and there is visibility of opportunities in the long-run.

e) **Increase in Competition/Decrease in market dominance**

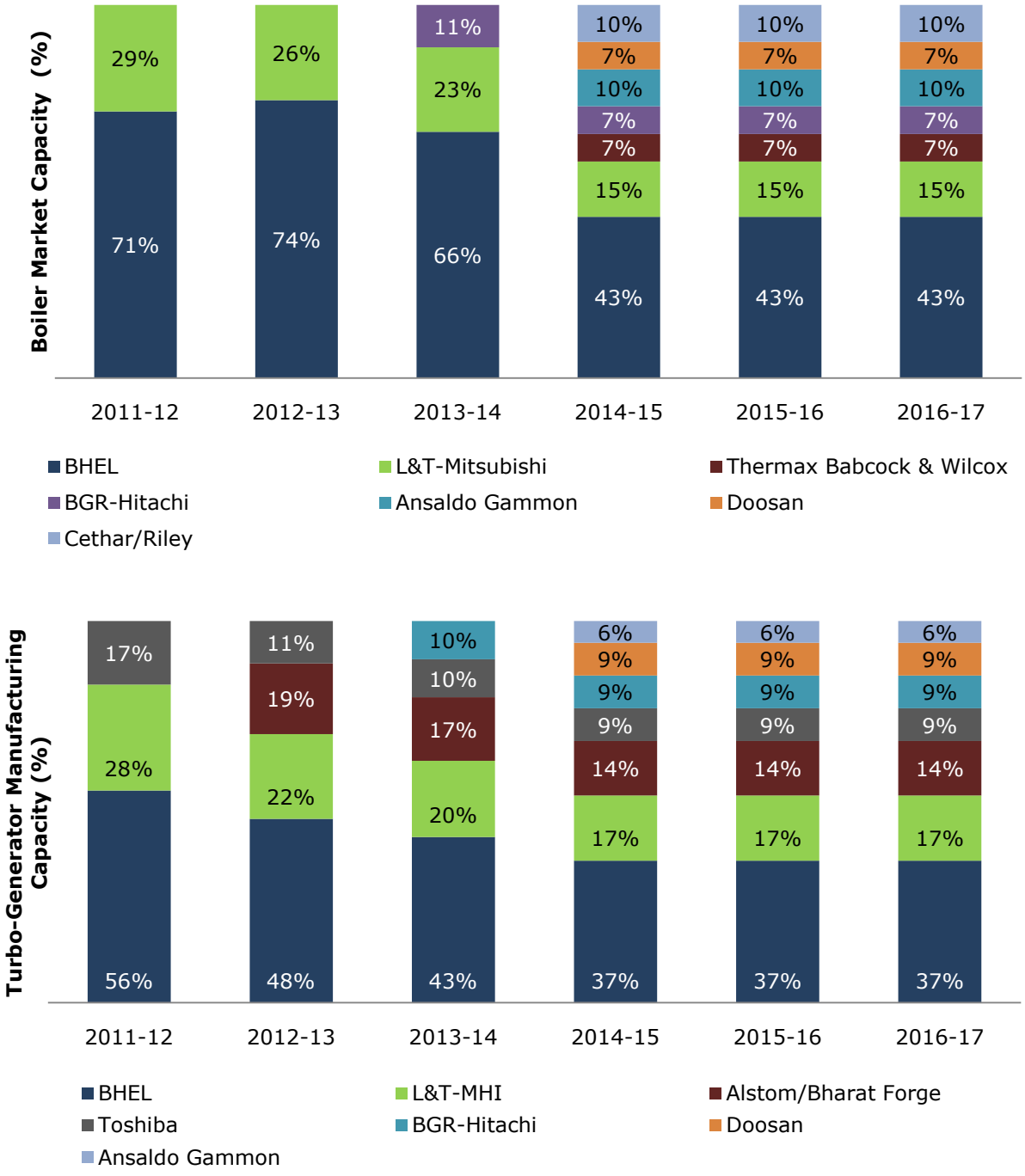
The market for BTG until now has been dominated by BHEL, the leading domestic player in the country. However, with the opening up of the Indian market and liberal policies followed by the GOI to

[18] The manufacturing capacity indicated above reflects the total capacity which can support the requirement of Greenfield and R&M projects.

[19] Plants which are under construction, we have assigned expected date of commissioning on the basis of their Progress status.

encourage foreign players to set up and/or accelerate their manufacturing capacities in India, the market share of BHEL has declined significantly in both boiler and turbine and generator segment.

Figure 4-5: Player-wise break-up of BTG manufacturing capacity

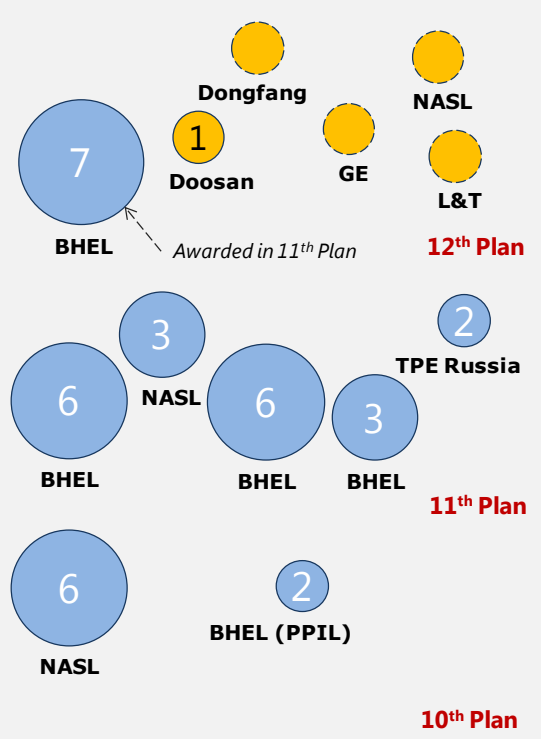


Source: IndustryInput and AF Mercados EMI analysis, Report of the Manufacturing Capacity & Construction Agencies for Sub Group 7 of the Working Group on Power for formulation of XII 5 Year Plan

Similarly, BHEL being the OEM has dominated the R&M market as well. It can be observed that during the last decade majority of the projects have been awarded to BHEL (mostly on nomination basis). However, with the increase in participation of international players, adoption of tendering route for award of projects as against projects on nomination basis and involvement of IFI funding to undertake pilot projects with different implementation models/packaging structures, the market dominance of any single player is expected to decrease going forward. Thus, the opportunity space is likely to broaden encouraging new vendors into the market.

The executing agencies involved in undertaking comprehensive R&M works in the state sector during previous five year plans in India is depicted in Figure below.

Figure 4-6: Details of selected R&M projects undertaken by executing agencies



BHEL	Bathinda Unit 3 and 4 (2*110 MW), PSPCL
BHEL	Barauni TPS Unit 6 and 7 (2*110 MW), BSEB
BHEL	Muzaffarpur TPS Unit 1 and 2 (2*110 MW), KBUNL
Doosan-BTG	Bandel Unit 5 (1*210 MW), WBPDCL
BHEL	Harduaganj Unit 7 (105 MW), UPRVUNL
TPE Russia/UCCI & ILK	Obra TPS Unit 1 and 2 (2*50 MW), UPRVUNL
BHEL	Ukai TPS Unit 1 and 2 (1*120 MW), GSECL
BHEL	Panipat TPS Unit 1 (1*110 MW), HPGCL
NASL	Amarkantak Ext. TPS Unit 1, 2 (2*120 MW), MPGCL
NASL/Alstom	Korba (E) TPS Unit 1,2,3 and 4 (4*50 MW)
BHEL (PPIL)	Korba (E) TPS, Unit 5 to 6 (2*120 MW)
NASL	Bathinda TPS, Unit 1 and 2 (2*110 MW)

Source: AF-Mercados EMI Analysis

Following can be observed from the above figure

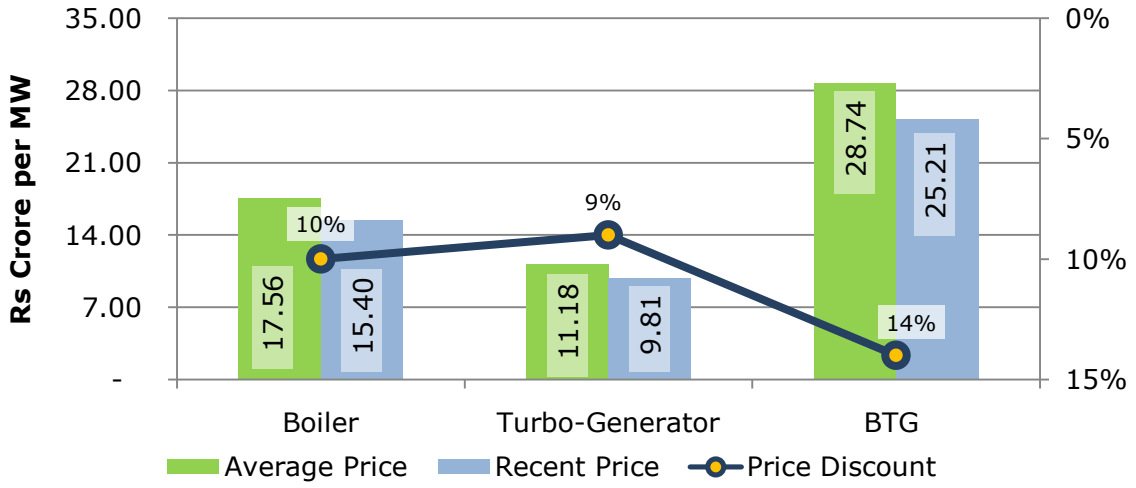
- Most of the R&M expereince in India so far has been shared among BHEL and NASL
- Majority of the R&M projects have been implemented by BHEL in past decade. Being the OEM (which generally happens to be the first point of contact) various projects were awarded on nomination basis to BHEL. NASL has also considerable expereince in undertaking R&M works in the country.

- With the involvement of IFI funding in the country, bidding has gained prominance due to which participation from foreign players such as Doosan Heavy Industries & Construction Co. Ltd, Dongfang Electric (India) Private Limited is observed, indicating signs of market opening to new vendors.

- Doosan with significant international R&M expereince have been awarded R&M works for Bandel Thermal power station Unit 5 (1*210 MW) recently.

Increased participation of players has also led to competitive pricing in the BTG market. The market for BTG equipments has been saturated with majority of the BTG requirement in the 12th Plan already been ordered. As a result, most of the new BTG equipment players do not have a healthy order book[20]. This scenario has resulted in intensified competition in the market leading to aggressive pricing by the players. For e.g. BGR Energy-Hitachi in the bid for NTPC 9x800MW placed the price for turbine-generator at Rs 0.9 Crore/MW and for boiler at Rs. 1.4 Crore/MW, well below the market price trends. The figure below presents the average price correction in the BTG market in the recent past.

Figure 4-7: Price Competition in BTG Industry due to intense competition



Source: Industry Inputs and AF Mercados EMI analysis

It can be observed from the above diagram that prices in the boiler, turbo generator and BTG segment has decreased by 10%, 9% and 14% respectively.

The above has implications for the R&M market as well. Increasing participation from new vendors if continued and encouraged through suitable market strengthening measures, is likely to encourage competition ensuring most

[20] Indian Electrical Equipment Industry Mission Plan 2012 – 2022: Base Document, Department of Heavy Industry, September 2011

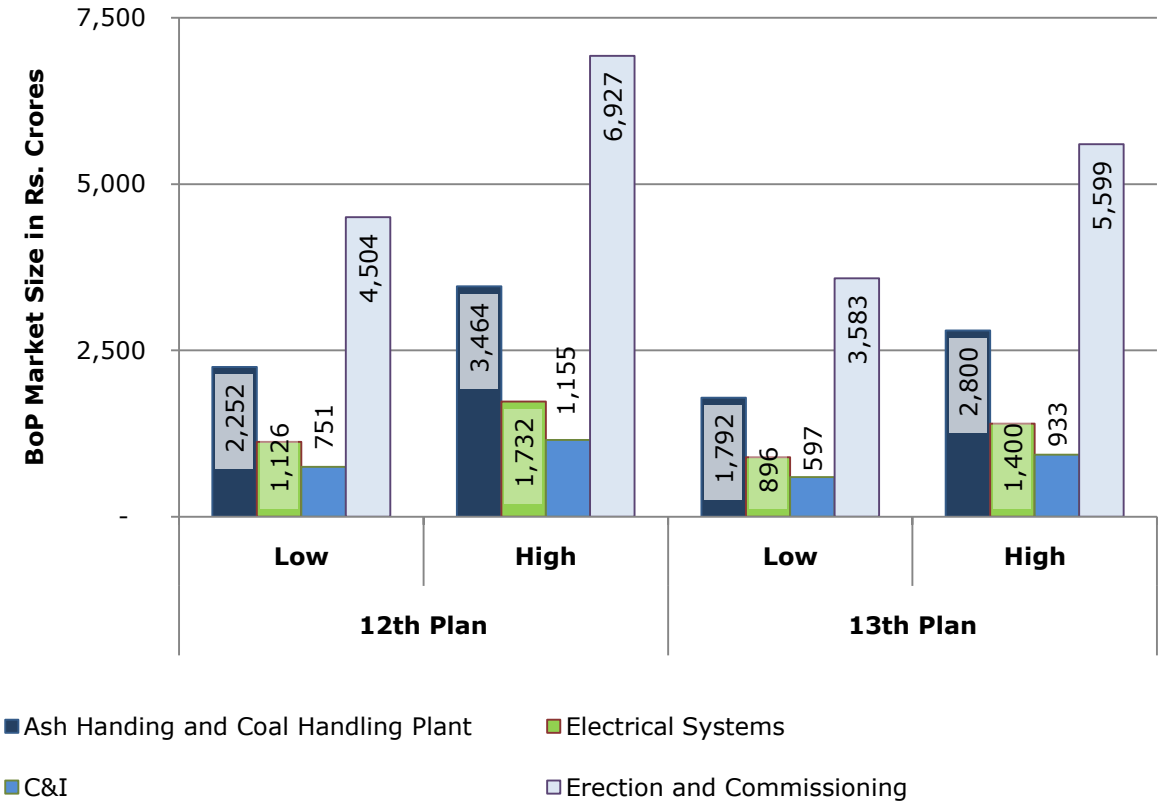
efficient prices and services on offer. Increased BTG manufacturing capacities, slowing down of green field projects, increased IFI funding for pilots etc. provide significant opportunities which if capitalised can go a long way in developing competitive R&M markets.

2.2. BoP Segment

The BoP system typically includes Coal Handling System (CHP), Ash Handling System (AHP), Water Treatment Plant, Electrostatic Precipitator, Cooling Towers, Electrical Systems, Control and Instrumentation System, Chimneys and Fuel Oil System, Civil Works etc.

Assessment of R&M market size indicates that BoP segment has business opportunities to the tune of ~ Rs. 13,000 Crore during the 12th Plan and~ Rs. 11,000 Crore in the 13th Plan. The component wise breakup of potential during the 12th and 13th Plan is presented below

Figure 4-8: R&M market size of different components in the BoP segment in Rs. Crore

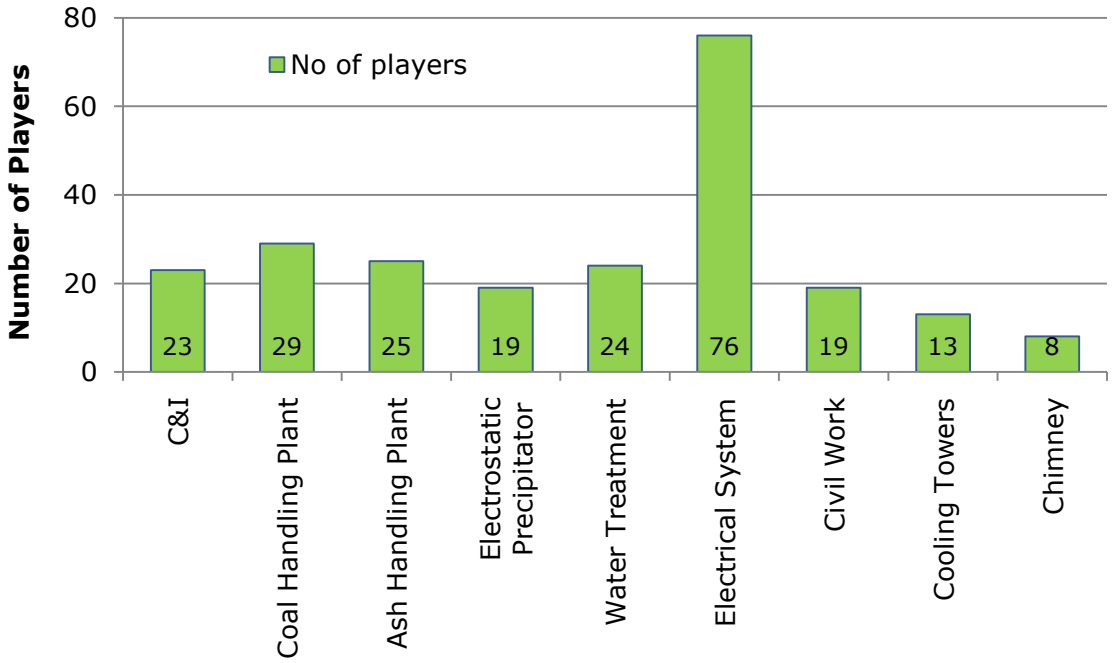


Source: AF-Mercados EMI Analysis

The BoP market is typically characterised with low entry barriers as it has relatively lower technology intensity and involves lower capital requirement than the BTG segment. Therefore, the market is characterised with large number of fragmented domestic players. The number of key players in different

components of the BoP segment is presented in figure below:

Figure 4-9: Number of players present across the BoP segment



Source: AF-Mercados EMI Analysis

It must be noted that many of the players have presence in more than one component of the BoP segment.

Given that there is substantial potential for BoP players, it is imperative to map the capability matrix of these players in order to assess whether there are sufficient players and whether these players have wide portfolio to support the R&M market. The capability matrix aims to capture capability of the firm in servicing the requirement of R&M market. The table below maps the key players of the BoP market, their origin (national and international) and service offerings

Table 4-4: Capability Matrix of BoP Players

S. No.	Company Name	National	International	C&I	CHP	AHP	ESP	WT	ES	Civil	CT	CHM
1	L&T	■		■	■	■	■	■	■	■	■	■
2	NTPC Alstom Power Services Pvt Ltd	■		■	■	■	■	■	■			
3	BHEL	■		■	■	■	■		■			
4	Siemens		■	■		■	■	■	■	■		
5	Dong Fang		■	■			■	■	■			
6	Sokeo Power Private Ltd		■		■	■						
7	Alstom India Ltd		■	■								
8	Doosan		■				■					
9	Thermax	■			■	■	■	■				
10	Cethar	■		■	■	■	■	■	■			
11	GE		■	■					■			
12	Toshiba		■	■					■			
13	BGR Energy-Hitachi	■						■	■	■		
14	Toshiba JSW Turbine and Generator Pvt. Ltd		■	■					■			
15	Gammon (I) Ltd.	■								■	■	■
16	Hitachi		■	■			■					
17	Greenesol Power Systems Pvt. Ltd		■	■					■			
18	Cheema Boilers Ltd	■			■	■	■					
19	Shanghai Electric		■						■			
20	ThyssenKrupp Industries		■		■							
21	UB Engineering Limited	■		■	■	■	■	■	■	■	■	■

S. No.	Company Name	National	International	C&I	CHP	AHP	ESP	WT	ES	Civil	CT	CHM
22	Energo Engineering Projects Ltd	■			■	■		■		■	■	
23	Punj Lloyd	■		■	■	■	■	■	■	■	■	■
24	Tata Projects Ltd.	■		■	■	■	■	■	■	■	■	■
25	Desein	■			■	■	■			■		
26	SPML	■		■		■		■	■	■		
27	TRF Ltd.	■			■	■		■	■		■	■
28	SKF India Ltd		■		■	■			■			
29	McNally Bharat Engineering Company Limited	■			■	■		■	■	■		
30	Tecpro System Pvt Ltd.	■			■	■	■	■	■			
31	Clyde Bergemann		■		■	■	■					
32	Sunil Hitech Engineers Ltd.	■			■		■			■		
33	IVRCL Infrastructures & Projects Ltd.	■			■	■		■	■	■		
34	GEA Heat Exchangers		■				■				■	
35	National Buildings Construction Corporation Ltd	■								■	■	■
36	Lanco Infrastructures Ltd.	■								■		
37	OSM Projects Pvt. Ltd	■			■	■			■			
38	Technofab Engineering Ltd	■			■			■				
39	Macawber Beekay		■		■	■						
40	Schneider Electric		■	■					■			
41	Crompton Greaves Ltd	■		■					■			
42	Schweitzer Engineering Laboratories		■	■					■			
43	Air Systems Limited	■					■					

S. No.	Company Name	National	International	C&I	CHP	AHP	ESP	WT	ES	Civil	CT	CHM
44	Bengal Tools Ltd	■			■							
45	Driplex Water Engineering Ltd	■				■		■				
46	ABB Ltd		■	■					■			
47	Bygging India Ltd		■								■	■
48	Paltech Cooling Towers & Equipment Ltd	■						■			■	
49	Powergear Ltd.	■		■					■			
50	Indiana Group	■			■				■			
51	Techno Electric & Engineering Co. Ltd	■							■	■		
52	Paharpur Cooling Towers	■									■	
53	Vinar Systems Pvt. Ltd.	■			■							
54	Power Control Equipments	■		■								
55	Apar Industries Ltd											
56	Swagelok		■	■								
57	Aplab Ltd	■							■			
58	National Electric Coil											
59	QRE Greenesol Power Transformer Co. Pvt. Ltd		■						■			
60	EMCO Ltd	■							■			
61	3M		■						■			
62	Roberts & Schaefer		■		■							
63	Sandvik Asia Pvt. Ltd.		■		■							
64	Technical Associates Ltd.	■							■			
65	Rallison Electricals Pvt. Ltd	■							■			

S. No.	Company Name	National	International	C&I	CHP	AHP	ESP	WT	ES	Civil	CT	CHM
66	Bharat Bijlee Ltd	■							■			
67	United Conveyor Corporation (I) Pvt. Ltd.		■			■						
68	Voltamp Transformers Ltd	■							■			
69	Swati Enterprises	■							■			
70	Gactel Turnkey Projects Ltd	■									■	
71	HBL Power Systems Ltd		■						■			
72	SMS Infrastructure Ltd.	■							■			
73	Pragati Electricals Pvt. Ltd.	■							■			
74	Raychem RPG Pvt. Ltd	■							■			
75	Aquatech Systems Asia Private Ltd		■					■				
76	Modern Insulators Ltd.	■							■			
77	Elecon Engineering Co. Ltd.	■			■							
78	BCH Electric Ltd	■							■			
79	Ion Exchange India Ltd	■						■				
80	Sai Electricals	■							■			
81	Lapp India Pvt. Ltd.								■			
82	Leighton Welspun Contractors Pvt Ltd		■							■		
83	Exide Industries	■							■			
84	Essenar Transformers Pvt Ltd	■							■			
85	Finolex	■							■			
86	Diamond Power Infrastructure Ltd	■							■			
87	Cable Corporation of India Ltd	■							■			

S. No.	Company Name	National	International	C&I	CHP	AHP	ESP	WT	ES	Civil	CT	CHM
88	Transformers & Rectifiers (I) Ltd	■							■			
89	Universal Cables Ltd.	■							■			
90	Transformers and Electricals Kerala Ltd	■							■			
91	Jaiprakash Associates Ltd	■								■		
92	Universal Power Transformer Pvt. Ltd.	■							■			
93	Kostons Private Ltd		■						■			
94	LS Cable Ltd	■							■			
95	Indian Transformers Company Ltd		■						■			
96	Prolec GE		■						■			
97	D C Industrial Plant Services	■				■						
98	IMP Powers Ltd	■							■			
99	C&S Electric Ltd	■							■			
100	Brass Copper & Alloy (I) Ltd	■							■			
101	Jyoti Ltd.	■							■			
102	Kirloskar Electric Company Ltd	■							■			
103	Kirloskar Brothers Ltd	■						■				
104	KEI Industries Ltd	■							■			
105	Kanohar Electricals Ltd	■							■			
106	Gemscab Industries Ltd	■							■			
107	General Cable Energy India Pvt Ltd		■						■			
108	Amara Raja Power Systems Private Ltd	■							■			
109	Doshion	■						■				

S. No.	Company Name	National	International	C&I	CHP	AHP	ESP	WT	ES	Civil	CT	CHM
110	Eaton Fluid Power Ltd		■						■			
111	Easun Reyrolle		■						■			
112	ECE Industries Ltd	■							■			
113	Triveni Engineering & Industries Ltd	■						■				
114	Statcon Power Controls Ltd.	■							■			
115	Accurate Transformers Ltd	■							■			
116	Aditya Birla Insulators Ltd	■							■			
117	TBEA Energy (I) Pvt. Ltd.	■							■			
118	Simplex	■								■		

Where

C&I- Control and Instrumentation;
CHP- Coal Handling Plant;
AHP- Ash Handling Plant;
ESP- Electrostatic Precipitator;
WT- Water Treatment;
ES- Electrical System;
CT- Cooling Tower;
CHM- Chimney;

Source: AF-Mercados EMI Analysis

2.2.1 Key Features of the BoP market and implications for R&M Market

The key features of the BoP market along with the implications for R&M market are presented below:

a) **Classification of the BoP market**

BoP market can be categorised into three parts depending upon the service/product offerings of the players' i.e.

i. **Forward Integrated Suppliers**: There are few large integrated players like BHEL, NASL, Dongfang and L&T who offer services both in BTG as well as BoP market. These players have strong bargaining power as they can offer complete solution to a utility.

ii. **Component Suppliers**: Suppliers that deal in single or multiple components of the BoP package. This includes players such as Tecpro, Energo, McNally Bharat Engineering Company Ltd, TRF, SPML etc. There are few players in this group who are slowly consolidating and widening their base to provide multiple components in the BoP segment.

iii. **EPC or Turnkey Suppliers**: Suppliers that offer entire range of BoP services as a comprehensive package. These suppliers' offers complete BoP services and subcontract it to numerous component suppliers. This includes players like Punj Llyod, U. B. Engineering Limited, Tata Projects Ltd. etc.

The following observation can be drawn from the above:

- Due to the fragmented nature of the BoP market, the forward integrated players and EPC/Turnkey players have stronger bargaining power because such setup reduces the administrative time of the utilities in contracting and also in coordination among large number of contractors. This however raises the cost of the R&M projects.

- It has been observed that entities such as NTPC which have strong project management skills *(particularly ability to manage multiple smaller contracts)* split the BoP packages into several individual components to obtain competitive pricing.

- The market besides being fragmented is also unorganized

with presence of several local/territorial players that in several cases participate only within the state boundaries.

b) **Packaging of BoP works**

Different packaging models exist in the BoP segment. It has been observed that in R&M projects, the selection of packaging model depends upon the capability of the generating companies in managing the large number of suppliers, ability to integrate different BoP components and cost involved. While state utilities with limited capacities favour EPC contractor in case of BoP works, central generating companies such as NTPC have divided the BoP component into large number of packages (at times BoP components are divided into more than 100 packages) due to the availability of in-house capability to manage interface requirements in different BoP packages. The packaging strategy has a direct impact on the cost. Breaking of BoP components into large packages increases competition and leads to competitive prices. In case of EPC, cost increases significantly as BoP works for individual components is further sub-contracted and the entire interface risk is being assumed by the EPC contractor.

R&M experience in Bihar exemplifies the same wherein in Barauni TPP managed by BSEB, BoP was awarded on turnkey basis (owing to limited capacity of BSEB to award and monitor large number of packages), and in case of Muzzaffurpur TPP managed by NTPC, BoP was awarded as separate packages. Recently, a hybrid approach is also being adopted by the state utilities wherein the key BoP packages such as Coal handling, Ash Handling, Electrical etc. are individually awarded and rest of BoP works is awarded as one package. For e.g.: in case of R&M of Koradi TPS, (Unit-6,210 MW) the R&M project consisted of four major packages i.e. BTG, Electrical, BOP & CHP.

c) **Capacity constraints in BoP market**

Due to high level of fragmentation, no authentic information is available in public domain. Also, there is no reliable mechanism to assess the capacities. In several cases, vendors have claimed to have adequate capacity however are unable to deliver on time. BoP shortage is one of the key concern affecting Greenfield projects also. This is even corroborated by the observations of Sub Group 7 of the Working Group on Power for formulation of 12^{th} Plan that the vendors tend to claim adequate capacities but are unable to supply on time highlighting the capacity constraints in the market.

d) **Inter-linkages with other infrastructure sector**

Demand and supply of the BoP segment is also influenced by other infrastructure sectors. For example civil construction forms an important aspect of the entire BoP package. Although there exists large number of civil contractors, demand from other infrastructure sectors such as road, bridges, real estate etc. have significant impact on the timely execution of power projects.

e) **Inadequate focus on BoP**

It has been observed that while finalising scope of work for R&M project, utilities do not undertake condition assessment studies for BoP items and low priority is provided towards BoP works. Instances of compromising on the scope of BoP to fit the available budgets are common in the Indian R&M market.

f) **Quality related considerations**

Since the market for BoP is fragmented and consists of large number of small players ensuring quality of works in case of BoP is an important aspect for sustainability of R&M benefits. Awarding of contract to the reputed EPC player may not always lead to quality works as most of the work is subcontracted. Lack of assessment of the BoP vendor's quality procedures with regard to its sub-vendor may significantly impact the quality of works executed by the utility.

"One of the utilities visited by AF Mercados EMI raised concerns about the quality of material supplied by the sub vendor with regard to gear box and spares supplied for Wagon tippler. Gear box supplied by the sub-vendor was required to be replaced within 2 years of its installation due to its poor performance. Also, spares supplied for Wagon tippler were of inferior make/quality. Substandard equipment and installation service has a direct impact on the long term performance and life of the plant."

g) **Participation of BoP players in the R&M market**

In the past decade large numbers of R&M projects were awarded on nomination basis. Thus, BoP players in the market did not get adequate opportunities to participate in the market. However, similar to the trends witnessed in the BTG segment, involvement of IFI funding in the sector has been coupled with services being procured through bidding process. This has improved participation from new players and has diversified vendor base. This is also

corroborated from the level of participation/interest shown by the players during the bidding of R&M works of World Bank Financed Koradi Unit 6 (210 MW) of Mahagenco.

Table 4-5: Number of players interested in BoP for LE of Koradi Unit 6

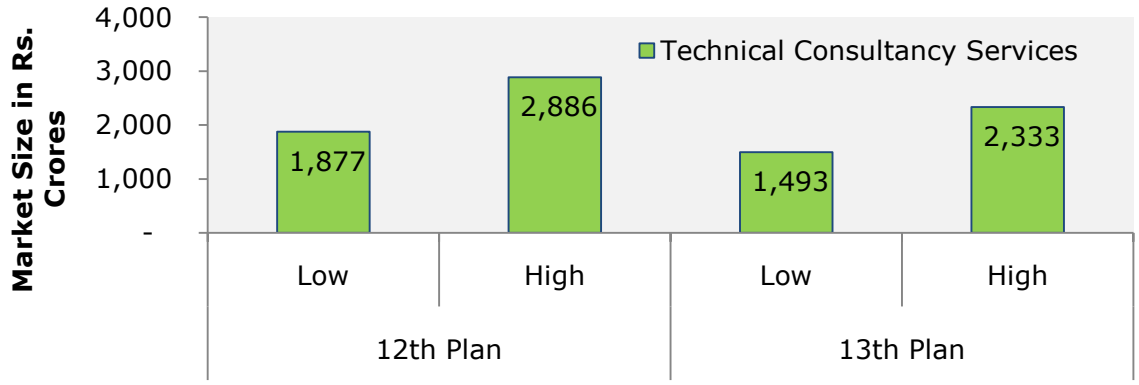
Electrical Package	Other Balance of Plant works
• BHEL • NASL • A2Z Group • Toshiba India Pvt. Ltd and • ABB	• Technofab Engineering Ltd, • U.B.Engineering Limited, • Tecpro System Ltd., • Unity Infraprojects Ltd., • Energo Engineering Projects Ltd., • OSM Engineering Pvt. Ltd., • Doshion Ltd., • Sunil Hi-tech Engineering Ltd., • SPML INFRA Ltd. and • BHEL

2.3. Technical Consultants

Specialized agencies in form of technical consultants are engaged by the utility to assist them on different aspects starting from design to implementation of R&M works.

Assessment of R&M market size indicates that technical consultancy services provide business opportunities to the tune of about ~ Rs. 3,000 Crore during the 12th Plan and about ~ Rs. 2,400 Crore in the 13th Plan. This is provided in Figure below

Figure 4-10: R&M market size of technical consultancy segment in Rs. Crore



Source: AF-Mercados EMI Analysis

The work of technical consultants can be divided according to different stages in R&M as detailed below:

1. Plant Assessment: The consultants carry out detailed technical study such as RLA, energy audit, condition assessment etc, identification and selection of best feasible option for R&M, preparation of DPR, scope finalization etc.

2. Design Consultants: The consultant provide assistance in preparation of technical specifications for tendering and help the utility in the bidding process.

3. Implementation Support Consultants: The consultant provides support to the utility in the implementation and management of R&M project during execution.

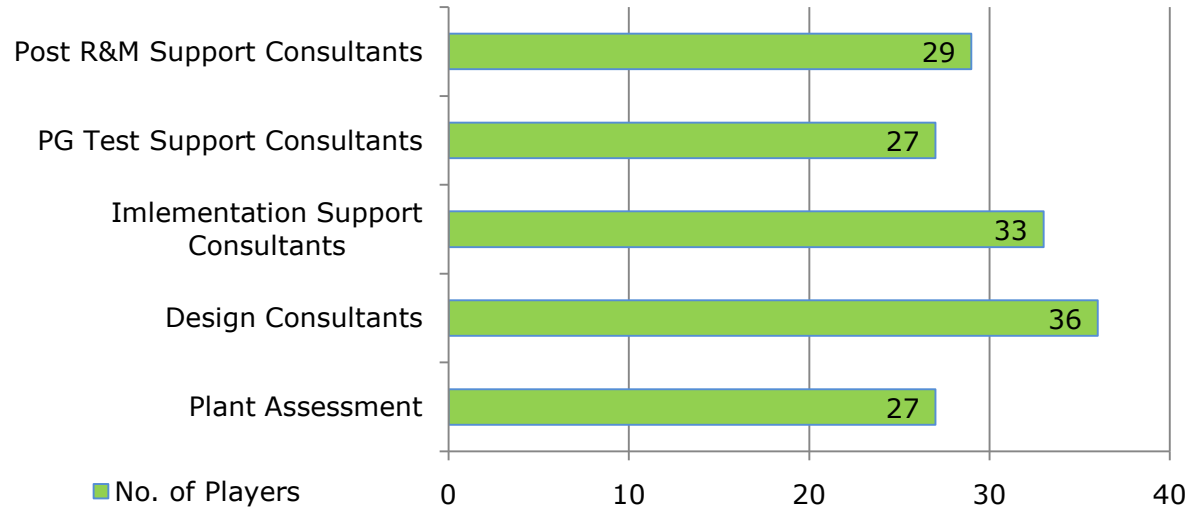
4. PG Test Support Consultants: The consultant provides assistance to the utility during PG Test to ensure conformation of the desired output of the R&M/LE project.

5. Post R&M Support Consultants: The consultant provides the necessary O&M training and other related support to the utility to ensure sustainability of benefits from the R&M.

It is worthwhile to mention that the roles of technical consultants are overlapping in nature and the utility may select different consultants or take assistance from the same consultant depending on their requirements/institutional capacity. Accordingly the contracts and duties of the consultants will be defined to ensure successful implementation of R&M.

The numbers of players have been divided according to the R&M roles as mentioned above.

Figure 4-11: Number of Players in Technical Consultancy



Source: AF-Mercados EMI Analysis

Large number of national and international players exists providing technical consultancy services. The table below maps the key technical consultants along with their service offerings.

Table 4-6: Capability Matrix of Technical Consultants

S. No	List of Companies	National	International	PA	TC	ISC	PGS	TR
1	L&T	■		■	■	■	■	■
2	NTPC Alstom Power Services Pvt Ltd	■		■	■	■	■	■
3	BHEL	■		■	■	■	■	■
4	Siemens		■		■	■	■	■
5	Dong Fang		■	■	■	■	■	■
6	Sokeo Power Private Ltd		■	■	■	■	■	■
7	Alstom India Ltd		■	■	■	■	■	■
8	Doosan		■	■	■	■	■	■
9	Thermax	■		■				■
10	GE		■		■	■	■	■
11	Toshiba		■	■				
12	Ansaldo Caldaie Boilers India Pvt. Ltd.		■	■	■			■
13	UB Engineering Limited	■		■	■	■	■	■
14	Energo Engineering Projects Ltd	■		■	■	■	■	■

S. No	List of Companies	National	International	PA	TC	ISC	PGS	TR
15	Desein	■			■	■	■	■
16	Sunil Hitech Engineers Ltd.	■		■				
17	Lanco Infrastructures Ltd.	■			■	■		
18	STEAG Energy Services (India) Pvt. Ltd.		■	■	■	■	■	■
19	Development Consultants Private Ltd	■		■	■	■	■	■
20	Mecon Limited	■		■	■	■	■	■
21	National Thermal Power Corporation	■		■	■	■	■	■
22	RWE Power International		■	■	■	■	■	■
23	Indo Engineering Projects Corporation	■		■	■	■	■	■
24	Encotec Energy (India) Pvt. Ltd	■		■	■	■	■	■
25	SGS India Pvt. Ltd		■	■	■	■	■	■
26	L&T Sargent & Lundy Ltd	■		■	■	■	■	■
27	Chadha Power	■		■	■	■	■	■
28	Vasavi Power Services Pvt. Ltd.	■		■	■	■	■	■
29	TCE Consulting Engineers Ltd	■			■	■	■	■
30	Worley Parsons		■	■	■	■		■
31	Black & Veatch		■		■	■	■	■
32	EM Services (I) Pvt. Ltd.	■		■	■	■	■	
33	Tractebel Engineering GDFSuez		■		■	■		■
34	Lahmeyer International India		■		■	■	■	
35	CPRI	■		■	■			
38	Parsons Brinckerhoff		■		■	■		
39	Fichtner Consulting Engineers (India) Pvt. Ltd		■		■	■		
40	AECOM		■		■	■		
41	SNC-Lavalin Group		■		■			

Where
PA- Plant Assessment Studies;
TC- Technical Consultancy;
ISC- Implementation Support Consultancy;
PGS- PG Test Support Consultancy;
TR- Post R&M Support

Source: AF-Mercados EMI Analysis

2.3.1. Key Features of the Technical Consultancy market and implications for R&M Market

The key features of the technical consultancy segment along with the implications for R&M market are presented below:

a) **Classification of the technical consultancy market**

Technical consultancy market can be categorised into two parts depending upon the nature of the players' i.e.

i. **Technical Consultancy as the core area**: It consist of players whose core area is consultancy and are present not in the business of main plant equipment. These are purely technical or management consulting companies. It includes players such as Steag, DCPIL, Mecon Ltd, Encotec Ltd, TCE etc.

ii. **Equipment Supply as the core area**: It consist of players whose core area is equipment supply but also provide design consulting services. These players generally provide these services in case the entire contract of R&M is given as EPC or when such studies are included in the scope of supplier. However, when the contract is split into various packages these players generally do not participate as technical consultants as their core area of work is main plant equipment. It includes players such as BHEL, Siemens, L&T, Doosan, Alstom, NASL, Dongfang, Thermax etc.

The following observation can be drawn from the study of the market:

- The bargaining power of players present only in the technical consultancy domain has been low since most of the market opportunities were never tendered out, and hence the main point of contact for nomination based allocation were the OEMs.

- There exists potential conflict of interest wherein the same equipment supplier is involved in designing of the project and actual implementation of works.

- The presence of international consulting players in the Indian market has been low in the BOP segment, particularly because business being un-fragmented with high competition among smaller local players.

b) **Limited R&M experience of Domestic consulting firms**

While there are significant numbers of technical consultants with ability to service the R&M sector, only few players have strong experience in R&M projects in India. This may be largely attributed to the focus/ preference of consultants to Greenfield field projects vis-à-vis R&M projects and limited focus of the utilities on undertaking detailed studies. Further, from the analysis of the award of past technical consultancy contracts it can be observed that many of the contracts for undertaking technical studies were given either to suppliers/OEMs on nomination basis or the scope of R&M works of selected suppliers included the scope of technical studies also. This has impeded the interest of international technical consultancy companies to enter the R&M market. It can be observed that in the last decade majority of the technical consultancy studies were given on nominated basis to equipment suppliers. However, with the increase in IFI funding i.e. World Bank, kfW, JCoal etc. the role of technical consultants in different stages of R&M works has gained due importance.

c) **New opportunities in the field of technical consulting**

The market for technical consultancy has traditionally been limited to conducting only technical studies. The State Utilities have, by and large, used the services of Consultants for carrying out RLA studies and related tests/assessment. Based on the recommendations of these studies, the State Utilities prepared their own technical specifications, prior to floating tenders. Simple cost benefit analysis was undertaken to justify the investments with no emphasis on detailed economic evaluation for selection of different options for R&M. This has limited the overall market size for technical consultants and impeded the interest of international technical consultancy companies to enter the market. However, with the greater realisation by the utilities on the need to undertake robust assessment, planning, implementation and post implementation support for executing successful R&M projects, the field and size of technical consultancy market is on a rise.

d) **Limited participation of foreign consulting companies in R&M market in India**

The technical consultancy market majorly comprises domestic consultants with limited participation of foreign consulting firms. Domestic consulting firms have significant cost advantage vis-à-vis foreign entities. In addition to the above, limited budget of the

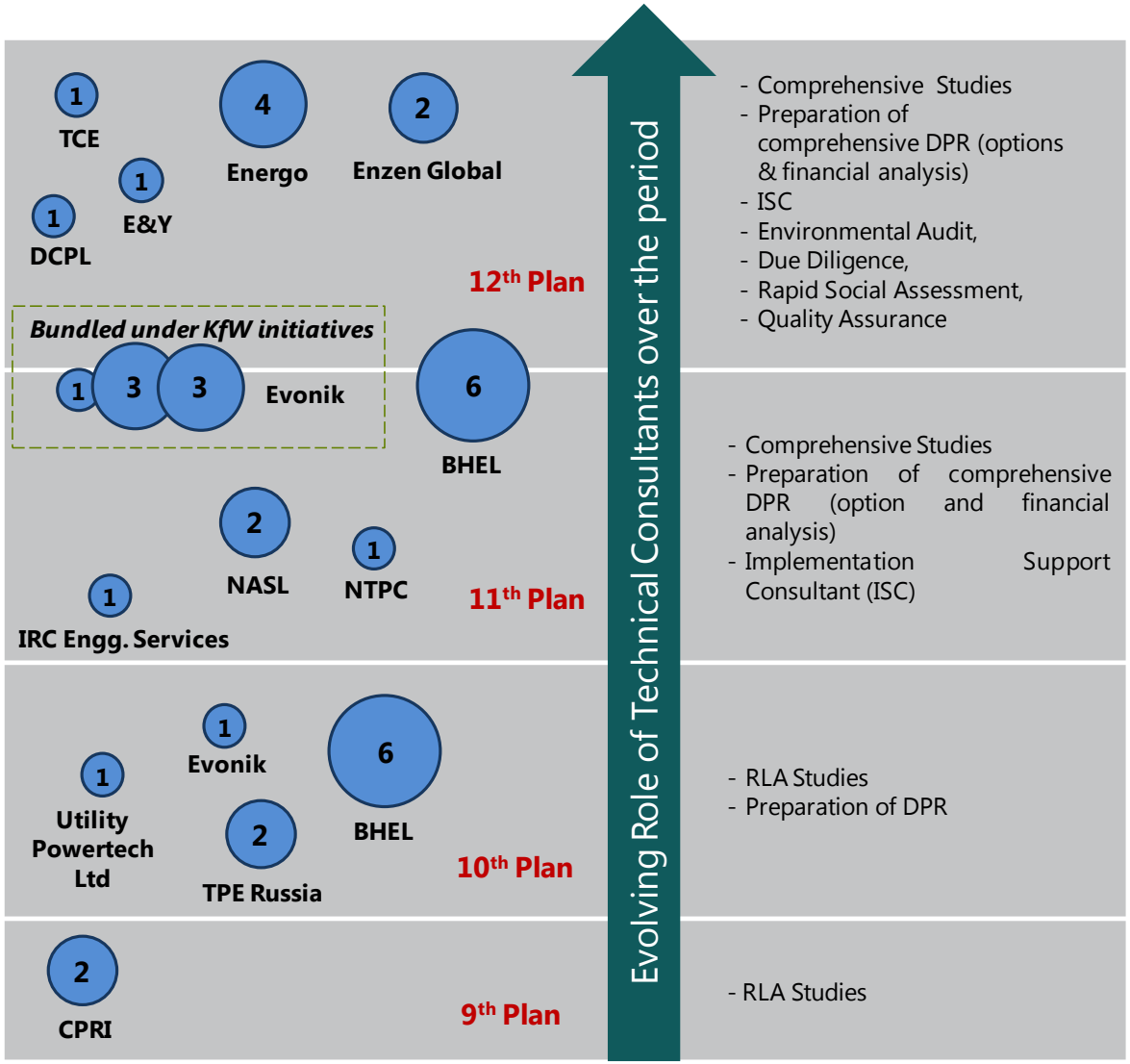
utilities with respect to studies hinders participation of foreign consulting firms.

e) **Inadequate focus on technical studies**

Inadequate focus of the utilities in undertaking technical studies has impacted the market adversely. The focus of the utilities has been limited to undertake only specific studies and assessment and discussions with stakeholders have corroborated the above fact that utilities are generally not inclined towards undertaking detailed assessment of plant. In many cases RLA/CA study is undertaken for boiler and turbine but no study is undertaken to diagnose critical areas in BoP and auxiliaries. Also, studies such as energy audit may not be undertaken at all, inhibiting identification of energy efficiency measures for improved performance of the plant. Further, in case of multiple units, it is sometimes assumed that since these units are operating under same condition, assessment of any one of the units would suffice the purpose. These actions of the utilities have limited the technical consultancy market in India.

Figure below presents the technical consultancy agencies involved in carrying out studies for comprehensive R&M works in the state sector during previous five year plans in India. The figure also depicts the evolving role of technical consultants utililised by generating companies over the period from 9^{th} to 12^{th} Plan. Initially the utilities employed technical consultants for RLA studies only but now the role of technical consultants have broadened to conducting Comprehensive Studies, Preparation of comprehensive DPRs (including options and financial analysis), Providing implementation support, conduct Evironmental Audits, Due Diligence, Assurance of Quality, Rapid Social Assessment etc.

Figure 4-12: Details of selected R&M projects undertaken by technical consultants



12th Plan	Energo	Chandrapur TPS # 1 and 2
	Energo	Bhusawal TPS # 2
	Energo	Parli TPS # 3
11th Plan	BHEL	Obra # 9,10,11,12, 13
	NTPC	Harduaganj # 7
	Evonik	GGSSTPS, Ropar # 1, 2
	BHEL	Panipat # 1
	IRC Services	Dr. N T Rao TPS # 2
	NASL	Amarkantak Ext. # 1, 2
	Evonik	Nasik TPS # 3
	Evonik	Kolaghat TPS # 1, 2, 3
	Evonik	Bokaro 'B' TPS # 1, 2 3
	Evonik	Koradi TPS # 6
10th Plan	Utility Powertech	Dr. N T Rao TPS Unit 1
	TPE Russia	Obra Unit 1, 2
	BHEL	Ukai Unit 1 and 2
	BHEL	Barauni TPS Unit 6, 7
	BHEL	KBUNL TPS Unit 1, 2
	Evonik	Bandel Unit 5
9th Plan	CPRI	Bathinda Unit 3 and 4

Following can be observed from the above figure:

- Majority of technical studies are being undertaken by equipment suppliers. Majority of the R&M projects and also technical studies for such projects have been undertaken by BHEL in past decade. Being the OEM various projects were awarded on nomination basis to BHEL.

- Role of specialised technical consultants (with technical consulatancy work as core area) has been minimal in the past. With the increasing recognition of the importance of such services, the role of such agencies is on a rise.

- With the involvment of IFI funding (green shaded box), role of technical consulting is increasingly being appreciated i.e implementation support consultants, quality assurance consultants, enviornment audit and due deligence etc.

3. Assessment of Attractiveness of the Overall R&M Market

This section assesses the attractiveness of R&M market using Porter Five Forces Model. Porter Five Forces Model is a well established globally recognised framework for industry analysis and business strategy development to derive competitive intensity and market attractiveness of a particular Industry. (Refer Box for details).

Box 4-1: Porter's Five Forces

This model identifies and analyses five competitive forces that shape every industry and helps in determining the competitive intensity and therefore attractiveness of a market. The five forces defined are as follows:

1. Competition in the industry or rivalry among the existing firms which includes industry concentration, growth, capacity, product differentiation, switching costs, brand identity and diversity of rivals.

2. Potential new entrants into industry or entry barriers includes cost advantages, learning curve, government policies, capital requirement, brand identity, access to market and proprietary advantages

3. Power of suppliers includes supplier concentration, cost and input differentiation, business integration and importance of volume to supplier

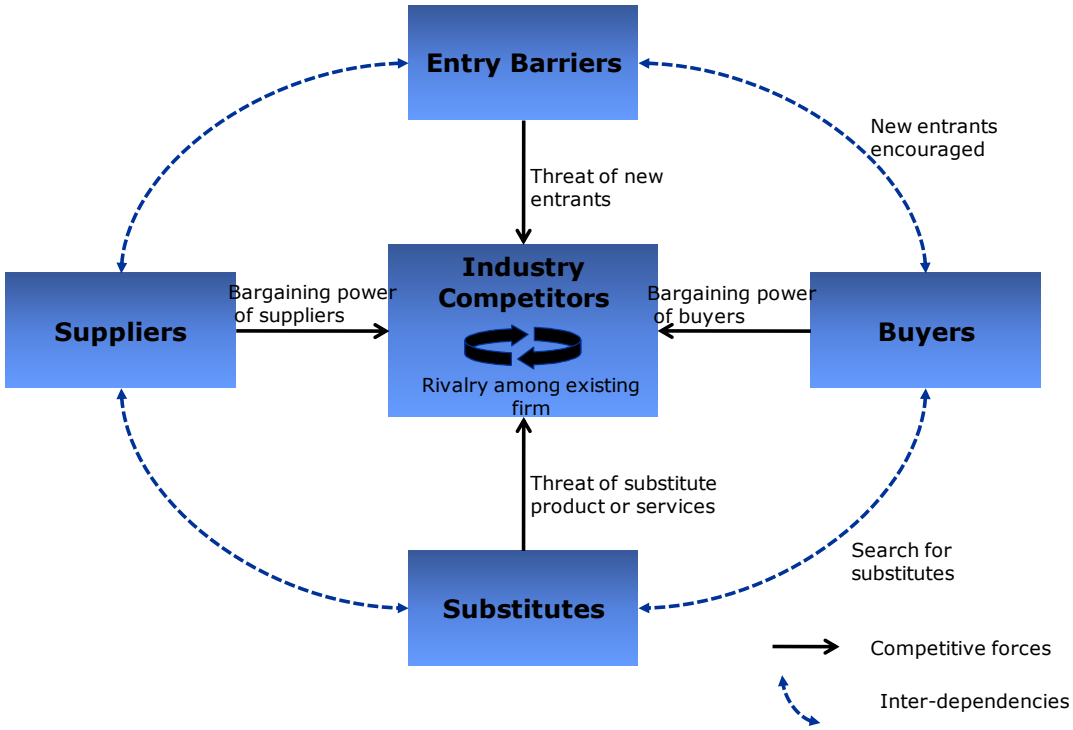
4. Power of buyers includes bargaining leverage, buyer volume, price sensitivity and buyer's incentives

5. Threat of substitutes includes switching cost, price-performance and inclination of buyer's towards substitute

Market attractiveness in this context refers to overall industry profitability where in ideal scenario the profits for all firms are driven to same profitability. However, due to the above five forces, it compels the companies to develop, strategize and make investment decisions to achieve profitability above the industry average. Moreover these five competitive forces distinguish any short term shock from structural changes and allow the companies to take advantage of undue pessimism or optimism.

Each of the above aspects has been explained from the perspective of R&M industry.

Figure 4-13: Attractiveness of R&M sector in India



Each of the above competitive forces is explained below:

a) **Bargaining Power of Buyers**

In case of R&M industry, the buyers mainly constitute the central and state generation companies (or utilities) unlike Greenfield projects wherein a significant share of new capacity is being developed by private players. Therefore, the R&M industry lack diversified base of

buyers resulting in a near monopsony[21] market. In addition to the above, the following factors further add to the barging power of the buyers:

- Central/ State utilities plays a critical role in identifying and finalising R&M requirement and have sole jurisdiction on decision to go ahead with R&M and LE work. Hence, even if viable, utility is the decision master of whether plant will go for R&M or not.
- Utilities decision to contract suppliers/technical consultants on either bid or nomination basis
- Low recognition for the need of technical consulting as a specialised service by the utilities and the market for technical consultancy has generally been traditionally limited to conducting only technical studies.
- Design of Bid (or commercial contracts) packaging influences the participation from suppliers. For example, splitting of R&M contract into more number of packages is likely to increase the participation.
- Bid document design including risks allocation is decided by the utility transferred, guarantees required.
- Utilities set the eligibility criteria suiting their risk outlook and project managerial skills.

b) **Bargaining Power of Suppliers and Consultants**

The suppliers in R&M industry include Equipment suppliers and technical consultants. The following are the main factors influencing the bargaining power of suppliers:

- Domestic equipment suppliers though limited in numbers have undertaken majority of R&M projects in the country so far. Hence, a few domestic suppliers dominate the supply market owing to their longer presence in the market.
- Supplier base with comprehensive offering is limited even after entry of few international firms especially for BTG. This is slowly changing with increased adoption of tender based

[21] Monopsony describes a market where a single buyer substantially controls the market as the buyer is the major purchaser of goods and services. For example: Military and Space Industry

selection method that is mandatory in IFI supported procurement

- Policy encourages domestic manufacturing of equipments.
- Price competition prohibits use of international experts by domestic consultants that have strong international presence.
- Participation from international players has been increasing, and is generally through a local partner.

c) **Entry Barriers**

This factor influences the interest of potential entrants. Appropriate levels of barriers are essential to protect the profitability of existing supplier base as free entry and exit of firm in Industry would subdue the profit of firms to nominal levels and hence, making the industry unattractive. The key entry barriers currently being faced by potential entrants are listed below:

- Policy favours domestic manufacturing of equipment.
- Limited clarity on the size of the R&M potential and commitment of the central/state utilities to implement R&M projects.
- Very few opportunities in open market. Historically, most of the opportunities were directly initiated with the OEM. Hence, these opportunities never entered the market.
- Limited brand awareness of potential entrants and smaller players in Indian market.
- Burgeoning market for Greenfield projects becomes the first preference.
- Technical studies being undertaken through suppliers with cost included in the supply contracts impacting the market for technical consultancy organisations.
- Limited cases of success in the past establish performance improvement and financial returns.

d) **Threat of Substitutes**

A substitute to R&M project could be Greenfield projects (coal, gas, hydro or renewable). The financial viability of R&M project is largely contingent on the extent of improvement of plant performance and cost economics vis-à-vis Greenfield project. The rising cost of coal based Greenfield projects currently estimated to be around Rs. 5-6 Crore per MW, has enabled R&M projects to emerge out as the least cost option for capacity addition under certain condition. Factors influencing the threat of substitutes are summarised below:

- Greenfield projects after commissioning have higher efficiency; higher PLF and better SHR than plants that have undergone R&M/LE.
- High capital cost of Greenfield coal based power projects.
- Long gestation period for Greenfield projects.
- Continuing fuel shortage for Greenfield coal and gas based power projects.
- Relative assurance and continuity of fuel supply for R&M projects.
- Delay in regulatory, environmental and forest clearances in case of Greenfield projects results in cost and time escalation.

e) **Competition among the existing firms**

Increased rivalry or competition among the existing firms results into lowering of cost of service which is in the interest of the buyer. Appropriate level of competitive pressure is essential for improvement in the quality of service offering beside the reduction in cost. R&M industry in India is largely concentrated around limited players which in turn have resulted into high level of competition. Following are the factors driving the rivalry among the existing firms:

- Lower participation (in comparison to interest witnessed in Greenfield projects) due to high risk involved in R&M projects.
- High competition due to limited opportunities.
- Jobs largely concentrated towards few players.

Based on the above assessment of various competitive forces, the R&M industry attractiveness is evaluated in the matrix below. The above matrix rates each of the above influencing competitive force under following categories:

- Favourable - enables the growth and attractiveness of the industry and benefits all stakeholders.
- Moderate – Moderately impacting the growth and attractiveness of the industry and there is further scope for improvement.
- Unfavourable – Against the overall growth and interest of the industry.

Table 4-7: Evaluation matrix for attractiveness of R&M Industry[22]

Competitive Forces	High Level	Medium Level	Low Level	Impact on Attractiveness
Buyer Power				**Unfavourable**
Threat of Entry Barriers				**Moderate**
Rivalry				**Moderate**
Threat of Substitutes				**Favourable**
Supplier (OEMs/Equipment vendors) Power				**Moderate**
Supplier (Technical Consultants)				**Unfavourable**
Overall Attractiveness				**Moderate**

As evident from the above matrix, the overall attractiveness of the R&M industry is moderate (or neutral) and needs to be further improved for enhancing the interest of the players. The main reasons for the moderate level of attractiveness is higher bargaining power of buyers compared to that of supplier. It is worthwhile to also understand the potential impact of the prevailing competitive forces in R&M industry on the interdependencies. Following could be some of the possibilities:

- Central/ state utilities may promote Greenfields project as preferred alternative over R&M option primarily due to lack of confidence / experience of successful R&M projects and their

[22] It is worthwhile to note that the evaluation matrix is worked out based on the overall perspective of the R&M sector and does not reflect the skewed interest of individual stakeholder class.

commitment on implementation of R&M projects.

- R&M decision is delayed resulting in altering the risk profile (due to deteriorated performance) of the project or projects with potential to be improved being retired prematurely.

- Moderate level of entry barriers may lead potential entrants to either acquire or form alliances with existing players. This would benefit the sectors as alliances (or joint ventures) would strengthen the technological capabilities and skills of the players particularly in the technical consulting space. It would also enable supplier not present across BTG and BoP, to form alliance and offer comprehensive products.

In summary, a SWOT analysis of R&M market is presented below:

Strength	**Weakness**
• Cost effective in several cases when compared to Greenfield projects • Significant domestic equipment manufacturing capacity added in last few years which remain largely unutilised. Further domestic capacity is supplemented by import capabilities • Short gestation period, limited issues related to clearances etc.	• Lack of appropriate regulatory incentives for utilities to undertake efficiency improvement program • Market dominated by few players (till recently) • Limited ability of utilities to manage R&M projects • Weak opportunity pipe in the market • Limited certainty of market size
Opportunities	**Threats**
• Huge R&M potential in next decade – 23,840 MW for LE and 25,520 MW for R&M • Slowdown in Greenfield projects implementation due to fuel shortage, rising cost of natural gas, delays in environmental and forest clearances • Huge potential for reduction of GHG potential at national level • Regulatory initiative viz. PAT scheme encourages plant owners towards efficiency improvement	• High cost of R&M projects due to Skewed risk-benefit balance in contractual arrangement • Difficulty in controlling project scope, schedule and budgets that causes delays in completion of R&M • Newer and efficient technologies (viz. supercritical power plants) • Limited success stories leading to uncertainty with regard to achievement of R&M benefits. • Poor O&M practises of the utility impacting the sustainability of R&M benefits. • Poor financial health of state utilities

Chapter - 5

Assessment of Key Challenges

As observed in the preceding sections the potential and the size of R&M market is reasonably large. The assessment also indicates that in most cases R&M works out to be a viable alternative for utilities that are faced with various alternatives (operate, retire, R&M, LE etc). This presents a huge market opportunity for both suppliers and technical consultants present across the R&M value chain. However, ever since its initiation in 1980s, the R&M market continues to face a variety of challenges and issues that have impeded market growth and scale up plans. The focus of this section is to identify these challenges and provide actionable recommendations to address them.

The key challenges impeding market development are categorized into the following categories:

- Market related challenges
- Funding related challenges
- Regulatory related challenges
- O&M related challenges
- Contracting related challenges
- Institutional related challenges
- Implementation related challenges

Each of the above along with recommendations is discussed below:

1. Market Related Challenges

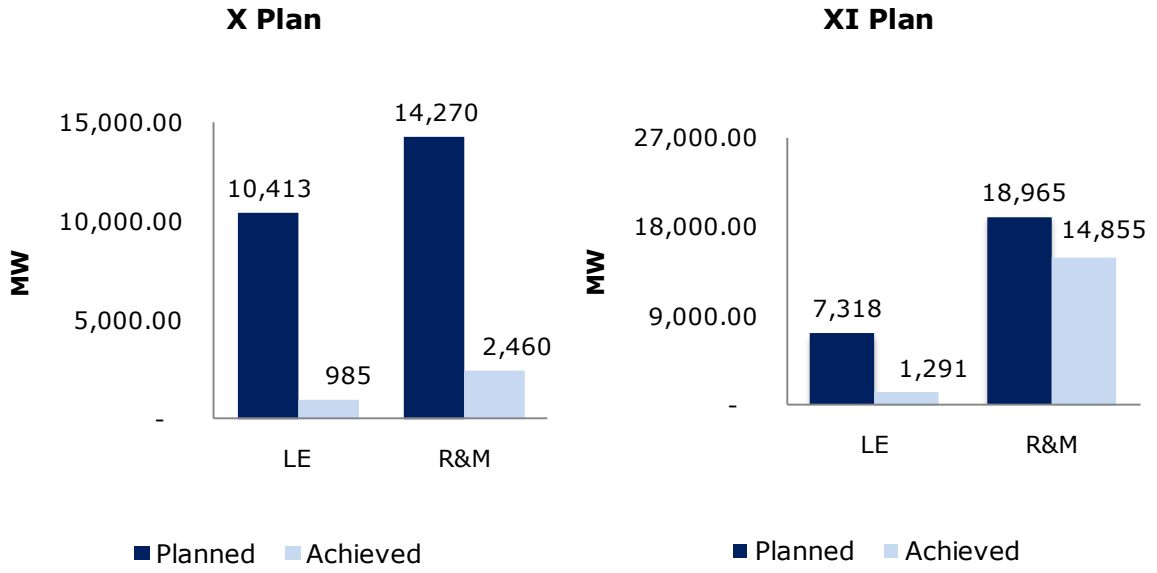
Some of the key market related concerns that have emerged during discussions with various stakeholders are discussed below

a) **Limited market opportunities**

Despite of significant R&M potential in the country, commercial opportunities in the market have been limited. The actual achievement vis-à-vis targets planned in 10th Plan for LE and R&M has been only 9% and 17% respectively. Further, during 11th Plan, the actual achievement vis-à-vis targets planned for LE and R&M has been only 18% and 78% respectively. The Planned capacity

and achievement of LE and R&M works during 10th and 11th Plan has been provided in figure below

Figure 5-1: Planned capacity and achievement of LE and R&M works during X and XI Plan



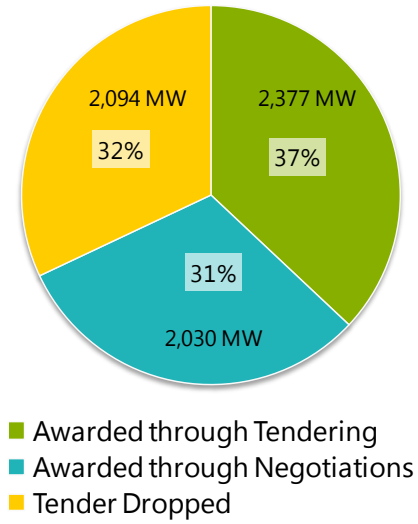
Source: National Electricity Plan and Quarterly Review Report- Renovation, Modernisation and Life Extension of Thermal Power Stations, (January – March; 2012), CEA

b) **Award of contract on nomination basis**

As explained in earlier chapters, utilities have adopted two different models (nomination and tendering of projects) for selection of suppliers for undertaking R&M works. Award of projects on nomination basis to OEM's, have restricted competition in the market and has acted as major entry barrier for various suppliers. Past analysis of R&M market opportunities indicates that out of total R&M capacity of 6501 MW on offer, ~ 31% (2030 MW) of the capacity was awarded on a nomination basis. Out of the tendered capacity of 4471 MW, majority (~47%, 2094 MW) of the tenders were dropped. Some of these tenders were dropped even after price negotiations. For example: In case of Koradi Unit 1-4 of Mahagenco, tenders were floated for undertaking R&M works but were subsequently cancelled for various reasons. Refer Box below for details.

Figure below presents the breakup of R&M projects offered in MW capacity during 2000-2007.

Figure 5-2: Break-up of R&M projects offered during 2000-07 in MW and in percentage

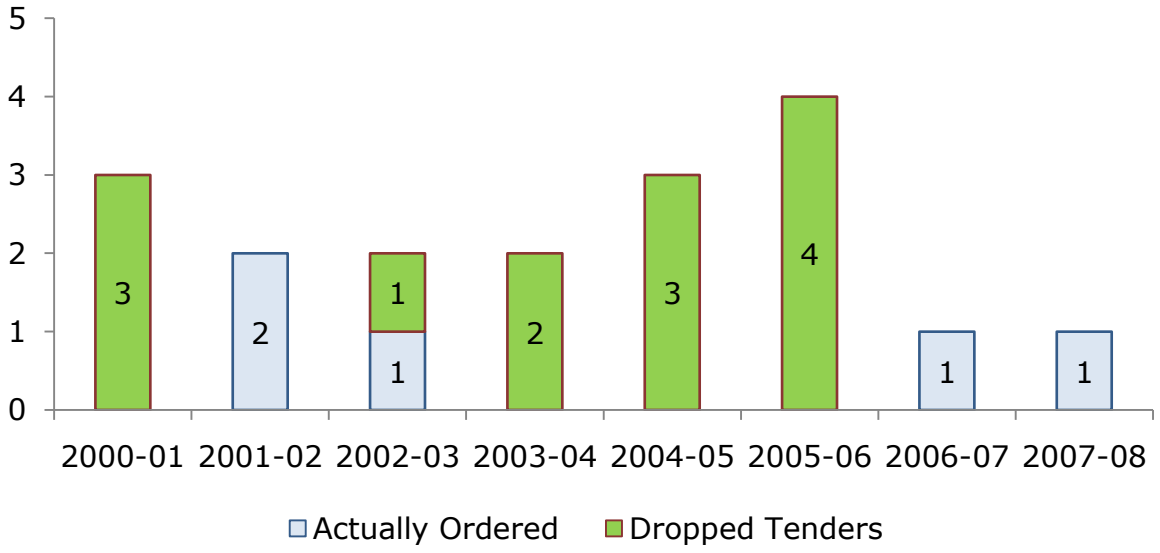


Source: NASL Presentation

In total ~18 tender opportunities (equivalent to 4471 MW) were offered to market during 2000-2007, of this only 5 (equivalent to 2377 MW) were awarded to bidders.

Figure 5-3 presents year wise break-up of the number of awarded and dropped tenders during 2000-2007. Thus, it can be observed that contracts awarded on nomination basis vis-à-vis that on tender were almost equivalent.

Figure 5-3: Break-up of awarded and dropped tender for R&M projects



Source: NASL Presentation

Box 5-1: Market opportunities vis-à-vis Dropped tenders in the market

Market opportunities vis-à-vis Dropped tenders in the market: Case of Maharashtra Power Generation Corporation Ltd. (Mahagenco)

Plant	Details of the opportunities	Decisions on tenders
Koradi Unit 4, Mahagenco	Mahagenco planned to undertake R&M works in 2004. Global Tender was floated in May 2004 and technical bids were opened in October 2004.	Tender was cancelled in December 2004 as it was planned to tender R&M works of two units simultaneously instead of one unit alone.
Koradi Unit 1 and 2, Mahagenco Nasik 2x140 MW Paras1x62.5 MW	Global Tender for undertaking R&M works was floated in January 2005 and technical bids were opened in May 2005. Due to major variation in one of the commercial bid, post bid meetings were held and revised bids and price bids opened in September 2005. Lowest price bid (L1) was higher than the estimated cost by Mahagenco. Based on this, an economic evaluation of expenditure on LE works on Units 1-4 vis-à-vis a new plant of 500 MW was undertaken by the utility.	Based on the findings of the evaluation it was analysed that new project is more viable and thus, tenders for Unit 1 and 2 were cancelled. Subsequently, Mahagenco cancelled the R&M proposals of other Units of capacity less than 200 MW. This included - Nasik 2x140 MW –at tenderizing stage. - Paras1x62.5 MW –after Tenderizing stage

Source: Interactions of AF Mercados EMI with the officials of the KTPS, Mahagenco; Presentation by Mahagenco on Renovation & Modernisation and Life Extension Programme, Mahagenco's Experience

Delay in finalisation and award of contract at the utility end has also been observed as one of the major concerns by the suppliers.

c) **Non-existence of market for technical consultants/ Lack of recognition for the need of technical consulting as a specialised service**

The market for technical consultancy has generally been traditionally limited to conducting only technical studies. The State Utilities have, by and large, used the services of Consultants for carrying out RLA studies and related tests/assessment. Based on the recommendations of these studies, the State Utilities generally prepared their own technical specifications, prior to floating

tenders. Simple cost benefit analysis was undertaken to justify the investments with no emphasis on detailed economic evaluation for selection of different options for R&M. Further, from the analysis of the award of past technical consultancy contracts it can be observed that many of the contracts for undertaking technical studies were either given to suppliers/OEMs on nomination basis or the scope of R&M works of selected suppliers included the scope of technical studies. This has limited the overall market size for technical consultants and impeded the interest of international technical consultancy companies to enter the market. However, with the greater realisation by the utilities on the need to undertake robust assessment, planning, implementation and post implementation support for executing successful R&M projects, the field and size of technical consultancy market is on a rise. Recent years accordingly have seen several new firms being involved in actual R&M jobs in the country.

Recommendations:

1. Utilities should prepare R&M roadmap to reflect management commitment towards implementing the R&M project through fair and transparent process. This would enable the suppliers to plan their capacities and map the requirements of the market with their respective service offerings in order to service the market when the opportunity is offered in the market.

2. Regulators in each state need to design incentive and enforcement mechanism that encourage utilities to undertake R&M of their inefficient and old plants. It is further suggested that this issue may be discussed and deliberated at Forum of Regulators in order to formulate appropriate regulations that are implemented uniformly across states.

3. R&M Opportunities should not be offered on a nomination basis to any particular supplier. In order to develop the market, it is important to encourage competition by awarding R&M projects through fair, transparent and competitive mechanisms.

4. CEA should prepare standard bid documents which could assist utilities in awarding R&M projects through tendering/competitive process. The bid document should also reflect the evaluation procedure and timelines for evaluation and award of contract.

5. A single entity should generally be avoided to assume the role of design consultant as well as the supplier and potential conflict of interest wherever possible should be avoided.

6. Independent assessment through specialized agencies to develop the technical specifications, and the scope of work should be mandatory. Also,

utilities must be required to undertake a detailed cost benefit analysis by estimating the net present value (NPV), rate of return (IRR), payback period and cost-benefit ratio for different R&M options. Analysis should also include the impact on key parameters such as life, PLF, heat rate, efficiency etc. Further, the robustness of the selected option should be tested through scenarios such as time and cost over-run, shortfall in capacity, change in shut-down, heat rate or a combination of adverse factors. The financial institutions and regulatory commissions must make this mandatory while approving financing for the project and before providing in principle approval for R&M projects.

7. While need for comprehensive R&M is well established as it leads to overall benefit at the plant level, exploring approach involving Component Based Retro-Fitting can also be considered by utilities on case to case basis. This approach brings several benefits - Reduced time of implementation, Obviates need for huge investments. Success achieved in such smaller modules also builds up confidence of the utility to take up R&M for remaining components in the near future

8. **Bulk tendering**

   In order to increase participation of suppliers/technical consultants, it is important to provide adequate bulk opportunities to the suppliers (that bundles a few R&M opportunities together). Besides, suppliers this approach has substantial benefits for utilities as well. For the utilities bulk tendering reduces significant time gap involved in contracting and bidding and may also provide price benefits related to economies of scale.

   - Bulk tender has already been adopted by NTPC for their R&M projects.

   - Another option that could be considered is the adoption of ***Strategic Alliance Model (SAM)***, wherein the Utility develops strategic alliance with R&M Vendor, through a competitive bidding process for a longer-time frame (say 4-5 years). The key difference between a standard R&M tender and a Strategic Alliance model is that under the former R&M vendor is selected on a project-wise basis; whereas SAM requires strategic partner's support on programmatic basis to assist the Utility for a bundle of projects identified upfront within the contracted timeframe. A similar model has in fact been adopted by the National Grid of UK for implementing transmission projects. National Grid was faced with challenge of executing large investments and has therefore opted for alliances that consist of partnerships with equipment and EPC players on a programmatic basis over an extended timeframe. Some benefits of this model are: (i) reduced effort and costs in tendering; (ii) shorter lead times in project implementation due to advance planning, resource commitment and common logistics

planning; (iii) savings on equipment cost due to large package size; and (iv) superior practices, as good credible players with solid experience would be able to participate.

9. **Role of CEA/Ministry of Power**

The plants identified in the National Perspective Plan for undergoing R&M/LE could be taken up for feasibility studies/RLA studies simultaneously through a common tender process that allocates the projects to a various technical consultants present in the market. The following process could be adopted:

- RLA studies are performed on plants (units) identified for R&M/LE in the National Perspective Plan. This is allotted through a common tender process to various technical consultants present in the market
- Delay in obtaining requisite environmental and other clearances for R&M needs to be examined further and appropriate changes as required should be considered by Ministry of Environment and Forests (MoEF).
- The scope of work for each unit is finalized based on the studies conducted in the previous step.
- The scope finalized above is then input into the standard bidding documents already being designed by the CEA. This process is decentralized and taken up by respective utilities. The utilities based on the tender response allot the projects for R&M to various implementation vendors.
- The above is likely to accelerate the pre-implementation process and permit harnessing the identified potential.

2. Funding Related Challenges

Currently, most of the R&M projects are being taken up through public sector funds and loans/grants from the International Financial Institutions (IFIs). In a regulated scenario, the requirement (unless it is a grant), are likely to be met through the normative structure i.e. 70% loan borrowing from commercial banks and 30% self financing/equity contribution from the state. Table below indicates the funding requirement under such scenario:

Table 5-1: Fund requirement break-up for 12th and 13th Plan

Fund requirement break-up (Rs. Billion)	%	12th Plan	13th Plan
Fund Requirement from its own resource/equity	30%	143	73
Fund Requirement through borrowings	70%	333	172
Total		**476**	**245**

At the estimated potential, a total commercial loan of ~ Rs. 333 billion would be required to finance the R&M projects planned during the 12th plan period. This has also been recognized by the 12th plan working group wherein the total funding requirement for the power sector as a whole has been estimated at Rs. 13725 billion (including funds required for R&M). Considering the overall funding requirement of the power sector, several constraints could emerge specifically for R&M projects:

- As per the prudential norms stipulated by RBI, the credit exposure to single borrower and group shall not exceed 15% and 40% respectively of Bank's capital funds.
- As per data published by RBI, power sector alone deploys 9.3% of the gross bank credit as of 31st March 2013. The working group for XII plan estimates a total requirement of power sector from scheduled commercial banks (excluding NBFCs, ECBs, IFI loans, insurance companies etc) as Rs. 2705 billion. Considering this, the exposure of power sector is likely to hit the limits set by various commercial banks. This trend may lead to serious financing issues for the R&M projects.
- Also, the IFI support in several cases has been to demonstrate the benefits of Energy Efficient R&M in the country through select pilots. The funding channelized to R&M is unlikely to continue at the scale it is being received currently. Any reduction in IFI funds for R&M is likely to further stress the market and increase the requirement of funds from commercial banks.
- Further, utilities will need approx. Rs. 143 billion equity investment to finance implementation of R&M during the 12th plan period. Considering, the current financial positions of Gencos, this is unlikely to be funded by internal finances. Hence, alternative modes including private financing need to be explored to enhance the financing possibilities for utilities.

Recommendations:

1. Private sector can play an important role in supporting the R&M market not only through provision of adequate funds but also through O&M support so that the efficiency gains realized during the R&M are sustained over long-term.

2. Private-Public-Partnership (PPP) models for R&M (and also for O&M) should be promoted. CEA in its National Perspective Plan for R&M has suggested several models for private sector participation. These are elaborated below.

Table 5-2: Models for Private Sector Financing

Options	Modality
Lease, Rehabilitate, Operate and Transfer (LROT)	• Private promoter (PP) would take over the power station on a long -term lease, say 10 years or more wherein PP would invest and carry out the R&M of the power station and would also take over its operation and maintenance • After the completion of the contracted lease period, either the lease may be renewed or the station may be transferred to the power utility. For e.g. discussions with the MPPGCL officials revealed that due to paucity of funds, R&M of Satpura TPS is being explored on LROT basis
JV between Utility and Public/ Private Companies	• A new JV company is formed of state utility or generating company and selected public/private company to undertake the R&M/ LE works and subsequently own, operate and maintain the plant. The selected entity could be an equipment vendor, EPC player, private or public generating company. • BSEB undertook the R&M of its Muzzaffurpur Plant (Unit 1 and 2 (2x110)) by forming a new company, KBUNL, as a Joint Venture (JV) of the State Power Utility (BSEB)/ State Government (Government of Bihar) and public power utility (NTPC)

These models though discussed at various levels, have been implemented only in a few cases. Large scale adoption of such models has been limited. Therefore, it is recommended that such models must be actively considered by the generating company for financing R&M projects and suitable modalities can be designed to address the issues of manpower involved in the same.

3. The standard bid document and contracts being designed for R&M should also have provision of introducing R&M through models or a separate

exercise should be undertaken to prepare standard documents for such models. This could promote increased adoption of such models by the utilities.

4. Demonstration projects being taken up by IFI could selectively include provision of such models to demonstrate benefits. This while on one hand would support the utilities through private financing, on the other hand will also encourage private players in the market.

3. Regulatory Related Challenges

Some of the key regulatory concerns that have emerged during discussions with various stakeholders are discussed below.

a) **Misaligned Benefit Sharing**

The current regulatory framework provides limited incentive to the generating company to improve efficiency of the generating unit and implement R&M/LE.

- Under the annual tariff setting process, benefits of improved efficiency achieved after R&M are fully passed on to the consumer during tariff revision. Further, the regulator adjusts the target value (implies improved values) for plant performance parameters viz. auxiliary consumption and station heat rate during the tariff determination exercise every year.

- In an MYT framework, during the control period, if a generator over achieves its targets, it may retain the benefit for the remaining years of the control period. However, the benchmarks for the next control period are likely to be reset based on the actual performance in the previous years. This acts as a disincentive for the generator as the performance improvement achieved is retained only for a short period.

- The risk in both the above cases lies with the utility wherein failure to achieve the norms leads to lower revenue recovery, and the benefits of overachievement are passed onto the Discoms/consumers.

b) **Limits to R&M investments**

R&M investments need to consider the technical realities of specific power plant and should be based on the fact that even at higher quantum of R&M investment, the R&M project may be viable as long as the improvement in the plant parameters viz. SHR and

auxiliary consumption achieved after R&M is significant enough to make the project financially viable.

c) **Provision of Allowance**

As per CERC tariff regulations 2009-14, a special allowance of Rs. 5 lakh/MW-year is allowed under alternate efficiency improvement option other than R&M, to be recovered by coal/lignite based thermal plants in 2009-10 (to be subsequently escalated @5.72% each year during the period 2009-14) post completion of the useful life of a plant. While the above provision encourages improvement of plant performance by alternate routes viz. improvement of O&M practise, it can under best case sustain the plant performance but not achieve the level of efficiency improvement that can be achieved through comprehensive R&M.

Recommendations:

1. Generating companies undertaking R&M should be permitted to retain a part of benefit achieved through R&M. The tariff regulations for Gencos should explicitly provide for provision that permit them to retain a part of benefit achieved through R&M. This is also consistent with the Tariff Policy that envisages providing incentives to utilities for undertaking R&M, relevant section is reproduced below

   "Renovation and modernization (it shall not include periodic overhauls) for higher efficiency levels needs to be encouraged. A multiyear tariff (MYT) framework may be prescribed which should also cover capital investments necessary for renovation and modernization and an ***incentive framework to share the benefits of efficiency improvement between the utilities and the beneficiaries with reference to revised and specific performance norms to be fixed by appropriate Commission****. Appropriate capital costs required for pre-determined efficiency gains and/or for sustenance of high level performance would need to be assessed by appropriate Commission."*

2. Net financial returns should be the determining factor rather than capital expenditure incurred on R&M. The actual cost depends on a variety of factors including: (i) Periodicity and quality of regular maintenance and overhauls; (ii) Overdue maintenance works imply a larger scope of R&M works; and (iii) Age, technology and condition of the plant.

3. The capital cost incurred for R&M should be capitalised and not passed as O&M expense. Capitalisation is likely to increase the capacity charge however efficiency improvement on account of better heat rate and lower auxiliary consumption is likely to bring down the energy charge.

4. O&M related challenges

O&M practises being followed by state owned generation companies in India are weak. Most of the state owned generating companies do not adhere to the schedule of annual maintenance and periodic capital overhaul of the plant leading to deterioration in the condition and performance of the plant. Most of the DPRs (pre-R&M study) reviewed corroborate the above fact. Poor O&M practises can offset the expected efficiency gains of a successful R&M project before the stipulated extended life of the plant. The box below substantiates the weak O&M practices of various state generation companies.

Box 5-2: Weak O&M practices of various State Generation Companies in India

Most of the utilities do not adhere to the Maintenance Schedule and periodic Capital Maintenance Schedule.

PTPS, HPGCL - Annual Maintenance of majority of Units at PTPS has been delayed. The delay ranging from 107 to 328 days in respect of most of the units was found during the CAG review period from 2005-06 to 2009-10.

GSECL- Annual Maintenance/Overhauling (AOH) (part of O&M) of Units of majority of TPS was carried out with a delay up to 11 months from the date on which AOH was due to be taken up.

BSEB - Annual Maintenance has not been undertaken at regular intervals. For Barauni TPS Unit 6 the first and last capital maintenance was done during October 1988- November 1989 and for unit 7 during July 1992-May 1993 respectively.

UPRVUNL- Annual Maintenance has not been undertaken at regular intervals. Inordinate delays observed in case of (i) Obra 'A' & 'B': 21 to 58 months, (ii) Parichha: 24 to 34 months, (iii) Panki: 19 to 22 months, Harduaganj: 17 to 20 months and (iv) Anpara 'A' & 'B': 13 to 20 months in various units.

In most of the states the shutdown of the units for planned maintenance depends upon the power availability situation of the state and thus, annual maintenance of majority of units is delayed in many states.

Poor O&M practices impacts the long term performance of plant and leads to its continual deterioration.

Source: CAG Audit Reports and Interaction of AF Mercados EMI with officials of various utilities

In view of the above, the following recommendations emerge:

Recommendations:

1. **Preparation and implementation of O&M action plan**

   O&M practices of the plant should be reviewed at the start of the project and based on the assessment a long term O&M action plan like preparation of O&M manuals including preventive, capital and breakdown maintenance procedure / guidelines should be formulated. This should include the time schedule and maintenance requirements for each component, institutional structure, resource requirements in terms of both financial and personnel etc. Further, the plan so formulated should be approved at the highest authority and credible actions should be taken to implement the plan on priority. *The financial institutions and regulatory commissions must make the preparation of O&M action plan mandatory while approving financing for the project and before providing in principle approval for R&M projects.*

2. **Engagement of specialised agencies**

   Generating Company can engage specialised agencies to undertake O&M of the plant. Sterlite Energy has engaged Evonik Energy Services India (now Steag Energy Service India Ltd.) for O&M of their 4x600 MW coal based TPS at Jharsuguda, Orissa. Appropriate mechanisms also need to be developed to engage the OEMs/ equipment vendors to assist the generating companies in building sound O&M practices.

   - One of the mechanisms can be wherein generating company can include O&M supervision in the contract of executing agency for a pre-specified period. However, a right mix of balance needs to be ensured between performance and guarantees. In the case of Korba East TPS (Unit 1 to 6), O&M supervision was included in the contract of executing agency to meet and sustain the guaranteed performance for a period of three years.

   - Demonstration projects being taken up by IFI could selectively include provision of such models (O&M through independent private parties) to demonstrate benefit of such models. Promotion of such models would also promote private sector participation in the field of R&M.

5. Contracting related challenges

Contracting plays an important role in encouraging or discouraging players to participate in the R&M projects. The contracting undertaken by the state generation companies have been largely skewed with significant risk being passed on to the contractor. During consultation process with suppliers and consultants, several issues with respect to contracting were highlighted which

impedes the interest and participation of players in the market and are provided below

a) Weakly defined scope and open ended statements in the commercial contract shifts the risk substantially to bidders. Clauses such as the following: *"Anything not mentioned above, but required for safe, efficient, reliable and requirement by the engineer-in-charge has to be carried out by the bidder within the same time frame and with no financial implication"*[23] increase the risk of contractor substantially leading to increased risk premium or price for absorbing/sharing higher risk.

b) High level of guarantees that results into unfair balance of risk-reward and in turn high price of the project. Further, sometimes guarantees are asked for the entire plant/system while the works have to be implemented on certain components of the plant altering the risk profile of the contractor's substantially. Example: in case of R&M works of Bathinda, NASL agreed for guarantee for total auxiliary power of the plant while it was responsible for undertaking R&M works related to specific components of the plant such as boiler, turbine and parts of C&I etc. Ideally, auxiliary power for equipments to be replaced should have been sought and guaranteed for.

c) Delays in bid evaluation and award causing time gap between technical studies and commencement of actual work. It normally takes around 3-4 years between the technical studies (RLA, DPR preparation) and actual award of contract (and commencement of R&M work). This combined with the inadequate technical information provided prior to bid disables the executing agency to realistically predict the condition of the equipment before they are opened and inspected which ultimately increase the risk profile of the project. The box below indicates time gap between completion of plant assessment studies and commencement of R&M work in few R&M projects.

Box 5-3: Time gap between studies and Execution of Work

Table below presents the time gap between the completion of RLA study and execution of work.

Plant (Unit)	Completion of RLA study	Actual Date of Start of Work

[23] Compiled from the review of contract documents of plants undergoing R&M and stakeholder consultations

Bathinda Unit 3 (110 MW), PSPCL	March 2001	January 2010
Bathinda Unit 4 (110 MW), PSPCL	December 2001	November 2011
Ukai TPS, Unit 2 (120 MW), GSECL	April 2003	August 2008
Barauni TPS, Unit 6 (110 MW), BSEB	May 2006	November 2009
Bandel TPS, Unit 5 (210 MW), WBPDCL	December 2006	February 2012

Source: CEA and interaction of AF- Mercados EMI with various utilities

d) Packaging of R&M projects plays a vital role in participation of players in the market. Different packaging strategy along with the related issues adopted to implement R&M projects in the country are discussed as below:

- **Turnkey (or EPC) basis**

  An arrangement wherein the utility provides the contract/responsibility of implementing entire R&M works to a single entity. The benefit of such approach is that utility has to coordinate with single entity/supplier and the responsibility of successful implementation of the project rests with one supplier. In the case of turnkey projects, it is easier for the utility to fix the guarantees and warrantees with the supplier. Further, implementing projects on turnkey basis reduces the contracting time for the utilities. However, the cost of implementing such projects is high due to high risk premium charged by the supplier. Most part of the work is subcontracted and the turnkey provider/supplier is not only responsible for managing the entire works including that of the subcontractor but also for ensuring quality of such works. This approach has been followed in implementation of large number of R&M projects such as Korba (East) Thermal Power Station- Unit 1 to 4 (4x50 MW) and Unit 5 & 6 (2x120 MW), Ukai TPS unit 1 and 2 (2x120 MW) etc. It must be noted that the adoption of this model has significantly impacted the R&M market of the country as only few players in the market have the capability to perform work on Turnkey basis. Thereby, large number of players did not have the opportunity to participate in the market severally impacting their interest.

- **Division of R&M works into BTG as one package and BoP into multiple packages**

Besides turnkey project, other approach followed by utilities include dividing the entire R&M works into BTG as one package and 3-4 (or in certain cases may be more than this) packages for BoP and other works. This approach has been followed in case of recent R&M projects such as Bandel Thermal Power Station Unit 5 (1x210 MW), Koradi Thermal Power Station Unit 6 (1x210 MW) etc. The benefit of dividing the work into BTG and BoP packages is the fact that it encourages competition in the market and leads to a better price discovery by the utility. Further, specialized agencies can be directly hired for different works. However, this may be a time consuming process for the utility and it may involve coordination issues with different suppliers.

- **Division of R&M works into separate individual package for Boiler, Turbine and Generator and BoP into multiple package**

  Another strategy that can be adopted by the utilities includes breaking down of BTG into separate packages. The benefit of this approach is that with the breaking down of BTG into separate packages, number of players in the market further increases leading to increased competition. However, integration and fixing of individual guarantees may become an issue for the utilities. During stakeholder interactions it was observed that NTPC is expected to follow this approach for R&M works of the Badarpur Thermal Power Station. In addition, structuring of guarantees in such cases becomes an issue.

Recommendations:

1. **Use of specialised agencies for preparation of specifications**

   The State Utilities have, by and large, used the services of Consultants for carrying out RLA studies and related tests/assessment. Based on the recommendations of these studies, the State Utilities generally prepared their own technical specifications, prior to floating tenders. This has been one of the reasons for weak specifications. It is important that Design Consultants besides being involved in undertaking technical studies should also be involved in preparing the final scope of work for the study. Also, discussions should also carried with the plant level officials as they are aware of actual plant level condition and can facilitate in effective identification of problem areas and formulation of effective specifications.

2. **Preparation of Standard documents**

   In order to reduce time gap in implementation of R&M works, it is

important to prepare standard documents for conducting different studies such as RLA, Condition Assessment etc.; preparation of DPR and model bidding and contract documents. In this regard CEA has prepared standard bid documents which may be used by the utilities.

3. **Packaging strategy**

While it can be seen that each of the above packaging strategy has its own merits and demerits, selection strategy depends upon the strength of the utility to act as the plant integrator. It is suggested that utilities may select the packaging strategy based on the evaluation of their individual strengths. Involvement of multiple suppliers has definite benefits in terms of price and quality of works but harnessing of such benefits lays on the fact that how well the utility is able to manage and integrate the plant.

6. Institutional related challenges

There exist various institutional gaps which need to be addressed for successful implementation of R&M projects. This includes the following:

a) **Limited Capacity of Utilities in Undertaking R&M Works**

Limited training of utility professionals in the area of planning and execution of R&M projects, absence of dedicated cell/department at the company level, deployment of the best personnel in the field of new generation capacity and frequent transfers are some of the reasons which have contributed to the limited skills and expertise of the generating company to plan and implement R&M projects.

b) **Weak Implementation support by utilities during Implementation support of R&M**

Interactions with the various stakeholders including suppliers have revealed that after the projects are awarded, the entire risk and responsibility for completion of the project is passed on to the suppliers with limited support by utilities during the implementation process. This has impacted the success of R&M projects to a great extent. In a number of successful examples of large projects being implemented, a key governing philosophy of the host entity has been that "Success of the contractor/supplier is success of the projects". Hence, lack of collaborative approach has serious implications on the R&M projects.

Recommendations:

1. **Formation of dedicated R&M cell by the utilities**

Based on stakeholder interactions undertaken during the course of the project it was observed that creation of strong project management team within the utility is a key for successful implementation of R&M projects. Further, frequent transfer of employees should be avoided in case of such projects. The benefit of such approach is that it builds institutional capacity and memory. Further, creating a dedicated and experienced team of professionals have significant benefits as learning from the past experience, issues encountered etc. can be incorporated in implementation of subsequent R&M projects and such issues can be handled in a more effective manner.

2. **Creation of a formal system by utilities to document learning and experience of executing R&M projects**

   It is important that utility must create a formal system to document various issues faced during the execution of the R&M project, risks encountered, occurrence of technical surprises etc. and lessons learnt. It is also important that while executing R&M projects such system is being compulsorily referred to and experience/ learning from past projects are suitably incorporated in the planning of new R&M projects. Formalizing such approach within the utility would lead to creation of a learning curve and would benefit the entire R&M market.

3. **Knowledge sharing at central level**

   The generating companies and other stakeholders should disseminate their experience of implementing R&M. This besides being hosted on their respective websites should also be disseminated through a common platform such as the CEA official website. Utilities should submit case studies to CEA upon completion of R&M projects highlighting their experience and key learning in implementing R&M projects which CEA may host on their websites after review. Knowledge sharing would enable effective capacity building for all the concerned stakeholders.

7. Implementation Related Challenges

One of the major implementation challenges faced by the utilities is that they are unable to schedule timely shutdown for executing R&M due to grid conditions. Significant energy and peak deficit scenario in most of the states coupled with lack of planning with regard to procurement of power from other sources inhibits shutdown of state owned units for executing R&M works. In certain cases this is driven by socio-political consideration that results in delay in obtaining the shutdown. This has significant impact on the R&M project as delay in providing shutdown leads to further deterioration of plant and may change the baseline parameters due to time gap between the studies and actual execution. Further, it may lead to contractual disputes between the utility and suppliers.

Recommendations:

1. **Advance Planning for Scheduling of Shutdown for Execution of Works**

   Shutdown for executing R&M works must be planned well in advance and distribution utilities must be informed accordingly. This would provide sufficient time to the distribution utility for arranging for additional power to meet the shortfall on account of the above. The current power market provides several avenues for procurement of power in the short and medium term, which should be considered.

2. **Additional Allocation of Power to States from Unallocated Quota of Central Pool**

   As per clause 6.2 (ix) of the CEA Guidelines For Renovation And Modernisation/Life Extension Works Of Coal/Lignite Based Thermal Power Stations, October 2009, the utilities may approach the Government for additional allocation of power to the extent possible from unallocated quota of central sector power stations during the period of shut down of units for comprehensive life extension works. Utilities can approach the Central Government well in advance to procure power in line with the above guideline.

Chapter - 6

Way Forward

The role of R&M in bridging the demand supply gap through generation optimisation is well recognised in the Indian context. This is increasingly becoming important in view of the shortage of fuel experienced in recent times and the necessity to optimally utilize this scarce resource. In addition, several other challenges viz. inadequate capacity addition, poor financial health of the utilities and the increasing cost of new installation, R&M including LE of existing power plants emerges the most economic option to maximize generation from the existing power stations (by means of restoring their rated capacity) at improved efficiencies with short gestation period. Based on the analysis undertaken in the study, R&M is observed to be least cost when compared to a new power plant or operating the plant under BAU scenario. It is worthwhile to note that the viability of R&M project is critically depended on the operational plant parameters that are achieved post R&M.

The potential as given below clearly indicates that the size of R&M market is reasonably large. The assessment also indicates that in most cases R&M works out to be a viable alternative for utilities that are faced with various alternatives (operate, retire, R&M, LE etc).

Table 6-1: R&M and LE Potential in 12th and 13th Plan under High Case

Sector	R&M		LE		Total	
	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units	Capacity (MW)	No. of Units
12th Five Year Plan						
State Sector	6,250	27	7,940	38	14,190	65
Central Sector	11,070	32	3,640	15	14,710	47
Sub-total 12th Plan	**17,320**	**59**	**11,580**	**53**	**28,900**	**112**
13th Five Year Plan						
State Sector	3,770	16	5,120	23	8,890	39
Central Sector	4,430	14	1,250	6	5,680	20
Sub-total 13th Plan	**8,200**	**30**	**6,370**	**29**	**14,570**	**59**

This presents a huge market opportunity for both suppliers and technical consultants present across the R&M value chain. However, ever since its

initiation in 1980s, the R&M market continues to witness a variety of challenges and issues that have impeded market growth and scale up plans. The table below presents the key challenges and action plan for strengthening the interest of the R&M stakeholders.

Table 6-2: Key Challenges and Action Plan for Strengthening the Interest of R&M Market players

S. No	Key Challenges	AF-Mercados EMI Recommendations	Responsibility
7.	Market related challenges • Limited Opportunities entering the Open market • Award of contracts through Nomination • Non-existence of market for technical consultants	R&M Roadmap to be developed and adopted at the State level with frequency similar to the plan periods	State Utilities/State Governments
		Regulatory Incentives and Enforcement Mechanisms to be designed to enable adoption of R&M on a timely basis	Regulators (Central/ State ERCs or Forum of regulators) through appropriate regulations
		R&M work to be awarded through competitive bidding route only	Utilities/ Gencos
		Preparation of standard bid documents. These should potentially also cover terms and conditions for introducing various private sector participation models already identified by the CEA	CEA
		Delay in obtaining requisite environmental and other clearances for R&M needs to be examined further and appropriate changes as required should be considered.	Ministry of Environment and Forests (MoEF)
		Stringent compliance of timelines for selection/ award of contractor	Central/ State ERCs
		Independent technical assessment of R&M projects by design consultants (Separate from OEM/ Suppliers)	Lenders (enforce as pre-condition to financing)
		Bulk Tendering (wherever	Utilities/ Gencos

S. No	Key Challenges	AF-Mercados EMI Recommendations	Responsibility
		possible and applicable)	
		Creation of National R&M Repository by undertaking feasibility studies for plants identified by CEA under its National Perspective Plan	• Funding support by Ministry of Power • Implementation through CEA through the empanelled consultants
8.	Funding related challenges • Limited ability of utilities to infuse equity investment in R&M projects • Credit exposure to power sector is likely to hit limits set by many commercial banks	Standard bid documents for private sector financing models viz. private-public partnership (PPP) and Joint venture (JV) models	CEA
		Pilot projects for demonstration of model of private sector involvement to be undertaken	Lenders (IFIs)/ Utilities
9.	Regulatory related challenges • Lack of appropriate incentive sharing mechanism for Gencos • Limit to R&M Investment • Provision of O&M special allowance	Gencos to be allowed to retain part of benefits achieved through R&M	Central/ State ERCs
		No benchmark to be set for R&M projects or alternatively, the capital cost should be capitalised based on cost-benefit analysis than the benchmark costs.	Central/ State ERCs
10.	O&M related challenges • Poor O&M Practices	Preparation and implementation of O&M action plan by utilities to ensure long-term sustainability of R&M	Lenders and Central/ State ERCs to enforce O&M action plan as a

S. No	Key Challenges	AF-Mercados EMI Recommendations	Responsibility
	leading to accelerated deterioration of plant performance	benefits	pre-condition to approval of R&M project
		Assistance from specialised technical agencies for O&M support	Utilities/ Gencos
11.	Contracting related challenges • Unfair and skewed balance of risk and reward among utilities and contractor • Delays in bid evaluation and award of contract • Inappropriate packaging strategy	Preparation of scope and technical specification of contract by independent technical consultant	Lenders and Central/ State ERCs
		Standard bid documents	CEA
		Packaging strategy to be based on implementation capabilities of utilities	Utilities/ Gencos
12.	Institutional related challenges • Limited capacity of utilities in undertaking R&M • Weak implementation support from utilities during R&M work	Formation of dedicated R&M cell by the utilities	Utilities
		Mechanism to capture learning/ experience during implementation of R&M projects at state level	Utilities
		Knowledge sharing platform at central level. The case study should specifically include the experience in implementing R&M, description of experience at various stages, outcomes achieved, and performance after R&M (over a period of time).	CEA supported by respective state utilities

Further, stakeholder consultation has revealed that one of the most critical barriers to R&M is Opportunity Origination. In addition to the above

recommendations, a multi-pronged strategy is needed that pushes the R&M agenda at various levels:

a) **Ministry of Power**

Need for policy advisory directing the state utilities to develop roadmaps/plan for R&M in their respective states. A minimum expected performance level for each technology could also be specified either through policy directive or through regulatory mechanism. This will encourage inefficient plants to take up R&M at the earliest.

b) **Ministry of Environment and Forests**

Needs review of barriers and issues on aspects such as need for environmental and other similar clearances for capacity uprating through R&M/LE, although the overall coal consumption comes down.

c) **Forum of Regulations**

Adoption of tariff regulations should include an incentive and penalty structure that promotes adoption of R&M.

d) **Planning Commission**

Special schemes that promote funding for R&M projects e.g. bridge financing, initial funding support etc could be considered to facilitate R&M projects.

e) **State Governments and Utilities**

Adoption of State level road-map that provides visibility on the plants likely to be taken up as R&M candidates. This will also enable vendors and suppliers to plan their respective capacities.

Annexure - I

Scope of the Consultancy Services for Study Report "Developing Markets for Implementation of R&M Schemes in Thermal Power Stations in India"

1. Study with the aim of developing markets to meet the impending demand of R&M in India

a) Under this task, the Consultant shall examine the overall requirement of R&M of coal based thermal power stations in India during the 12th and 13th Five Year Plan (2012-22). The analysis of requirement of R&M would be undertaken considering the key drivers for R&M i.e. technical feasibility, efficiency improvement, reduction in generation costs, life extension, improvement in equipment reliability and plant availability.

b) The Consultant shall study the existing bidders/suppliers interest and examine the ability of the existing suppliers in serving the requirement of R&M activities being carried out in India. The analysis would encompass the study of the existing capacity of the suppliers and their future expansion plans to cater to the existing and forthcoming demand for R&M interventions in India. The analysis will include all the players who have expressed their interest in the past and other prospective players who intend to play a role in the R&M activities in India.

c) To examine the interest of the existing bidders/suppliers the Consultant shall interview the key 4–5 players and understand the drivers behind interest of the suppliers in participating in R&M activities in India. In the pilot R&M projects we have seen that all bidders who purchase the bid document do not eventually bid for the project. The Consultant through the interviews should understand their concerns and constraints.

d) For executing the R&M projects, the interest of technical consultants involved in providing quality services for the project design report of R&M projects and for supporting utilities during implementation of R&M activities also needs to be elaborated. The Consultant shall interview 5-6 existing technical consultancy organizations who have executed assignments for design or implementation support for R&M projects in the past to assess the problems faced by them and their interest in future R&M projects. The Consultant shall also assess the capabilities of new players who have expressed interest to act as Design or Support Consultant for R&M Projects. Based on interaction with the existing players and new players, the Consultant will

suggest the measures for strengthening the interest of such consultants in carrying out the R&M activities in thermal power stations in India.

e) The consultant will then suggest ways of strengthening the interest of the key players (bidders/ suppliers, consultants, generation companies) in the R&M in the future, as well as ways to attract new entrants. The Consultant shall suggest the possible measures that need to be undertaken at the generating company level, Central and State Government level, and by the Regulatory Commissions to promote R&M interventions in India.

f) On the basis of the study, the Consultant shall prepare and submit a draft report to CEA. Further, based on the comments of CEA, the Consultant shall finalise the report and submit the same.

2. Road-shows for showcasing R&M requirements in India to generate greater supplier and consultant interest:

a) The Consultant on behalf of CEA shall organize two (2) road-shows one each in Delhi and Mumbai, in order to create greater awareness about the R&M of thermal power stations and enhance the interest of the utilities, suppliers and consultants in participating in R&M activities. In these workshops/road-shows the Consultant will share the findings from Task 1 with the wider audience and brainstorm on the possible ways and measures to generate interest in R&M in India.

b) The Consultant would be required to meet the expenditure for organizing and executing such road shows from the cost of the proposed consultancy services, and CEA shall not be liable for making separate payments for such activities

Annexure - II

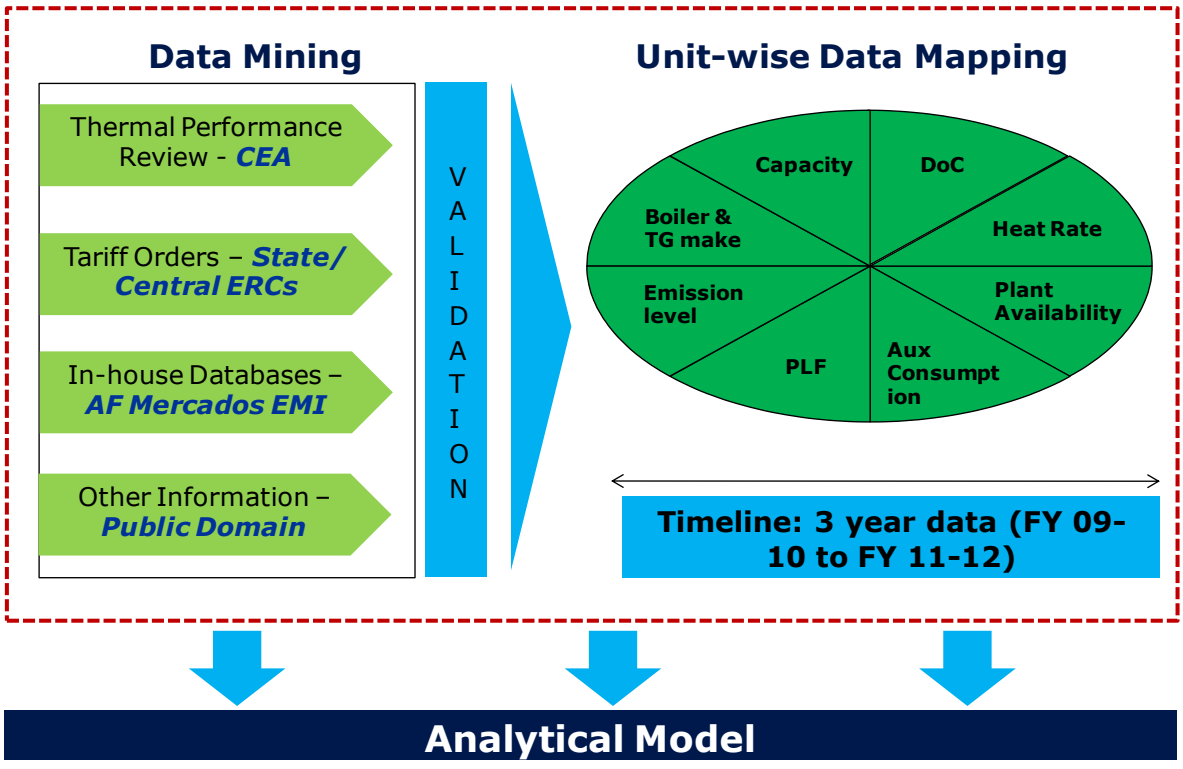
Analytical Model for Estimation of R&M Potential during 12th and 13th Plan in India

The key features including the assumptions and basis of the analytical model are explained below:

1. Mapping of Plant Parameters

Under this task, detailed review of various public documents was undertaken to collect plant performance and ageing related parameters for all operational coal based thermal units (Central and State Sector)[24] for last three years (FY 09-10 to FY 11-12). The figure below presents the structure of the database developed for mapping the plant related data for all operating coal based thermal units.

Figure AX-1: Database Structure



The data set includes following parameters

- **Ageing/ Basic Plant Characteristics**
  - Plant capacity (MW)
  - Date of commissioning (DoC)

[24] Private plants are excluded from the database

- **Operational Data**
  - Gross station heat rate (kCal/kWh)
  - Plant availability (%)
  - Auxiliary power consumption (%)
  - Plant load factor (%)
  - Forced Outage (%)

The following sources were referred/ reviewed to

- CEA Publications - Thermal Performance Review for FY 09-10, FY 10-11 and FY 11-12
- Tariff related orders/ petitions (State and central ERCs) for all the states for last three years. This also included the tariff filings/proposals, true-up filings by GENCO's/ state utilities
- Internal databases of AF Mercados EMI (updated from time to time during our engagements with various utilities in different states)
- Other relevant information in the public domain

The following data related constraints were encountered while compilation of the data:

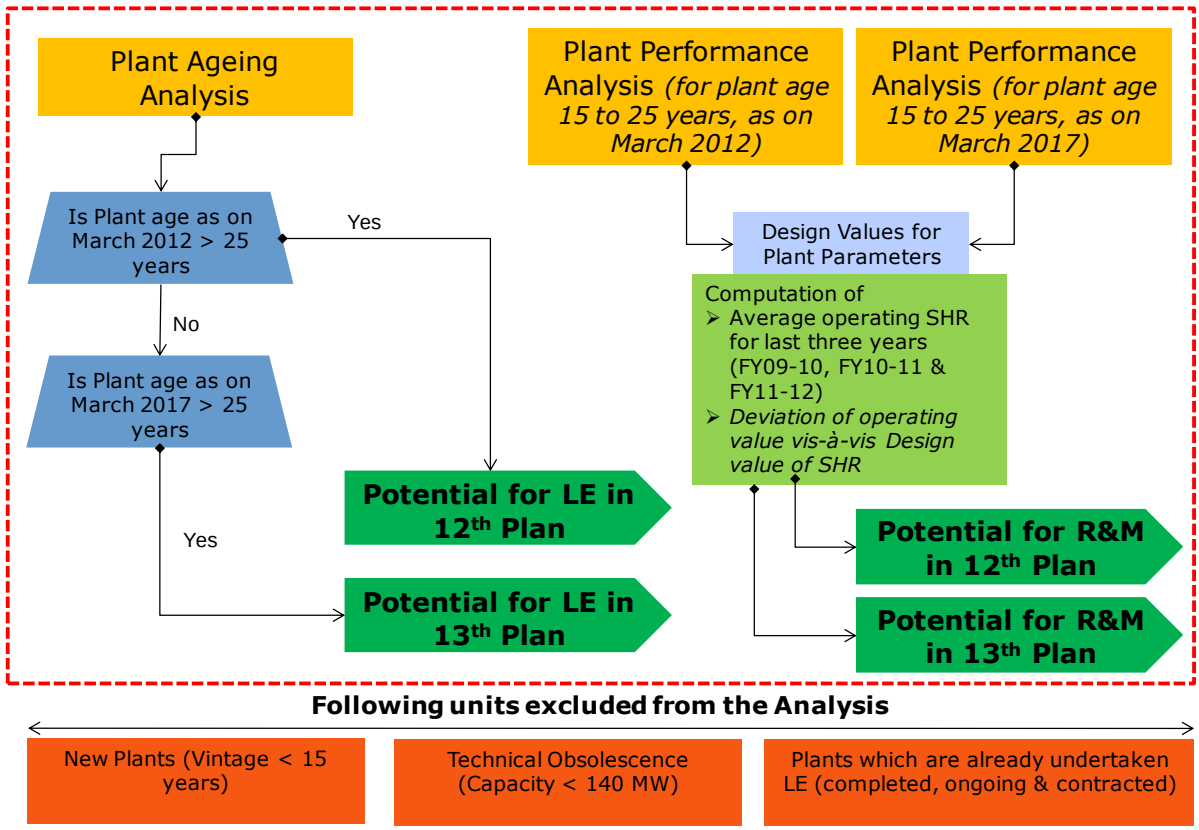
- Various operational parameters particularly station heat rate was not available unit-wise for state sector plants as these parameters are generally reported plant wise. Thus, for units for which the SHR data is not available, the model assumes SHR value of a unit of the same plant with similar capacity and vintage.
- Unit-wise Station Heat Rate for NTPC plants was not available in public domain (including the thermal performance review of CEA). Hence, in order to include the NTPC plants in the overall R&M potential the National Perspective Plan for 12th FYP (CEA) and other publicly available documents (regarding NTPC's R&M/LE plan) have been considered to include the identified plants in the estimation of R&M potential.

2. Ageing and Performance Analysis

Under this task, the plant related data as compiled above is fed to the analytical model which primarily comprises two modules i.e. i) Ageing Analysis, and ii)

Performance Analysis. As stated the objective of the analytical model is to test each operating unit for its age/ life characteristics and level of performance. In order to operationalize the above, the following architecture of the model is adopted.

Figure AX-2: Architecture of Analytical Model[25]



The key features of the above analytical model are explained below:

- The database comprising the plant parameters as explained in the earlier section is the key input to the analytical model. The analytical model tags all the operating units based on their capacity and operational age (Age), under the following categories:

Table AX-1: Capacity and Age Group

Capacity Group		***Age Group***	
1	200/ 210 MW (LMZ Units)	1	0-15 years
2	200/ 210 MW (KWU Units)	2	16-25 years
3	250 MW and above	3	25 years and above

[25] The exclusions are in accordance with the discussion and deliberation with the CEA, and subsequently with the Task Force constituted by the CEA for world bank financed project "Coal Fired Generation Rehabilitation Project-India"

- Plants completing their operational life (i.e. age more than 25 years as on March 2012) form the potential market for Life Extension scheme during the 12th Five Year Plan. Likewise, the units that will complete their operational life by year 2017 (i.e. age more than 25 years as on March 2017) form potential market for Life Extension scheme for 13th Five Year Plan[26].

- The performance analysis module considers the operational performance of plants in the age group 16 to 25 years for all the operational units in the database and computes the deviation of average operating SHR for FY 09-10, FY 10-11 & FY 11-12 vis-à-vis the design values to rank the efficiency of the plant operation. The model also considers they plants that will exceed 15 years of operational life during the five year plan.

- The rationale behind categorization of the units based on the above capacity group is to set a benchmark value for efficient operation of the plants under each of these capacity group based on their technology (primarily based on their design parameters). The table below presents the design values of operational parameters that are fed into the analytical model.

Table Annexure-2: Design Parameters (Benchmark Value) [27]

Capacity group	SHR (kcal/ kWh)
200/ 210 MW (KWU)	2342
200/ 210 MW (LMZ)	2402
250 MW and above	2297

- The prime objective of the performance analysis module is analysis of the current efficiency level of the operating units and to identify whether their performance level is within the acceptable range or beyond. In order to perform such analysis, the model computes the deviation of operating values vis-à-vis design values (or benchmark values) for each unit and classifies units into various performance groups as following categories.

[26] LE estimates for NTPC plant during 13th Plan is based on ageing analysis. This approach was also discussed with NTPC during the task force meeting.

[27] These design/benchmark values are derived from the following references

- CO_2 Baseline Database for Indian Power Sector, 2012 – CEA
- Mapping of 85 coal fired thermal power units (IGEN) , CEA

Table Annexure-3: Deviation Levels

Performance level	Deviation (%)	Remark
High	Less than 7.5%	Acceptable Range
Medium	> 7.5% & < 15%	Inefficient Range
Low	> 15% & above	

The acceptable deviation range is up to 7.5% from the design values of the respective parameters and the rationale for the same is as follows:

- CERC tariff norms provide a deviation of 6.5% over design heat rates.
- Additional 1% of deviation is provided over CERC norm for uncontrollable factors viz. degradation of coal quality, equipment wear & tear etc.

- The above analysis is carried out on all the coal based thermal units that have an operational life exceeding 15 years and less than 25 years, to assess EE R&M potential in the country.
- Plants that are in 16-25 years age category as on March 2012 and have low/medium level of plant performance are identified for R&M during under 12th Plan while plants that are in 16-25 years age category as on March 2017 and have low/medium level of plant performance are identified for R&M during 13th Plan. Further, this also provides better understanding of the current levels of inefficiencies in power generation systems.
- It is worthwhile to mention that the above analytical model is designed to identify the overall market potential for R&M/ LE in the 12^{th} and 13^{th} Plan. Identification of exact units is a matter of management strategy of respective states and can only be carried out through a detailed technical examination on the plants considered for R&M.

3. Financial Viability

During the interactions with various stakeholders involved in the R&M, various opinions about the need and viability of the R&M projects were encountered and thus, the need to understand the financial viability of R&M project emerged. It is worthwhile to investigate whether R&M is really the least cost option to improve the efficiency/ upgrade capacity of the power generation system, and the range of performance level wherein R&M will prove beneficial.

This task of assessing the financial viability of R&M projects is undertaken to create a framework to enable R&M decisions based on the economic cost benefit analysis of alternate options available to a utility / GENCO.

An excel based model was developed to project the life cycle cost of power generation of the plant being considered for R&M under the following options

- **Option A:** Operated under Business As Usual (BAU) scenario
- **Option B:** Existing plant undergoing comprehensive LE/ R&M
- **Option C:** Greenfield plant of equivalent capacity

The life cycle cost of power generation is the price that covers the recovery of all kinds of capital cost (including IDC), fuel cost, operation and maintenance cost over the operational life of the plant. A number of key parameters influence the life cycle cost of power generation of a plant. Each of these parameters is listed below:

- **Capital Cost of the plant**

  Higher capital cost would mean a higher fixed cost of generation for equivalent energy compared to a lower capital cost plant. Needless to mention that R&M project brings in advantage in form of lower capital cost generally ranging 40-50% of a Greenfield project.

- **Fuel Cost**

  The fuel cost for a plant is combination of the coal price and the efficiency of the plant basically measured in terms of the station heat rate and auxiliary consumption. A Greenfield project brings in advantages in terms of scale and efficiency of newer technology and hence, is likely to consume lower quantum of fuel than compared to an old plant.

- **Other parameters that also impact the life cycle cost of power generation are listed below:**

  - Higher operational life of the plant.
  - Lower period for construction of the plant
  - O&M cost of the plant
  - Deterioration rate for the plant performance parameters viz. SHR, auxiliary consumption, PLF, specific oil consumption etc.
  - Debt to Equity Ratio and the interest rate on term loans

The table below provides the key inputs to the financial Model under various options

Table Annexure-4: Key Inputs to the Financial Model

Input Parameter	Unit	Option A: BAU	Option B: Comprehensive R&M/LE	Option C: New Plant	Basis
Basic Assumptions					
Capital Cost	Rs Crore/ MW	NA	2.5	5	Typically, a new Greenfield coal based project costs Rs. 5 Crore/ MW. Further, as per CEA guideline, the cost of life extension is ~50% of new project cost
Plant life	Years	8 (Residual Life)	20	25	Based on DPR of past R&M projects
Construction period/Shutdown period	Months	NA	9	36	Based on past experience of projects
O&M cost	Rs. Lakh/ MW	22.5	15	15	CERC Norm. Also, an additional 50% O&M expenditure in case of BAU is assumed

Input Parameter	Unit	Option A: BAU	Option B: Comprehensive R&M/LE	Option C: New Plant	Basis
Annual escalation in O&M	%	5.72%	5.72%	5.72%	CERC Norm
Fuel related Assumptions					
Landed cost of coal[28]	Rs./ tonne	2213	2213	2213	Estimated based on standard industry assumption (Break-up of cost provided in Annexure V)
Annual escalation in coal cost	%	5%	5%	5%	Past Market Trends
GCV of coal	Kcal/Kg	3200	3200	3200	Recent Industry trends
Operational Assumptions					
PLF	%	60%	85%	90%	-
Annual reduction in PLF	% per year	3%	NA	NA	-
Auxiliary consumption	%	11%	9.5-8.5%	7.5%	CERC Norm
Annual escalation in auxiliary consumption	%	0.3%	0.15%	0.15%	Based on DPR of past R&M projects
Gross station	Kcal/	2950	2540	2540	Based on

[28] The break-up of landed cost of coal is provided in the Annexure V

Input Parameter	Unit	Option A: BAU	Option B: Comprehensive R&M/LE	Option C: New Plant	Basis
heat rate (SHR)	kWh				DPR of past R&M projects
Annual escalation in SHR	%	0.4%	0.2%	0.2%	As per DPR of past R&M projects
Specific Oil consumption	ml/ kWh	1.9	1.5	1	CERC Norms
Annual escalation in Oil consumption	%	2%	1%	1%	CERC Norms
GCV of Oil	Kcal/ ml	9.36	9.36	9.36	-
Cost of Oil	Rs./ KL	33,000	33,000	33,000	Average range
Financial Assumptions					
D/E Ratio		70:30	70:30	70:30	CERC Norm
Interest on term loan	%	12%	12%	12%	SBI PLR
Loan repayment period	Year	12	12	12	CERC Norm

The impact of the above inputs on the cost of generation of electricity/ levelised tariff is computed by the financial model and the option with the least levelised tariff is considered the best option that will not only maximize the efficiency and energy availability but also minimize the cost of generation. In addition, the model also evaluates the sensitivity of cost of generation/ levelised tariff with the operational parameters viz. SHR and Aux achieved after R&M which in turn enables utilities/ Gencos to understand the minimum level of operational parameters that will ascertain R&M as the least cost option.

Annexure - III

List of Plants for R&M/ LE Potential under High Case for 12th and 13th Plan

1. R&M/ LE in 12th Plan

1.1. LIFE EXTENSION (STATE SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Bhusawal TPS, Unit - 2	Maharashtra	210	Aug-79
2	Bhusawal TPS, Unit - 3	Maharashtra	210	May-82
3	Chandrapur TPS Maha, Stage - 1, Unit - 1	Maharashtra	210	Apr-83
4	Chandrapur TPS Maha, Stage - 1, Unit - 2	Maharashtra	210	May-84
5	Chandrapur TPS Maha, Stage - 1, Unit - 3	Maharashtra	210	Jun-85
6	Chandrapur TPS Maha, Stage - 1, Unit - 4	Maharashtra	210	Jul-86
7	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 1	Chhattisgarh	210	Jun-83
8	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 2	Chhattisgarh	210	Mar-84
9	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 3	Chhattisgarh	210	Mar-85
10	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 4	Chhattisgarh	210	Mar-86
11	Kolaghat TPS, Unit - 2	West Bengal	210	May-84
12	Kolaghat TPS, Unit - 3	West Bengal	210	Apr-83
13	Koradi TPS, Unit - 5	Maharashtra	200	Apr-78
14	Koradi TPS, Unit - 7	Maharashtra	210	Jun-83
15	Nasik TPS, Unit - 3	Maharashtra	210	Apr-79
16	Nasik TPS, Unit - 4	Maharashtra	210	May-80
17	Nasik TPS, Unit - 5	Maharashtra	210	Jul-81

#	Plant Name	State	Capacity (MW)	Date of Commissioning
18	Parli TPS, Unit - 3	Maharashtra	210	Sep-80
19	Parli TPS, Unit - 4	Maharashtra	210	Mar-85
20	Raichur TPS, Unit - 1	Karnataka	210	Apr-85
21	Raichur TPS, Unit - 2	Karnataka	210	May-86
22	Ropar TPS, Unit - 1	Punjab	210	Apr-84
23	Ropar TPS, Unit - 2	Punjab	210	May-85
24	Satpura, Stage - 2, Unit - 6	Madhya Pradesh	200	Apr-78
25	Satpura, Stage - 2, Unit - 7	Madhya Pradesh	210	May-79
26	Satpura, Stage - 3, Unit - 8	Madhya Pradesh	210	Jun-82
27	Satpura, Stage - 3, Unit - 9	Madhya Pradesh	210	Apr-83
28	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 1	Tamil Nadu	210	Apr-77
29	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 2	Tamil Nadu	210	May-79
30	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 3	Tamil Nadu	210	Jun-81
31	Ukai Thermal Power Station, Stage 1, Unit - 3	Gujarat	200	Apr-79
32	Ukai Thermal Power Station, Stage 1, Unit - 4	Gujarat	200	Dec-79
33	Ukai Thermal Power Station, Stage 1, Unit - 5	Gujarat	210	Jan-85
34	Wanakbori Thermal Power Station, Unit - 1	Gujarat	210	Apr-82
35	Wanakbori Thermal Power Station, Unit - 2	Gujarat	210	May-83
36	Wanakbori Thermal Power Station,	Gujarat	210	Jun-84

#	Plant Name	State	Capacity (MW)	Date of Commissioning
	Unit - 3			
37	Wanakbori Thermal Power Station, Unit - 4	Gujarat	210	Apr-86
38	Wanakbori Thermal Power Station, Unit - 5	Gujarat	210	Dec-86
	Total LE (State Sector)	**7940MW**		

1.2. LIFE EXTENSION (CENTRAL SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Bokaro TPS B, Unit - 1	Jharkhand	210	Apr-86
2	Durgapur TPS, Unit- 4	DVC	210	Jun-80
3	Farakka Stage-1, Unit - 1	West Bengal	200	Jan-86
4	Farakka Stage-1, Unit - 2	West Bengal	200	Dec-86
5	Farakka Stage-2, Unit - 4	West Bengal	500	Sep-82
6	Korba STPP, Stage - 1, Unit - 2	Chhattisgarh	200	Oct-83
7	Korba STPP, Stage - 1, Unit - 3	Chhattisgarh	200	Mar-84
8	Neyveli TPS - 2, Stage 1, Unit - 3	Tamil Nadu	210	Mar-86
9	Ramagundam, Stage - 1, Unit - 2	Andhra Pradesh	200	Sep-84
10	Ramagundam, Stage - 1, Unit - 3	Andhra Pradesh	200	Dec-84
11	Singrauli Thermal Power Station, Unit - 3	Uttar Pradesh	200	Mar-83
12	Singrauli Thermal Power Station, Unit - 4	Uttar Pradesh	200	Nov-83
13	Singrauli Thermal Power Station, Unit - 5	Uttar Pradesh	200	Feb-84
14	Singrauli Thermal Power Station,	Uttar Pradesh	500	Dec-86

#	Plant Name	State	Capacity (MW)	Date of Commissioning
	Unit - 6			
15	Vindhyachal Thermal Power Station, Stage - 1, Unit - 1	Madhya Pradesh	210	May-86
	Total LE (Central Sector)	**3640 MW**		

1.3. R&M (STATE SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Chandrapur TPS Maha, Stage - 2, Unit - 5	Maharashtra	500	Apr-91
2	Chandrapur TPS Maha, Stage - 2, Unit - 6	Maharashtra	500	May-92
3	Gandhinagar TPS, Unit - 3	Gujarat	210	May-90
4	Gandhinagar TPS, Unit - 4	Gujarat	210	Jul-91
5	Khaperkheda TPS, Unit - 1	Maharashtra	210	Apr-89
6	Khaperkheda TPS, Unit - 2	Maharashtra	210	Jan-90
7	Kolaghat TPS, Unit - 1	West Bengal	210	Apr-89
8	Kolaghat TPS, Unit - 4	West Bengal	210	Oct-93
9	Kolaghat TPS, Unit - 5	West Bengal	210	Jun-90
10	Kolaghat TPS, Unit - 6	West Bengal	210	Aug-92
11	Kota TPS, Unit - 3	Rajasthan	210	Jun-88
12	Kota TPS, Unit - 4	Rajasthan	210	May-89
13	Kota TPS, Unit - 5	Rajasthan	210	Mar-94
14	Panipat Thermal Power Station, Unit - 5	Haryana	210	Jul-89
15	Parli TPS, Unit - 5	Maharashtra	210	Dec-87
16	Raichur TPS, Unit - 3	Karnataka	210	Jun-91
17	Raichur TPS, Unit - 4	Karnataka	210	Sep-94

#	Plant Name	State	Capacity (MW)	Date of Commissioning
18	Ropar TPS, Unit - 3	Punjab	210	Jun-88
19	Ropar TPS, Unit - 4	Punjab	210	Jul-89
20	Ropar TPS, Unit - 5	Punjab	210	May-92
21	Ropar TPS, Unit - 6	Punjab	210	Apr-93
22	Sanjay Gandhi (Birsinghpur), Stage 1, Unit - 1	Madhya Pradesh	210	Mar-93
23	Sanjay Gandhi (Birsinghpur), Stage 1, Unit - 2	Madhya Pradesh	210	Mar-94
24	TENUGHAT TPS, Unit - 1	Jharkhand	210	Apr-96
25	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 4	Tamil Nadu	210	Aug-89
26	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 5	Tamil Nadu	210	Apr-90
27	Wanakbori Thermal Power Station, Unit - 6	Gujarat	210	Apr-87
	Total R&M (State Sector)	**6,250 MW**		

1.4. R&M (CENTRAL SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Singrauli Thermal Power Station, Unit - 7	Uttar Pradesh	500	Nov-87
2	Korba STPP, Stage - 2, Unit - 4	Chhattisgarh	500	May-87
3	Korba STPP, Stage - 2, Unit - 5	Chhattisgarh	500	Mar-88
4	Korba STPP, Stage - 2, Unit - 6	Chhattisgarh	500	Mar-89
5	Ramagundam, Stage - 2, Unit - 4	Andhra Pradesh	500	Jun-88
6	Ramagundam, Stage - 2, Unit - 5	Andhra Pradesh	500	Jul-89
7	Ramagundam, Stage - 2, Unit - 6	Andhra	500	Oct-89

#	Plant Name	State	Capacity (MW)	Date of Commissioning
		Pradesh		
8	Unchahar TPS, Stage 1, Unit - 1	Uttar Pradesh	210	Apr-87
9	Unchahar TPS, Stage 1, Unit - 2	Uttar Pradesh	210	May-88
10	Unchahar TPS, Stage 2, Unit - 3	Uttar Pradesh	210	Apr-98
11	Unchahar TPS, Stage 2, Unit - 4	Uttar Pradesh	210	Nov-98
12	Vindhyachal Thermal Power Station, Stage - 1, Unit - 2	Madhya Pradesh	210	Jun-87
13	Vindhyachal Thermal Power Station, Stage - 1, Unit - 3	Madhya Pradesh	210	Jun-88
14	Vindhyachal Thermal Power Station, Stage - 1, Unit - 4	Madhya Pradesh	210	Dec-88
15	Vindhyachal Thermal Power Station, Stage - 1, Unit - 5	Madhya Pradesh	210	Apr-89
16	Vindhyachal Thermal Power Station, Stage - 1, Unit - 6	Madhya Pradesh	210	Jun-90
17	Vindhyachal Thermal Power Station, Stage - 2, Unit - 7	Madhya Pradesh	500	Apr-98
18	Vindhyachal Thermal Power Station, Stage - 2, Unit - 8	Madhya Pradesh	500	Jun-99
19	Simhadri TPS, Stage - 1, Unit - 1	Andhra Pradesh	500	Apr-02
20	Simhadri TPS, Stage - 1, Unit - 2	Andhra Pradesh	500	Jun-03
21	Talcher STPS, Stage - 1 for ER, Unit - 1	Orissa	500	Mar-95
22	Talcher STPS, Stage - 1 for ER, Unit - 2	Orissa	500	Mar-96
23	Dadri Thermal (NCTPP) - Stage 1, Unit- 1	Uttar Pradesh	210	Oct-91
24	Dadri Thermal (NCTPP) - Stage 1, Unit- 2	Uttar Pradesh	210	Dec-92
25	Dadri Thermal (NCTPP) - Stage 1,	Uttar Pradesh	210	Mar-93

#	Plant Name	State	Capacity (MW)	Date of Commissioning
	Unit- 3			
26	Dadri Thermal (NCTPP) - Stage 1, Unit- 4	Uttar Pradesh	210	Mar-94
27	Rihand STPS, Stage - 1, Unit - 1	Uttar Pradesh	500	Apr-87
28	Rihand STPS, Stage - 1, Unit - 2	Uttar Pradesh	500	May-88
29	Kahalgaon Thermal Power Station Stage 1, Unit - 1	Bihar	210	May-92
30	Kahalgaon Thermal Power Station Stage 1, Unit - 2	Bihar	210	Jul-94
31	Kahalgaon Thermal Power Station Stage 1, Unit - 3	Bihar	210	Aug-95
32	Kahalgaon Thermal Power Station Stage 1, Unit - 4	Bihar	210	Apr-96
	Total R&M (Central Sector)	**11,070 MW**		

2. R&M/ LE in 13th Plan

2.1. LIFE EXTENSION (STATE SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Chandrapur TPS Maha, Stage - 2, Unit - 5	Maharashtra	500	Apr-91
2	Gandhinagar TPS, Unit - 3	Gujarat	210	May-90
3	Gandhinagar TPS, Unit - 4	Gujarat	210	Jul-91
4	Khaperkheda TPS, Unit - 1	Maharashtra	210	Apr-89
5	Khaperkheda TPS, Unit - 2	Maharashtra	210	Jan-90
6	Kolaghat TPS, Unit - 1	West Bengal	210	Apr-89
7	Kolaghat TPS, Unit - 5	West Bengal	210	Jun-90
8	Kota TPS, Unit - 3	Rajasthan	210	Jun-88

#	Plant Name	State	Capacity (MW)	Date of Commissioning
9	Kota TPS, Unit - 4	Rajasthan	210	May-89
10	Mettur TPS, Unit - 1	Tamil Nadu	210	Jan-87
11	Mettur TPS, Unit - 2	Tamil Nadu	210	Dec-87
12	Mettur TPS, Unit - 3	Tamil Nadu	210	Jun-88
13	Mettur TPS, Unit - 4	Tamil Nadu	210	May-89
14	Panipat Thermal Power Station, Unit - 5	Haryana	210	Jul-89
15	Parli TPS, Unit - 5	Maharashtra	210	Dec-87
16	Raichur TPS, Unit - 3	Karnataka	210	Jun-91
17	Ropar TPS, Unit - 3	Punjab	210	Jun-88
18	Ropar TPS, Unit - 4	Punjab	210	Jul-89
19	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 4	Tamil Nadu	210	Aug-89
20	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 5	Tamil Nadu	210	Apr-90
21	Vijayawada TPS, Stage 2, Unit - 3	Andhra Pradesh	210	Oct-89
22	Vijayawada TPS, Stage 2, Unit - 4	Andhra Pradesh	210	Aug-90
23	Wanakbori Thermal Power Station, Unit - 6	Gujarat	210	Apr-87
	Total LE (State Sector)	**5,120 MW**		

2.2. LIFE EXTENSION (CENTRAL SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Bokaro TPS B, Unit - 2	Jharkhand	210	May-90
2	Farakka Stage-1, Unit - 3	West Bengal	200	Aug-87

#	Plant Name	State	Capacity (MW)	Date of Commissioning
3	Neyveli TPS - 2, Stage 1, Unit - 1	Tamil Nadu	210	Jan-88
4	Neyveli TPS - 2, Stage 1, Unit - 2	Tamil Nadu	210	Feb-87
5	Neyveli TPS - 2, Stage 2, Unit - 4	Tamil Nadu	210	Mar-91
6	Neyveli TPS - 2, Stage 2, Unit - 5	Tamil Nadu	210	Dec-91
	Total LE (Central Sector)	**1,250 MW**		

2.3. R&M (STATE SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Gandhinagar TPS, Unit – 5	Gujarat	210	Jul-98
2	Panipat Thermal Power Station, Unit – 6	Haryana	210	Apr-01
3	TENUGHAT TPS, Unit – 2	Jharkhand	210	Aug-98
4	Raichur TPS, Unit – 5	Karnataka	210	Apr-99
5	Raichur TPS, Unit – 6	Karnataka	210	Dec-99
6	Sanjay Gandhi (Birsinghpur), Stage 2, Unit – 3	Madhya Pradesh	210	Feb-99
7	Sanjay Gandhi (Birsinghpur), Stage 2, Unit – 4	Madhya Pradesh	210	Nov-99
8	KHAPERKHEDA TPS, Unit – 4	Maharashtra	210	Jan-01
9	KHAPERKHEDA TPS, Unit – 3	Maharashtra	210	May-00
10	Chandrapur TPS Maha, Stage – 2, Unit – 7	Maharashtra	500	Aug-97
11	Suratgarh TPS, Unit – 3	Rajasthan	250	Oct-01
12	Suratgarh TPS, Unit – 2	Rajasthan	250	Mar-00
13	Suratgarh TPS, Unit – 1	Rajasthan	250	May-98

#	Plant Name	State	Capacity (MW)	Date of Commissioning
14	Bakreshwar TPS, Unit – 3	West Bengal	210	Jan-00
15	Bakreshwar TPS, Unit – 2	West Bengal	210	May-99
16	Bakreshwar TPS, Unit – 1	West Bengal	210	Apr-98
	Total R&M (State Sector)	**3,770 MW**		

2.4. R&M (CENTRAL SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Mejia TPS, Unit - 1, (MTPS - A)	DVC	210	Jun-96
2	Mejia TPS, Unit - 2, (MTPS - A)	DVC	210	Jun-98
3	Mejia TPS, Unit - 3, (MTPS - A)	DVC	210	Jun-99
4	Bokaro TPS B, Unit - 3	Jharkhand	210	Jun-93
5	Talcher STPS, Stage - 2 for SR, Unit - 4	Orissa	500	May-04
6	Talcher STPS, Stage - 2 for SR, Unit - 3	Orissa	500	Apr-03
7	Neyveli TPS - 1, Expn (Stage - 3), Unit - 2	Tamil Nadu	210	May-03
8	Neyveli TPS - 1, Expn (Stage - 3), Unit - 1	Tamil Nadu	210	Sep-02
9	Neyveli TPS - 2, Expn, Unit - 1	Tamil Nadu	250	Oct-02
10	Neyveli TPS - 2, Stage 2, Unit - 7	Tamil Nadu	210	Jun-93
11	Neyveli TPS - 2, Stage 2, Unit - 6	Tamil Nadu	210	Oct-92
12	Rihand STPS, Stage - 2, Unit - 3	Uttar Pradesh	500	Apr-04

#	Plant Name	State	Capacity (MW)	Date of Commissioning
13	Rihand STPS, Stage - 2, Unit - 4	Uttar Pradesh	500	Dec-04
14	FARAKKA STAGE-2, Unit - 5	West Bengal	500	Feb-94
	Total R&M (Central Sector)	**4,430 MW**		

Annexure - IV

List of Plants for R&M/ LE Potential under Low Case for 12th and 13th Plan

1. R&M/ LE in 12th Plan

1.1. LIFE EXTENSION (STATE SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Wanakbori Thermal Power Station, Unit - 1	Gujarat	210	Apr-82
2	Ukai Thermal Power Station, Stage 1, Unit - 3	Gujarat	200	Apr-79
3	Ukai Thermal Power Station, Stage 1, Unit - 4	Gujarat	200	Dec-79
4	Raichur TPS, Unit - 1	Karnataka	210	Apr-85
5	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 1	Tamil Nadu	210	Apr-77
6	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 2	Tamil Nadu	210	May-79
7	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 3	Tamil Nadu	210	Jun-81
8	Raichur TPS, Unit - 2	Karnataka	210	May-86
9	Ropar TPS, Unit - 1	Punjab	210	Apr-84
10	Ropar TPS, Unit - 2	Punjab	210	May-85
11	Satpura, Stage - 2, Unit - 6	Madhya Pradesh	200	Apr-78
12	Satpura, Stage - 2, Unit - 7	Madhya Pradesh	210	May-79
13	Kolaghat TPS, Unit - 2	West Bengal	210	May-84
14	Kolaghat TPS, Unit - 3	West Bengal	210	Apr-83

#	Plant Name	State	Capacity (MW)	Date of Commissioning
15	Koradi TPS, Unit - 5	Maharashtra	200	Apr-78
16	Nasik TPS, Unit - 3	Maharashtra	210	Apr-79
17	Nasik TPS, Unit - 4	Maharashtra	210	May-80
18	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 2	Chhattisgarh	210	Mar-84
19	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 1	Chhattisgarh	210	Jun-83
	Total LE (State Sector)	**3,950 MW**		

1.2. LIFE EXTENSION (CENTRAL SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Bokaro TPS B, Unit - 1	Jharkhand	210	Apr-86
2	Durgapur TPS, Unit- 4	DVC	210	Jun-80
3	Farakka Stage-1, Unit - 1	West Bengal	200	Jan-86
4	Farakka Stage-1, Unit - 2	West Bengal	200	Dec-86
5	Farakka Stage-2, Unit - 4	West Bengal	500	Sep-82
6	Korba STPP, Stage - 1, Unit - 2	Chhattisgarh	200	Oct-83
7	Korba STPP, Stage - 1, Unit - 3	Chhattisgarh	200	Mar-84
8	Neyveli TPS - 2, Stage 1, Unit - 3	Tamil Nadu	210	Mar-86
9	Ramagundam, Stage - 1, Unit - 2	Andhra Pradesh	200	Sep-84
10	Ramagundam, Stage - 1, Unit - 3	Andhra Pradesh	200	Dec-84
11	Singrauli Thermal Power Station, Unit - 3	Uttar Pradesh	200	Mar-83

#	Plant Name	State	Capacity (MW)	Date of Commissioning
12	Singrauli Thermal Power Station, Unit - 4	Uttar Pradesh	200	Nov-83
13	Singrauli Thermal Power Station, Unit - 5	Uttar Pradesh	200	Feb-84
14	Singrauli Thermal Power Station, Unit - 6	Uttar Pradesh	500	Dec-86
15	Vindhyachal Thermal Power Station, Stage - 1, Unit - 1	Madhya Pradesh	210	May-86
	Total LE (Central Sector)	**3,640 MW**		

1.3. R&M (STATE SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Chandrapur TPS Maha, Stage - 2, Unit - 5	Maharashtra	500	Apr-91
2	Chandrapur TPS Maha, Stage - 2, Unit - 6	Maharashtra	500	May-92
3	Gandhinagar TPS, Unit - 3	Gujarat	210	May-90
4	Gandhinagar TPS, Unit - 4	Gujarat	210	Jul-91
5	Khaperkheda TPS, Unit - 1	Maharashtra	210	Apr-89
6	Khaperkheda TPS, Unit - 2	Maharashtra	210	Jan-90
7	Kolaghat TPS, Unit - 1	West Bengal	210	Apr-89
8	Kolaghat TPS, Unit - 4	West Bengal	210	Oct-93
9	Kolaghat TPS, Unit - 5	West Bengal	210	Jun-90
10	Kolaghat TPS, Unit - 6	West Bengal	210	Aug-92
11	Kota TPS, Unit - 3	Rajasthan	210	Jun-88
12	Kota TPS, Unit - 4	Rajasthan	210	May-89
13	Kota TPS, Unit - 5	Rajasthan	210	Mar-94
14	Panipat Thermal Power Station,	Haryana	210	Jul-89

#	Plant Name	State	Capacity (MW)	Date of Commissioning
	Unit - 5			
15	Parli TPS, Unit - 5	Maharashtra	210	Dec-87
16	Raichur TPS, Unit - 3	Karnataka	210	Jun-91
17	Raichur TPS, Unit - 4	Karnataka	210	Sep-94
18	Ropar TPS, Unit - 3	Punjab	210	Jun-88
19	Ropar TPS, Unit - 4	Punjab	210	Jul-89
20	Ropar TPS, Unit - 5	Punjab	210	May-92
21	Ropar TPS, Unit - 6	Punjab	210	Apr-93
22	Sanjay Gandhi (Birsinghpur), Stage 1, Unit - 1	Madhya Pradesh	210	Mar-93
23	Sanjay Gandhi (Birsinghpur), Stage 1, Unit - 2	Madhya Pradesh	210	Mar-94
24	Tenughat TPS, Unit - 1	Jharkhand	210	Apr-96
25	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 4	Tamil Nadu	210	Aug-89
26	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 5	Tamil Nadu	210	Apr-90
27	Wanakbori Thermal Power Station, Unit - 6	Gujarat	210	Apr-87
	Total R&M (State Sector)	**6,250 MW**		

1.4. R&M (CENTRAL SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Unchahar TPS, Stage 2, Unit - 3	Uttar Pradesh	210	Apr-98
2	Unchahar TPS, Stage 2, Unit - 4	Uttar Pradesh	210	Nov-98
3	Vindhyachal Thermal Power Station, Stage - 2, Unit - 7	Madhya Pradesh	500	Apr-98

#	Plant Name	State	Capacity (MW)	Date of Commissioning
4	Vindhyachal Thermal Power Station, Stage - 2, Unit - 8	Madhya Pradesh	500	Jun-99
5	Simhadri TPS, Stage - 1, Unit - 1	Andhra Pradesh	500	Apr-02
6	Simhadri TPS, Stage - 1, Unit - 2	Andhra Pradesh	500	Jun-03
7	Talcher STPS, Stage - 1 for ER, Unit - 1	Orissa	500	Mar-95
8	Talcher STPS, Stage - 1 for ER, Unit - 2	Orissa	500	Mar-96
9	Dadri Thermal (NCTPP) - Stage 1, Unit- 2	Uttar Pradesh	210	Dec-92
10	Dadri Thermal (NCTPP) - Stage 1, Unit- 3	Uttar Pradesh	210	Mar-93
11	Dadri Thermal (NCTPP) - Stage 1, Unit- 4	Uttar Pradesh	210	Mar-94
12	Kahalgaon Thermal Power Station Stage 1, Unit - 1	Bihar	210	May-92
13	Kahalgaon Thermal Power Station Stage 1, Unit - 2	Bihar	210	Jul-94
14	Kahalgaon Thermal Power Station Stage 1, Unit - 3	Bihar	210	Aug-95
15	Kahalgaon Thermal Power Station Stage 1, Unit - 4	Bihar	210	Apr-96
	Total R&M (Central Sector)	**4,890 MW**		

2. R&M/ LE in 13th Plan

2.1. LIFE EXTENSION (STATE SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Bhusawal TPS, Unit - 2	Maharashtra	210	Aug-79
2	Bhusawal TPS, Unit - 3	Maharashtra	210	May-82

#	Plant Name	State	Capacity (MW)	Date of Commissioning
3	Parli TPS, Unit - 3	Maharashtra	210	Sep-80
4	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 3	Chhattisgarh	210	Mar-85
5	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 4	Chhattisgarh	210	Mar-86
6	Satpura, Stage - 3, Unit - 8	Madhya Pradesh	210	Jun-82
7	Satpura, Stage - 3, Unit - 9	Madhya Pradesh	210	Apr-83
8	Ukai Thermal Power Station, Stage 1, Unit - 5	Gujarat	210	Jan-85
9	Wanakbori Thermal Power Station, Unit - 2	Gujarat	210	May-83
10	Wanakbori Thermal Power Station, Unit - 3	Gujarat	210	Jun-84
11	Kolaghat TPS, Unit - 1	West Bengal	210	Apr-89
12	Kolaghat TPS, Unit - 5	West Bengal	210	Jun-90
13	Kota TPS, Unit - 3	Rajasthan	210	Jun-88
14	Kota TPS, Unit - 4	Rajasthan	210	May-89
15	Mettur TPS, Unit - 1	Tamil Nadu	210	Jan-87
16	Mettur TPS, Unit - 2	Tamil Nadu	210	Dec-87
17	Mettur TPS, Unit - 3	Tamil Nadu	210	Jun-88
18	Panipat Thermal Power Station, Unit - 5	Haryana	210	Jul-89
19	Raichur TPS, Unit - 3	Karnataka	210	Jun-91
20	Ropar TPS, Unit - 3	Punjab	210	Jun-88
21	Ropar TPS, Unit - 4	Punjab	210	Jul-89
22	Vijayawada TPS, Stage 2, Unit - 3	Andhra Pradesh	210	Oct-89

#	Plant Name	State	Capacity (MW)	Date of Commissioning
23	Vijayawada TPS, Stage 2, Unit - 4	Andhra Pradesh	210	Aug-90
	Total LE (State Sector)	**4,830 MW**		

2.2. LIFE EXTENSION (CENTRAL SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Singrauli Thermal Power Station, Unit - 7	Uttar Pradesh	500	Nov-87
2	Korba STPP, Stage - 2, Unit - 4	Chhattisgarh	500	May-87
3	Korba STPP, Stage - 2, Unit - 5	Chhattisgarh	500	Mar-88
4	Korba STPP, Stage - 2, Unit - 6	Chhattisgarh	500	Mar-89
5	Ramagundam, Stage - 2, Unit - 4	Andhra Pradesh	500	Jun-88
6	Ramagundam, Stage - 2, Unit - 5	Andhra Pradesh	500	Jul-89
7	Ramagundam, Stage - 2, Unit - 6	Andhra Pradesh	500	Oct-89
8	Unchahar TPS, Stage 1, Unit - 1	Uttar Pradesh	210	Apr-87
9	Unchahar TPS, Stage 1, Unit - 2	Uttar Pradesh	210	May-88
10	Vindhyachal Thermal Power Station, Stage - 1, Unit - 2	Madhya Pradesh	210	Jun-87
11	Vindhyachal Thermal Power Station, Stage - 1, Unit - 3	Madhya Pradesh	210	Jun-88
12	Vindhyachal Thermal Power Station, Stage - 1, Unit - 4	Madhya Pradesh	210	Dec-88
13	Vindhyachal Thermal Power Station, Stage - 1, Unit - 5	Madhya Pradesh	210	Apr-89

#	Plant Name	State	Capacity (MW)	Date of Commissioning
14	Vindhyachal Thermal Power Station, Stage - 1, Unit - 6	Madhya Pradesh	210	Jun-90
15	Dadri Thermal (NCTPP) - Stage 1, Unit- 1	Uttar Pradesh	210	Oct-91
16	Rihand STPS, Stage - 1, Unit - 1	Uttar Pradesh	500	Apr-87
17	Rihand STPS, Stage - 1, Unit - 2	Uttar Pradesh	500	May-88
18	Bokaro TPS B, Unit - 2	Jharkhand	210	May-90
19	Farakka Stage-1, Unit - 3	West Bengal	200	Aug-87
20	Neyveli TPS - 2, Stage 1, Unit - 1	Tamil Nadu	210	Jan-88
21	Neyveli TPS - 2, Stage 1, Unit - 2	Tamil Nadu	210	Feb-87
22	Neyveli TPS - 2, Stage 2, Unit - 4	Tamil Nadu	210	Mar-91
23	Neyveli TPS - 2, Stage 2, Unit - 5	Tamil Nadu	210	Dec-91
	Total LE (Central Sector)	**7,430 MW**		

2.3. R&M (STATE SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Gandhinagar TPS, Unit - 5	Gujarat	210	Jul-98
2	Panipat Thermal Power Station, Unit - 6	Haryana	210	Apr-01
3	TENUGHAT TPS, Unit - 2	Jharkhand	210	Aug-98
4	Raichur TPS, Unit - 5	Karnataka	210	Apr-99
5	Raichur TPS, Unit - 6	Karnataka	210	Dec-99
6	Sanjay Gandhi (Birsinghpur), Stage 2,	Madhya Pradesh	210	Feb-99

#	Plant Name	State	Capacity (MW)	Date of Commissioning
	Unit - 3			
7	Sanjay Gandhi (Birsinghpur), Stage 2, Unit - 4	Madhya Pradesh	210	Nov-99
8	KHAPERKHEDA TPS, Unit - 4	Maharashtra	210	Jan-01
9	KHAPERKHEDA TPS, Unit - 3	Maharashtra	210	May-00
10	Chandrapur TPS Maha, Stage - 2, Unit - 7	Maharashtra	500	Aug-97
11	Suratgarh TPS, Unit - 3	Rajasthan	250	Oct-01
12	Suratgarh TPS, Unit - 2	Rajasthan	250	Mar-00
13	Suratgarh TPS, Unit - 1	Rajasthan	250	May-98
14	Bakreshwar TPS, Unit - 3	West Bengal	210	Jan-00
15	Bakreshwar TPS, Unit - 2	West Bengal	210	May-99
16	Bakreshwar TPS, Unit - 1	West Bengal	210	Apr-98
	Total R&M (State Sector)	**3,770 MW**		

2.4. R&M (CENTRAL SECTOR)

#	Plant Name	State	Capacity (MW)	Date of Commissioning
1	Mejia TPS, Unit - 1, (MTPS - A)	DVC	210	Jun-96
2	Mejia TPS, Unit - 2, (MTPS - A)	DVC	210	Jun-98
3	Mejia TPS, Unit - 3, (MTPS - A)	DVC	210	Jun-99
4	Bokaro TPS B, Unit - 3	Jharkhand	210	Jun-93
5	Talcher STPS, Stage - 2 for SR, Unit - 4	Orissa	500	May-04
6	Talcher STPS, Stage - 2 for SR, Unit - 3	Orissa	500	Apr-03

#	Plant Name	State	Capacity (MW)	Date of Commissioning
7	Neyveli TPS - 1, Expn (Stage - 3), Unit - 2	Tamil Nadu	210	May-03
8	Neyveli TPS - 1, Expn (Stage - 3), Unit - 1	Tamil Nadu	210	Sep-02
9	Neyveli TPS - 2, Expn, Unit - 1	Tamil Nadu	250	Oct-02
10	Neyveli TPS - 2, Stage 2, Unit - 7	Tamil Nadu	210	Jun-93
11	Neyveli TPS - 2, Stage 2, Unit - 6	Tamil Nadu	210	Oct-92
12	Rihand STPS, Stage - 2, Unit - 3	Uttar Pradesh	500	Apr-04
13	Rihand STPS, Stage - 2, Unit - 4	Uttar Pradesh	500	Dec-04
14	FARAKKA STAGE-2, Unit - 5	West Bengal	500	Feb-94
	Total R&M (Central Sector)	**4,430 MW**		

Annexure - V

Break Up of Coal Cost[29]

Cost Components	Unit	Value
Distance between Mine and Plant location	Km	1,000.00
Basic Run of Mine Price	Rs./tonne	570.00
Charges for Steam Coal	Rs./tonne	180.00
Stowing Excise Duty	Rs./tonne	10.00
Royalty	Rs./tonne	83.50
FOB Price	Rs./tonne	843.50
Sales Tax	Rs./tonne	33.74
Ex Pithead Cost	Rs./tonne	877.24
Surface Transportation Cost	Rs./tonne	30.00
Ex Mine Cost	Rs./tonne	907.24
Railway Freight	Rs./tonne	923
Additional charges	Rs./tonne	382.73
Total railway Freight	Rs./tonne	1306
Landed cost of coal	**Rs./tonne**	**2213**

[29] All above costs are computed at a Coal GCV of 3200 Kcal/ Kg

Annexure - VI

Sensitivity of Levelised Tariff Vis-À-Vis Heat Rate and Auxiliary Consumption at Various CAPEX Level

1. At R&M CAPEX of Rs. Crore 2/ MW

Auxiliary Consumption (%)					
SHR (kcal/ kWh)	Levelised Tariff (Rs./ kWh)	11%	10%	9%	8%
	2950	4.21	4.16	4.11	4.07
	2900	4.15	4.10	4.06	4.01
	2850	4.09	4.05	4.00	3.96
	2800	4.04	3.99	3.95	3.90
	2750	3.98	3.94	3.89	3.85
	2700	3.92	3.88	3.84	3.79
	2650	3.87	3.82	3.78	3.74
	2600	3.81	3.77	3.73	3.68
	2550	3.75	3.71	3.67	3.63
	2500	3.70	3.65	3.61	3.57

2. At R&M CAPEX of Rs. Crore 2.25/ MW

Auxiliary Consumption (%)					
SHR (kcal/ kWh)	Levelised Tariff (Rs./ kWh)	11%	10%	9%	8%
	2950	4.26	4.22	4.17	4.12
	2900	4.21	4.16	4.11	4.07
	2850	4.15	4.10	4.06	4.01
	2800	4.09	4.05	4.00	3.96

Auxiliary Consumption (%)					
	2750	4.04	3.99	3.95	3.90
	2700	3.98	3.94	3.89	3.85
	2650	3.92	3.88	3.84	3.79
	2600	3.87	3.82	3.78	3.74
	2550	3.81	3.77	3.73	3.68
	2500	3.75	3.71	3.67	3.63

3. At R&M CAPEX of Rs. Crore 2.75/ MW

Auxiliary Consumption (%)					
SHR (kcal/ kWh)	**Levelised Tariff (Rs./ kWh)**	**11%**	**10%**	**9%**	**8%**
	2950	4.38	4.33	4.28	4.23
	2900	4.32	4.27	4.22	4.18
	2850	4.26	4.22	4.17	4.12
	2800	4.21	4.16	4.11	4.07
	2750	4.15	4.10	4.06	4.01
	2700	4.09	4.05	4.00	3.96
	2650	4.04	3.99	3.95	3.90
	2600	3.98	3.93	3.89	3.85
	2550	3.92	3.88	3.84	3.79
	2500	3.87	3.82	3.78	3.74

4. At R&M CAPEX of Rs. Crore 3/ MW

Auxiliary Consumption (%)					
SHR (kcal/ kWh)	**Levelised Tariff (Rs./ kWh)**	**11%**	**10%**	**9%**	**8%**
	2950	4.43	4.38	4.34	4.29
	2900	4.38	4.33	4.28	4.23
	2850	4.32	4.27	4.22	4.18
	2800	4.26	4.22	4.17	4.12
	2750	4.21	4.16	4.11	4.07
	2700	4.15	4.10	4.06	4.01
	2650	4.09	4.05	4.00	3.96
	2600	4.04	3.99	3.95	3.90
	2550	3.98	3.93	3.89	3.85
	2500	3.92	3.88	3.84	3.79

Note: *The SHR and AUX values corresponding to the green highlighted cells indicate the minimum levels of plant performance that needs to be achieved post R&M to ensure that the R&M is the least cost option as compared to BAU scenario*