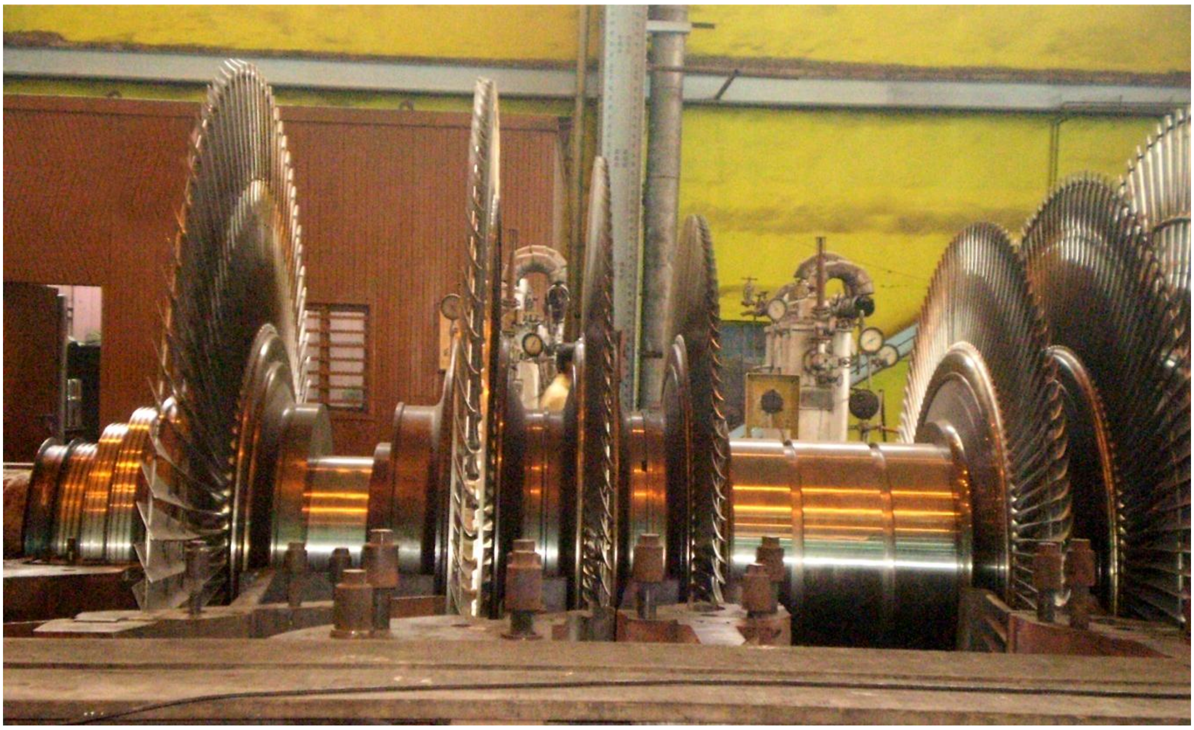
Study Report

Reduction of Barriers to Renovation and Modernisation Interventions in Thermal Power Stations in India

Includes:

Guidelines for Risk Identification and Mitigation in R&M Projects in Thermal Power Stations in India

Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them



Prepared By:
Mercados Energy Markets India Private Ltd.

Under
India: Coal Fired Generation Rehabilitation Project

(November 2013)

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Central Electricity Authority

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Table of Contents

List of Tables

List of Figures

List of Boxes

List of Abbreviations

AAUs	Assigned Amount Units
ABB	Asea Brown Boveri
AHP	Ash Handling Plant
AOH	Actual Operating Hour
AOP	Auxiliary Oil Pump
APEC	Asia-Pacific Economic Cooperation
B&W	Babcock & Wilcox
BEE	Bureau of Energy Efficiency
BFP	Boiler Feed Pump
BHEL	Bharath Heavy Electricals Limited
BoP	Balance of Plant
BSEB	Bihar State Electricity Board
BTG	Boiler, Turbine and Generator
BTPS	Barauni Thermal Power Station
C&I	Control and Instrumentation
CA	Condition Assessment
CAG	Comptroller and Auditor General
CDM	Clean Development Mechanism
CDM EB	CDM Executive Board
CEA	Central Electricity Authority
CEP	Condensate Extraction Pump
CERC	Central Electricity Regulatory Commission
CERs	Certified Emission Reductions
CHP	Coal Handling Plant
CM	Condition Monitoring
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
CPRI	Central Power Research Institute
CSPGCL	Chhattisgarh Power Generation Company Limited
CWP	Circulating Water Pump
DC	Designated Consumers
DCS	Digital Control System
DOE	Designated Operational Entity
DPR	Detailed Project Report
DRC	Dispute Resolution Committee

EA	Electricity Act	**GSECL**	Gujarat State Electricity Corporation Limited
EE R&M	Energy Efficient Renovation & Modernization	**GWh**	GigaWatt hour
EESL	Energy Efficiency Services Limited	**GCC**	Gross Coal Consumption
EPC	Engineering Procurement and Construction	**HFO**	Heavy Furnace Oil
ESCert	Energy Saving Certificate	**HP**	High Pressure
ESMAP	Energy Sector Management Assistance Program	**HPGCL**	Haryana Power Generation Company Limited
ESP	Electrostatic Precipitator	**HQ**	Headquarter
EU	European Union	**I&C**	Instrumentation & Control
EUA	EU Allowance	**IBR**	Indian Boiler Regulations
EUAS	Electricity Generation A.Ş. Turkey	**IBRD**	International Bank for Reconstruction and Development
EU-ETS	EU Emission Trading Scheme	**ID**	Induced Draft
FD	Forced Draft	**IDC**	Interest During Construction
FGD	Flue Gas Desulphurization	**IEA**	International Energy Agency
FMEA	Failure Modes and Effects Analysis	**IEX**	Indian Energy Exchange
GEF	Global Environment Facility	**IGEN**	Indo-German Energy Program
GENCO	Generation Company	**IP**	Intermediate Pressure
GHG	Green House Gases	**IRR**	Internal Rate of Return
GNDTP	Guru Nanak Dev Thermal Plant	**ISB**	Intelligent Soot Blowers
GoI	Government of India	**ISPE**	Institute for Studies and Power Engineering

JI	Joint Implementation	**Mt**	Million Tonne
JV	Joint Venture	**MU**	Million Units
KBUNL	Kanti Bijlee Utpadan Nigam Limited	**MW**	Megawatt
kCal	Kilo Calorie	**MYT**	Multi-Year Tariff
kJ	Kilojoule	**NASL**	NTPC Alstom Power Services Private Limited
KTPS	Koradi Thermal Power Station	**NCDMA**	National CDM Authority
kWh	Kilowatt	**NDT**	Non-Destructive Test
LDO	Light Diesel Oil	**NEP**	National Electricity Policy
LE	Life Extension	**NETL**	National Energy Technology Laboratory
LE&U	Life Extension and Uprating	**NLDC**	National Load Despatch Centre
LP	Low Pressure	**NOx**	Nitrous oxide
LROT	Lease, Rehabilitate, Operate and Transfer	**NPV**	Net Present Value
LTSH	Low Temperature Super Heater	**NRV**	Non Return Valve
Mg/NM^3	Milligrams per nominal cubic meter	**NSW GHGAS**	New South Wales GHG Abatement Scheme
MJ	Megajoule	**NTP**	National Tariff Policy
MoP	Ministry of Power	**NTPC**	National Thermal Power Corporation
MOU	Memorandum Of Understanding	**O&M**	Operation & Maintenance
MPPGCL	Madhya Pradesh Power Generation Company Limited	**OEM**	Original Equipment Manufacturer
MSEB	Maharashtra State Electricity Board	**P. A. Fan**	Primary Air Fan
MSPGCL	Maharashtra State Power Generation Corporation Limited	**PAC**	Provisional Acceptance

PAT	Perform Achieve and Trade	**SO_2**	Sulphur Dioxide
PDD	Project Design Document	**STEAG**	Steinkohlen-Elektrizität AG
PET	Performance Evaluation Test	**SUBC**	Sub Critical
PFC	Power Finance Corporation	**SUPERC**	Super Critical
PLF	Plant Load Factor	**TCE**	Tata Consulting Engineers
PLN	Perusahaan Listrik Negara (Indonesia)	**TOP**	Turbine Oil Pump
PSPCL	Punjab State Power Corporation Limited	**TPE**	Techno Prom Export
PXIL	Power Exchange of India	**TPP**	Thermal Power Plant
PTPS	Panipat Thermal Power Station	**TPS**	Thermal Power Station
QAC	Quality Assurance Consultants	**TWh**	Terawatt hour
R&M	Renovation & Modernization	**UNFCCC**	United Nations Framework Convention on Climate Change
RGGI	Regional Greenhouse Gas Initiative	**UPPCL**	Uttar Pradesh Power Corporation Limited
RLA	Residual Life Assessment	**UPRVUNL**	Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited
RMU	Removal Unit	**UPS**	Uninterrupted Power Supply
RSVY	Rashtriya Shram Vikas Yojana	**UPS**	Uninterrupted Power Supply
S&L	Sargent & Lundy LLC	**VCS**	Verified Carbon Standard
SEC	Specific Energy Consumption	**VERs**	Voluntary Emissions Reductions
SHR	Station Heat Rate	**VFD**	Variable Frequency Drives
SKM	Sinclair Knight Merz Pty. Ltd	**WBPDCL**	West Bengal Power Distribution Company Limited

Executive Summary

Planning and implementing Renovation and Modernisation (R&M) projects is often affected by occurrence of adverse events that can derail the objectives of the project. Identifying and mitigating project risks is crucial to successful management of R&M projects. For this, a well-structured and documented Risk Management Framework for each stage of the process is of utmost importance.

A thermal power plant undergoing R&M, despite undertaking prior plant assessment, might face unforeseen events after the unit has been shut down and opened up for R&M. Such unforeseen events - characterized as Technical Surprises - act as major barriers in up-scaling R&M of thermal power plants.

With this background the objective of the study was to identify key risks and surprises faced in planning and implementation of R&M of thermal power projects, and develop guidelines to mitigate such risks and technical surprises.

To achieve the above objectives, a case study based approach was adopted wherein select plants were identified across the country by the CEA for undertaking a detailed assessment of the experience of these plants in executing R&M works. Visits were undertaken to all these plants and discussions were held with concerned officials dealing with R&M including plant/unit level engineers, operation and maintenance department and commercial department to understand their experience in planning, tendering, procurement, executing R&M program and O&M of the units subsequent to R&M. Study of these units also enabled the project team to understand the type of technical surprises faced by the utilities, the root causes, impact on the project. The team investigated the existing mechanism adopted by utilities to handle such surprises. The team also undertook extensive stakeholder consultation to understand perspectives of various stakeholders. The stakeholder group included the State Generating Stations, Central and State Electricity Regulatory Commissions, Equipment Suppliers, Design Consultants, Implementation Support Consultants, Sector Experts, Funding Agencies and the CEA. The study team also evaluated international experiences from Czech Republic, Poland, Turkey, Romania, Indonesia and South Africa, and visited Poland and Czech Republic to obtain the relevant experiences from personnel involved in R&M of projects in these countries.

Basis the analysis and consultations a detailed set of guidelines for managing technical surprises was evolved. The process of finalisation of the guidelines involved intense consultation with the members of the Task Force, constituted by the CEA for "Promotion of Energy Efficiency R&M in Thermal Power Stations in India" under the Chairmanship of Member (Thermal), CEA.

The final outcomes of the study are a comprehensive report that includes two detailed guidelines, namely the "Guidelines for Risk Identification and Mitigation in R&M Projects in Thermal Power Stations in India" and "Guidelines for Early

Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them". The flow of the guidelines has been mapped in accordance to the different stages in R&M projects i.e. Identification Stage, Assessment Stage, Planning Stage, Execution Stage and Closure Stage. Under each stages of R&M life cycle, the guidelines contain the key risks that can arise during that stage, its root cause, its impact and key strategies to mitigate the risks. The key risks in R&M projects are categorized as Management Risk, Technical Risk, Operational Risk, Institutional Risk, Market Risk, Regulatory Risk, Contractual Risk, Funding Risk and Socio-Environmental Risk. The guidelines are intended to help the utilities in advance in identifying and understanding the risks that may arise as the R&M project progresses and can take corrective remedial actions for minimisation of such risks.

The key risks identified in the study, categorized according to different stages of the R&M life cycle along with appropriate strategies to handle the same are indicated in the table below.

Table ES: Potential Risks involved in R&M Process along with Key Strategies to Handle Risks and Surprises

S. No	Stages	Category of Risk	Risk	Strategies to handle risks and surprises
1	Identification	Management risk	Reactive approach to identification of plant for R&M	Strengthening of internal data acquisition, monitoring and alert systems to track unit performance. (Risk Avoidance)
2		Management Risk	Lack of long term generation plan and awareness of available market options	Establishment of rationale for R&M project at the state level taking into account all the alternative competing options. (Risk Avoidance)
3		Market Risk	Lack of confidence and uncertainty with regard to R&M projects	• Need for Experience Sharing and Dissemination (Risk Mitigation) • Need to Develop Market for R&M in the Country by communicating the overall market size and addressing concerns of various stakeholders (Risk Avoidance)
4	Assessment	Institutional Risk	Delay in obtaining unit shut down for undertaking technical studies	Advance Planning for Scheduling of Technical Studies so as to either coincide the timing with the annual/capital overhaul or provide advance notice to the discom for such shutdown (Risk Avoidance)
5		Technical Risk	Inadequate technical assessment/studies	Comprehensive Studies for the unit planned for R&M should be mandatory covering both Main Plant and Balance of Plant.

				Proxy assessment should be avoided. The assessment should cover review of O&M processes as well. (Risk Avoidance)
6		Management Risk	Weak analytical framework for selection of R&M options	Comprehensive Identification and Assessment of Options including computation of financial returns, payback period, shutdown time required and conformance to the set objectives.(Risk Avoidance)
7		Regulatory Risk	Appropriate Commission not apprised of the R&M project plan	Practice of obtaining in-principle approval from the Appropriate Commission should be encouraged.(Risk Avoidance)
8		Operational Risk	Limited capacity of utilities in undertaking R&M works	• Creation of dedicated R&M Cell by the utility both at the headquarter and the plant level. (Risk Avoidance) • Engaging Specialized Consultants especially design and implementation support consultants. (Risk Avoidance)
9		Contractual Risk	Weakly defined scope of work	Scope of Work to be as precise and comprehensive as possible including roles and responsibilities of each entity involved in the contract. General statements should be avoided. The scope of work should be built on the comprehensive studies conducted and strengthened by root cause analysis. (Risk Mitigation)
10		Funding Risk	Utility unable to mobilise funds	Increased proliferation of innovative financing approaches /models like LROT and JVs coupled with creation of awareness about benefits of R&M through pilot studies to be taken up. Standard bid document to include terms and conditions for the above models. (Risk Mitigation)
11	Planning	Market Risk	Low level of participation by the vendors in the bidding process	Focussed efforts should be taken up to involve potential players in the R&M market by the utilities and the CEA.(Risk Mitigation) Opportunity origination through designated state plans and regulatory measures.

12		Market Risk	Higher than expected price discovery	• Standard Contracts and Bid Documents (Risk Mitigation) • Bidding to be adopted as mode of allocation (Risk Mitigation) • Stringent Guarantees to be avoided (Risk Mitigation) • Adherence to O&M plan and minimizing time gap (Risk Mitigation)
13		Market and Operational Risk	Rebidding/Re-award/Delay in award of R&M packages/contract	• Rebidding should ideally be avoided through robust project preparation. (Risk Acceptance) • Time bound bid process and activities (Risk Avoidance) • Standardized bid document (Risk Avoidance)
14		Management Risk	Implementation contract awarded to vendor involved in carrying out technical studies	To avoid conflict of interest, a single entity should generally be avoided to assume both the role of design consultant as well as the supplier. (Risk Avoidance)
15	Execution	Management Risk	Weak decision-making framework	Creation of clearly defined decision making and reporting structures with nominated officials authorized to undertake decisions related to R&M (Risk Mitigation)
16		Technical Risk	Occurrence of technical surprises	• Preventive Measures – Robust studies; Strong internal data reporting & alerts; Good O&M practices including during interim stage; Dedicated R&M team; Minimizing the time gap b/w studies & execution and Site inspection by vendors • Measure to Manage Surprises- Defining a technical surprise plan upfront; Creation of dispute resolution mechanism with clear decision making authority; Provision of Unit/rate contractors; Supplier strategy to deal with surprises and Creation of Contingency fund
17		Contractual Risk	Weak dispute resolution mechanism	Creation of Dispute Resolution Committee at the start of project to address disputes

			constraining the execution of work	between the Utility and the Contractor in a timely manner (Risk Mitigation)
18		Market Risk	Mismatch (or delay) in supply of critical equipment and the shutdown period	• Availability of key components should be ensured before the start of the project and should be in accordance with the pre-defined plan finalized before the commencement of work.(Risk Mitigation) • Provision of Penalties for delay in completion of work. (Risk Sharing/Transfer) • Sequential delivery of materials to the R&M site (Risk Mitigation)
19		Operational Risk	Weak Supervision, Quality Control And Assurance	Approval of detailed quality plans and Engaging Quality Control and Quality Assurance Consultants by the Utility. (Risk Mitigation)
20		Socio-Environmental Risk	Failure Of The Plant To Achieve Environmental Standards And Plant Is Perceived To Have Negative Social/Environ mental Impact On Near-By Villages	Socio-environment impact assessment to be conducted and recommendations to be implemented in a time bound manner (Risk Mitigation)
21		Institutional Risk	Delay in provisioning of obtaining unit shut down for executing R&M works	• Advance Planning for Scheduling of Shutdown for Execution of Works (Risk Avoidance) • Additional Allocation of Power to States from Unallocated Quota of Central Pool (Risk Avoidance) • Implementation of partial R&M activities during Annual shutdown periods. (Risk Avoidance)
22	Closure	Operational Risk	Sustainability of R&M gains affected by weak O&M practices	• Preparation and implementation of O&M action plan by preparing O&M manuals including preventive, capital and breakdown maintenance procedure / guidelines for units undergoing R&M. This should be adopted through a

				Board Resolution and followed thereafter. (Risk Mitigation) • Engaging specialised agency for O&M of the plant, post R&M. (Risk Mitigation) • After sale services to be made an integral part of the contract (Risk Mitigation)
23		Technical Risk	Post R&M guarantees not achieved	• Rectification/replacement of components to meet guaranteed parameters at no extra financial cost to utility. (Risk Mitigation) • Levy of Liquidated Damages for shortfall in performance. (Risk Mitigation)
24		Regulatory Risk	Non-approval of costs incurred during R&M	Involvement of Regulator should be ensured from the inception of the project with regular updates about the progress of the project. (Risk Avoidance)
25		Operational Risk	Absence of ex-post evaluation and feedback loop	Experience gained must be documented and incorporated in subsequent units planned for R&M works. (Risk Mitigation)

The above provide essential guidance for the generating companies, who must evaluate and analyse the potential technical surprises and risks in necessary detail for implementing R&M projects and formulate appropriate strategies in line with those suggested in the guidelines to minimize such risks and surprises.

In addition to the above, the study also provides an estimate of the overall GHG reduction potential of EE R&M during the 12th and 13th Five Year Plan. In order to estimate the CO_2 emission reduction, potential various scenarios (Conservative, Intermediate and Optimistic) has been built in. These scenarios were developed considering the fact that different utilities may select different options for R&M depending upon the cost involved, timeframe for shutdown and their priorities.

On the basis of assessment it is seen that the current operating average net SHR of coal based thermal power plants assessed for R&M/LE in the 12th Plan is around 2962 kcal/kWh which translates into an efficiency of around 29.03%. If all the plants post R&M operate on their design efficiencies, the average net SHR can be improved to 2,551 kcal/kWh i.e. around 33.7%. This has an important consequence for the coal requirements in the country. At a time when the country is increasingly dependent on expensive coal imports that are affecting the balance of payments and the competitiveness of the country, the R&M

measures will have a significant macro-economic impact. Equally importantly, the R&M process will have a very significant bearing on the country's climate related goals. The CO_2 emission reduction potential ranges from 6%-13% depending upon the level of average efficiency achieved post R&M/LE in the 12th Plan. In absolute terms CO_2 emission reduction potential ranges from 14.91 Mt CO_2 to 29.81 Mt CO_2 across different scenarios with respect to the Baseline.

Similarly, the operating average net SHR is of around 2,926 kcal/kWh or efficiency of 29.39% in the 13th Plan which if the plants post R&M operate at designed efficiency can be improved to 2560 kcal/kWh which translates to efficiency of 33.59%. The CO_2 emission reduction potential ranges from 6%-12% in the 13th Plan with absolute terms CO_2 emission reduction potential ranging from 6.31 Mt CO_2 to 12.61 Mt CO_2.

For monetisation of the GHG emission reduction achieved through implementing R&M, utilities can take advantage of the available GHG monetization framework. Clean Development Mechanism (CDM) and Voluntary Carbon Standards (VCS) are two available monetisation frameworks for R&M in India. Further, the Government of India (GOI) has also launched the Perform Achieve and Trade (PAT) Scheme under National Action Plan on Climate Change (NAPCC). It provides the requisite mechanism to prompt the utilities to undertake R&M.

In summary, the role of R&M is increasingly becoming important in view of fuel scarcity, and the need to utilise it in the most possible efficient manner. However, R&M processes are prone to technical surprises, and these must be dealt in a systematic manner. It is expected that risks and surprises identified in this report and suggestions proposed for mitigating/avoiding various risks and surprises will aid the utility in up scaling R&M activities and would help promote good R&M practices in the country and support the objectives and policy goals of Government of India on clean and economically sustainable development.

Chapter - 1
Introduction

1.1. Concept of R&M and Life Extension Programme for Coal Fired Thermal Power Stations

1.1.1. Renovation and Modernization Programme

The main objective of R&M of power generating units is to make the operating units well equipped with modified / augmented latest technology equipment/components/ systems with a view to improving 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. Middle life R&M comes up preferably 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.

1.1.2. 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 help reveal the remaining life of various critical components of plants and equipment to enable introducing measures to extend the life of the plant by a further period of about 15-20 years. 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 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.

1.1.3. 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.

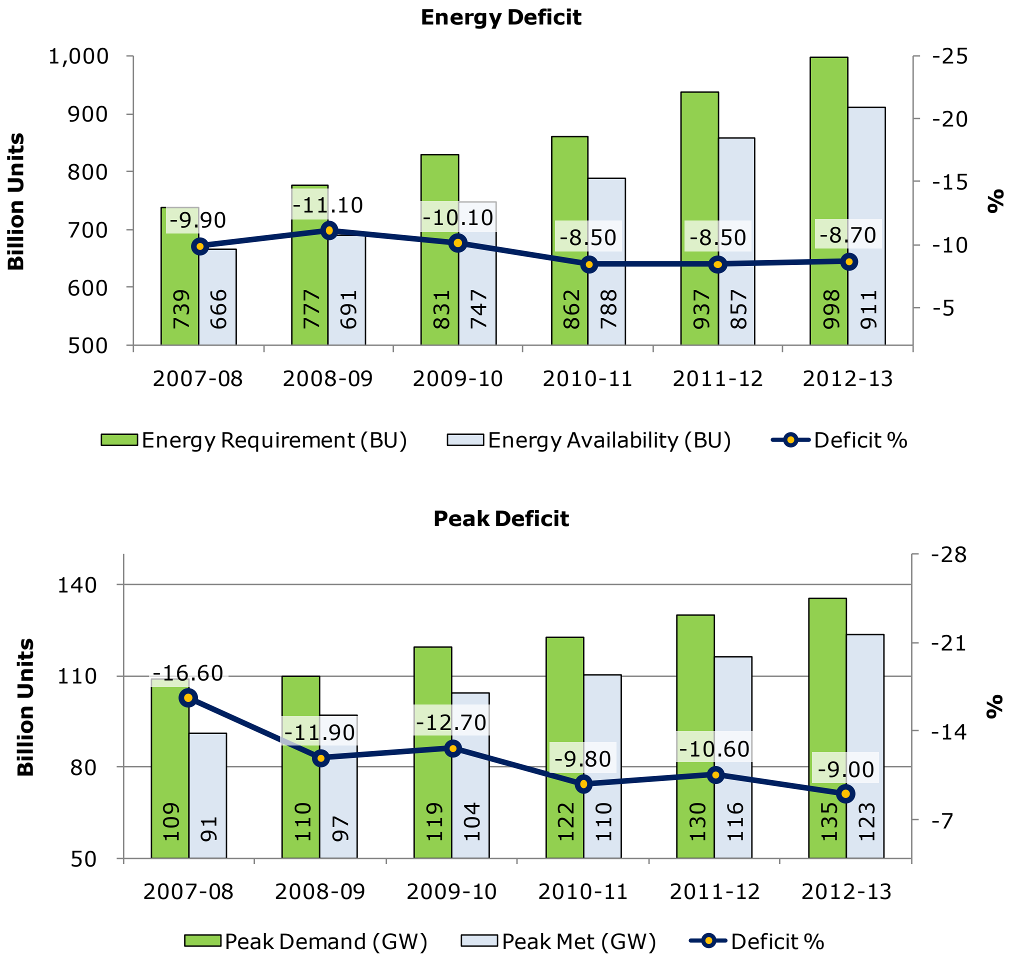
c) Routine repairs/replacements during annual/capital overhauls.

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.

1.2. Country Issues and Role of R&M

The power sector is imperative for sustained and inclusive economic growth. One of the key challenges faced by the power sector is the perpetual lack of adequate capacity addition viz-a viz demand leading to severe energy and peak shortages. In 2012-13, overall energy shortage and peak deficit in the country stood at 8.7% and 9% respectively. Trend of energy and peak shortages in India is presented in figure below.

Figure 1: Energy and Peak Deficit in India



With the high cost of new installations, poor financial health of the utilities and emerging fuel constraints it has become essential to maximize generation from the existing power stations by restoring their rated capacity and also improve the efficiency of the power stations through R&M/LE. It is one of the most cost effective options to achieve additional generation from existing old units within a short gestation period. The benefits of undertaking R&M of old plants are presented in the box below.

Box 1: Benefits of undertaking R&M of old thermal power plants

a) New plants are relatively expensive than the cost associated with R&M of plants, wherein the old plants can be renovated and modernized at lower costs along with the extension of their life.

b) Longer gestation period of new plant in comparison to outage time when R&M is undertaken

c) Availability and efficiency can be improved through improvement in heat rate, reduction in auxiliary consumption, hence lower emissions

d) Focus on optimal utilisation of scarce resource of coal

e) With tariff based bidding becoming a norm, utilities have to bring down their cost of generation to remain competitive.

f)	Minimal Rehabilitation and Resettlement issues.
g)	Incorporation of new technology
h)	Ability to comply with environmental and safety norms that are increasingly becoming stringent

R&M is thus a low hanging fruit that can be harnessed to bring in additional capacity in the country. Also, considering the extent of shortages and severity of challenges faced by the country, all modes of supply augmentation need to be pursued simultaneously including R&M of old thermal power plants.

As per the National Perspective Plan of CEA, under 12th Plan, LE works have been identified on 70 thermal units of total capacity 12,066 MW and R&M works have been identified on 65 units (17,301 MW) during the 12th Plan.

Considering that the old generation capacities are likely to remain in use (wherever possible) even after replacement capacities have been commissioned, R&M needs to be accorded adequate focus and priority. Over the last decade, the electricity supply industry has witnessed several changes that have significant implications for R&M in the country. These changes need to be understood in the context of the current legal, policy and regulatory framework, which has been elaborated in the following sub-section.

1.3. Legislative, Policy and Regulatory Framework in India

Various policy and regulatory measures and national level mission and programs lay emphasis on promoting R&M in the country. The enabling provisions for R&M in the country are provided below:

a) Electricity Act 2003

The Electricity Act 2003 (EA 2003) is the primary legislative instrument which governs the electricity supply industry in India.

Section 61 (C) of the Act requires the Appropriate Commission to set tariff by considering, the factors which would encourage competition, efficiency, economical use of resources, good performance, and optimum investments'.

b) Energy Conservation Act 2001

Similar to EA 2003, the Energy Conservation Act, 2001 contain provisions related to the promotion, efficient use and consumption of energy. It empowers the Central Government to force inefficient generation utilities to take "appropriate measures" to increase energy conversion efficiency in their operations.

c) National Electricity Policy 2005

National Electricity Policy notified by the Govt. of India (GOI) in 2005 under the provisions of EA 2003 states the following:

"One of the major achievements of the power sector has been a significant increase in availability and plant load factor of thermal power stations especially over the last few years. Renovation and modernization for achieving higher efficiency levels needs to be pursued vigorously and all existing generation capacity should be brought to minimum acceptable standards. The Govt. of India is providing financial support for this purpose.

For projects performing below acceptable standards, R&M should be undertaken as per well-defined plans featuring necessary cost-benefit analysis. If economic operation does not appear feasible through R&M, then there may be no alternative to closure of such plants as the last resort.

In cases of plants with poor O&M record and persisting operational problems, alternative strategies including change of management may need to be considered so as to improve the efficiency to acceptable levels of these power stations."

d) National Tariff Policy 2006

National Tariff Policy notified by the Govt. of India in 2006 under the provisions of EA 2003 states the following:

"Renovation and modernization (it shall not include periodic overhauls) for higher efficiency levels needs to be encouraged. A Multi-Year 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 the 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 the Appropriate Commission."

e) Integrated Energy Policy 2006

Integrated Energy Policy notified in 2006 within overall objective for sustainable growth with energy security and improved efficiency. The following provision directly pertains to R&M:

"Rehabilitation of existing thermal stations could raise capacity at least cost in the short run and this should be taken up urgently."

f) Guidelines for Renovation and Modernization / Life Extension works of Coal/Lignite based Thermal Power Stations, 2009

With a view to expedite the R&M/ LE works during the 10thplan period, GoI, Ministry of Power (MoP) issued guidelines in Feb, 2004. The guidelines provided a framework to be followed if generators are to benefit from debt financing from the Power Finance Corporation (PFC) at an interest rate subsidy of 3-4 per cent. Consequently, the guidelines were revised in 2009 by the MoP for R&M/LE works for power generating stations.

These guidelines provide detailed methodology for implementation of R&M and LE&U programmes along with roles and responsibilities of different stakeholder and timelines etc.; lays down the maximum cost for undertaking such programmes; emphasis on cost benefit analysis before undertaking investment decision on R&M/LE&U scheme driven by economic sensitivity analysis on cost of generation; and framework for participation of private sector in LE programme etc.

g) PAT Scheme of the Bureau of Energy Efficiency

In order to accelerate as well as incentivize energy efficiency, the Perform Achieve and Trade (PAT) mechanism has been designed by Bureau of Energy Efficiency (BEE). PAT is a market based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities (classified as Designated Consumers as per Energy Conservation Act 2001), through certification of energy savings that could be traded. A total of 144 Thermal Power Plants in the country have also been identified as a set of designated consumers. Among other measures, R&M is likely to be one of the means for achievement of the target heat rates provided to the above plants.

h) CERC (Terms and Conditions of Tariff) Regulations, 2009[1]

In order to provide requisite compensation to the generating utility for R&M, the tariff regulations notified by the CERC provide the following mechanism for recovery of the expenditure incurred on R&M of plants:-

> *"The generating company for meeting the expenditure on Renovation and Modernization (R&M) for the purpose of extension of life beyond the useful life of the generating station or a unit thereof shall make an application before the Commission for approval of the proposal with a Detailed Project Report giving complete scope, justification, cost-benefit analysis, estimated life extension from a reference date, financial package, phasing of expenditure, schedule of completion, reference price level, estimated completion cost including foreign exchange component, if any, record of consultation with beneficiaries and any other information considered to be relevant by the generating company."*
> *"Provided that in case of coal-based/lignite fired thermal generating station, the generating company, may, in its discretion, avail of a 'special allowance' as compensation for meeting the*

[1] New Regulations are under development which are likely to further incentivize R&M

requirement of expenses including Renovation and Modernization beyond the useful life of the generating station. Special allowance shall be @ Rs. 5 lakh/MW/year in 2009-10 and thereafter escalated @ 5.72% every year during the tariff period 2009-14, unit-wise from the next financial year from the respective date of the completion of useful life with reference to the date of commercial operation of the respective unit of generating station; provided that in respect of a unit in commercial operation for more than 25 years as on1.4.2009, this allowance shall be admissible from the year 2009-10."

i) Tariff Regulations by State Electricity Regulatory Commissions

In line with provision of the CERC tariff regulations various state electricity regulatory commissions have also incorporated relevant provisions for recovery of expenditure incurred on R&M as part of their tariff regulations.

j) National Perspective Plan for Renovation & Modernization and Life Extension & Uprating of Thermal Power Stations

The Central Electricity Authority (CEA) in consultation with state power utilities and other stakeholders have prepared a National Perspective Plan for Renovation and Modernisation and Life Extension of thermal power stations upto the year 2016-17.

The broad objectives of future R&M national plan include:

a) Identification of thermal units requiring LE during 11th and 12th Plans in order to extend their useful economic life for another 15-20 years beyond their designed economic life of 25 years.
b) Assessment of total investment required during 11th and 12th Plans for LE programme.
c) Identification of potential candidates for EE R&M programme and assessment about external funding and other sources of financing during the 11th and 12th Plan.
d) Providing a road map for smoother implementation of R&M/LE schemes.
e) Projection of expected benefits from these schemes.

k) Indian Boiler Regulations, 1950

Regulation 391 A of IBR, 1950 elaborates on the aging effects on boilers and maximum permitted working pressure allowed for operation of various types of boilers. Specifically, for water tube boilers, these regulations prescribe the following:

(i) The boilers which are operating at a temperature of 400°C and above including utility or industrial boilers and all boiler parts operating in the creep range of the boiler shall be non-destructively tested after they are in operation for 1,00,000

hours for assessment of the remnant life of the parts;

(ii) The parts of a boiler when it completes a life of twenty five years are to be tested as per table 2 for assessment of the remnant life of such parts. If results are acceptable as per the standards laid down by the Central Boilers Board, a certificate shall be issued by the Chief Inspector of Boilers for extending the life of the boiler for a further period of ten years or such less period as recommended by the Remnant Life Assessment Organisation. This assessment of remnant life shall be carried out thereafter every five years by the organisations working in the field of boilers and remnant life and extension thereof after such organisation is approved by the Central Boilers Board. Such organisation shall work in close coordination with the office of the Chief Inspector of Boilers in the field of remnant life assessment and extension. The working pressure of such boilers may be reduced on the recommendations of such approved organisation.

l) National Action Plan on Climate Change

Recognising that the climatic change is a global phenomenon, Government of India released India's first National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs addressing climate mitigation and adaptation. Emphasizing the overriding priority of maintaining high economic growth rates to raise living standards, the plan "identifies measures that promote development objectives while also yielding co-benefits for addressing climate change effectively."

The plan identifies eight core "national missions" running through 2017 which represents multi-pronged, long term and integrated strategies for achieving key goals in the context of climate change.

It may be worthwhile to mention here that while an enabling policy and regulatory framework has been provided for undertaking R&M, the performance from being reasonable until the 9^th^plan period, has deteriorated since the 10^th^ plan period. This is further discussed in the following sub-section.

1.4. Achievement of R&M and LE works in the past Plan periods

The importance of R&M was recognised by the GOI way back in 1984 when Phase-I R&M Programme for 34 thermal power stations in the country was launched by the CEA as a Centrally sponsored scheme. Since then R&M option has been effectively utilised over the various plan periods. R&M and LE works completed in various plan periods along with the results achieved in terms of additional generation in Million Units (MU) and equivalent Megawatt (MW) is presented in the table below.

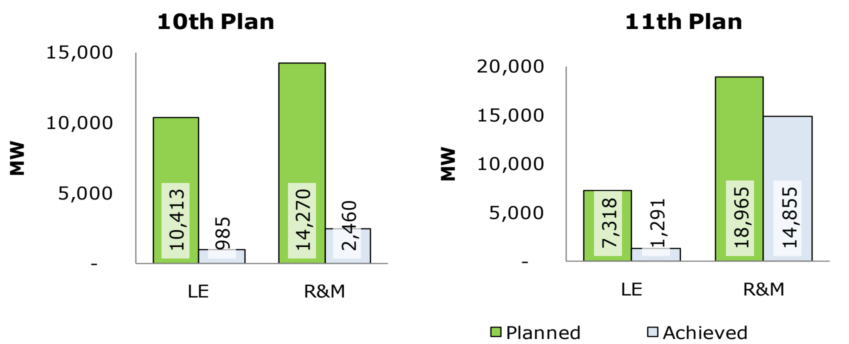
Table 1: Achievement of R&M and LE works in various Plan periods

S. No	Five Year Plan	No. of Units	Capacity (MW)	Additional Generation Achieved MU/Annum	Equivalent MW
1	7th	163	13,570	10,000	2,000
2	8th (R&M) (LEP)	198 (194) (4)	20,869	5,085	763
3	9th (R&M) (LEP)	152 (127) (25)	18,991	14,500	2,200
4	10th (R&M) (LEP)	25 (14) (11)	3,445	2,000	300
5	11th (R&M) (LEP)	129 (76) (53)	16,146	5,400	820

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

The momentum for undertaking R&M works continued till the 9th Plan but considerable slippages were observed thereon in the subsequent plan periods. Equipment capacity constraints, contractual delays, reluctance to shutdown units in light of chronic power shortages in the respective states, financial constraints etc. were some of the reasons for such slippages. Although the performance of the programme improved during the 11th Plan, achievement had only been 56% and 61.4% of the planned number of units and capacity respectively. Planned capacity viz-a-viz the achievement of R&M and LE works during 10th and 11th Plan is presented below.

Figure 2: Planned capacity and achievement of LE and R&M works during 10thand 11thPlan



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

1.5. Emerging Market Trends and its influence on R&M

Ever since the enactment of EA 2003, the electricity market has witnessed several changes that strongly influence the R&M market for thermal power plants. The table below maps out the changes prior to EA 2003 and after the enactment and also indicates implications for R&M projects in India.

Table 2: Emerging Power Sector Market Scenario and Implications for R&M

Characteristics / Market Changes	Before enactment of the EA2003	Current Scenario	Implications for R&M
Presence of Power Markets and Competition	Absent	Present	a) As a result of emergence of power markets, alternate procurement avenues are now available to the state utilities to prevent outages when plants undergo R&M b) Increased focus on efficiency improvement owing to competitive procurement of power and possibility of extension of the framework to state generating companies in the near future
Degree of Private Sector Participation	Low	High	Increased private sector participation across the value chain in the electricity supply industry has resulted in better response, lower lead-time and risk sharing.
Equipment Vendors Base	Small	Large	a) Open market policy of GoI and increasing capacity expansion has attracted many international players, decreasing market dominance of domestic players like BHEL by providing comparable technological competencies and services. b) Alongside, the equipment market has also seen emergence of several domestic players as well, leading to a much more diversified equipment vendor base.

Characteristics / Market Changes	Before enactment of the EA2003	Current Scenario	Implications for R&M
Focus on Optimization	Low	Higher	a) One of the strategies of PAT Scheme of the BEE is aimed at enhancing energy efficiency in existing power plants and has set power sector as one of the Designated Consumers (DC). b) Along with the above there are several generation optimization products/modules that many new generating plants or plants undergoing refurbishment are opting for to increase the overall plant output and increase process efficiency.
Market framework for GHG emission reduction and Environmental Compliance	Absent	Present	a) With power sector contributing 40% to carbon emissions of India, R&M with short gestation time can be short and medium term strategy to achieve National Action Plan on Climate Change. b) Although at present the contribution of R&M towards GHG mitigation is small, the capabilities promise the flexibility for responding to emerging economic, socio–environmental and sustainable development needs.
Coal Constraint	No	Yes	a) At present, acute coal shortage looms large on the sector. Domestic coal shortage was never envisaged in any of the previous plan period; however the sector today has suddenly awakened up to this reality. b) In such extreme coal supply constrained scenario, focus on available coal being used in most efficient form by the market participants is high. c) The above trend supports R&M

Characteristics / Market Changes	Before enactment of the EA2003	Current Scenario	Implications for R&M
			as energy efficient R&M results in lowering specific coal consumption of the plant and hence promotes optimal utilization.

All of the above trends indicate positive changes for R&M market in the country. However, the above changes have to be accompanied by introduction of measures that are aimed at addressing the inherent policy, technical, commercial, and regulatory barriers faced by the stakeholders involved in the R&M process. These barriers once removed can alter the risk profile of the R&M projects making them an attractive proposition for all stakeholders in the sector.

1.6. 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:-

a) **Component-1: Energy Efficiency R&M at Pilot Projects**
This component would fund implementation of Energy Efficient 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.

b) **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 provided 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) on April 02, 2012, for undertaking study on "Reduction of barriers to R&M interventions in thermal power stations in India".

1.7. Scope and objective of the study

The key objectives of the study of "Reduction of barriers to R&M interventions in thermal power stations in India" were as follows:

1. **Task 1-** Assess the key risks in planning and implementation of R&M of thermal power projects, and develop guidelines to mitigate such risks.

   a) Reviewing the past experiences of developing and implementing R&M with Life Extension Projects. The Consultant shall review the experience of R&M and Life Extension in Indian thermal power stations to identify the various risks encountered while carrying out such R&M works.

   b) Studying and analysing the risks identified in detail and the consequences of such risks on R&M projects. The Consultant shall study and analyse the various risks associated with development and implementation of R&M projects in technical, commercial, contractual and market aspects including but not limited to following risks:

      i. Policy and Regulatory Risks including recovery of Capital Cost and its impact on post R&M Tariff
      ii. Project Schedule and Time Over-run Risks along with its impact on Estimated R&M Cost due to time over-run and provisions in contractual arrangements;
      iii. Cost Over-run Risks including change in scope and provisions in contractual arrangements;
      iv. Risks during execution phase including resources risks;
      v. Political Risks if any;
      vi. Post R&M Performance Risks and associated mitigation measures i.e. Liquidated Damages, etc.

   c) Conducting meetings and interaction with the concerned stakeholders such as State Generating Stations, Central and State Electricity Regulatory Commissions, Equipment Suppliers, Design Consultants, Funding Agencies and CEA to analyze the identified risks.

d) Based on the above study and interactions with stakeholders, the Consultant shall develop strategies to mitigate the risks and prepare "Guidelines for Risk Identification and Mitigation in R&M Projects in Thermal Power Stations in India".

2. **Task 2-** Assess the technical surprises encountered during implementation of R&M and develop guidelines for early identification of potential surprises and ways of addressing them.

a) Reviewing the past experiences of developing and implementing R&M with Life Extension Projects. The Consultant shall review the experience of R&M and Life Extension in Indian thermal power stations (list enclosed at Annexure 1) to identify the technical surprises encountered by the utilities while carrying out the R&M works.

b) Interacting with State Generating Companies, various Suppliers and Design Consultants to collect information on surprises experienced in R&M works of thermal power stations and suggestions for addressing them. Based on the interaction, the Consultant shall study the identified technical surprises and experiences at thermal power stations in India in detail and develop strategies to address and mitigate such technical surprises.

c) On the basis of this study and interaction with Suppliers and Design Consultants, the Consultant shall develop "Guidelines for Early Identification of Potential Surprises in R&M Projects and Ways of Addressing Them".

3. **Task 3-** Review International best practices in R&M

a) The Consultant shall review the international best practices in developing and implementing the R&M projects considering the energy efficiency and rehabilitation of thermal power stations. The various best practices to be reviewed by the Consultant shall inter-alia include the following:

i. Selection of Unit/Plant for R&M along with objectives of carrying out R&M,
ii. Advanced technological options for EE R&M such as turbine up-gradation, efficient and environment friendly furnace-boilers, coal utilization etc.
iii. Finalisation of Scope of Work for R&M,
iv. Procurement Process for Selection of Consultant/Contractor,
v. Funding of R&M Projects,
vi. Cost Benefit Analysis,

vii. Implementation of R&M Projects including shut down time,
viii. Environmental safeguards,
ix. Measures for Guaranteed Performance post R&M

b) Based on the above review, the Consultant shall recommend and suggest alternate cost-effective options for R&M under Indian conditions with respect to the following parameters:

i. Augmentation of project capacity,
ii. Technical feasibility,
iii. Cost effectiveness,
iv. Efficiency Improvement,
v. Environmental safeguards.

c) The Consultant shall recommend best ways and means through which these International practices can be adopted by the generating companies in India.

d) On the basis of review of international best practices, the Consultant shall identify the measures that can be used to mitigate the risks and handle technical surprises in the thermal power stations in India.

e) Based on the review of the international best practices, the Consultant shall also develop standard menu of options for energy efficiency focused rehabilitation and life extension of 210 MW and above units in thermal power stations in India.

4. **Task 4-** Assess the potential reduction in Green House Gas (GHG) emissions on account of implementation of Energy Efficient R&M and suggest possible framework for monetizing the GHG emissions reduction.

a) The Consultant shall suggest the GHG emissions reduction potential under various technological options considering the advanced technologies of EE R&M of thermal power stations.

b) The Consultant shall also suggest the various possible frameworks for monetizing the GHG emissions reduction potential in the National and International markets.

Chapter - 2
Approach and Methodology

This chapter presents the Approach and Methodology (A&M) adopted by the team for undertaking different tasks of the study.

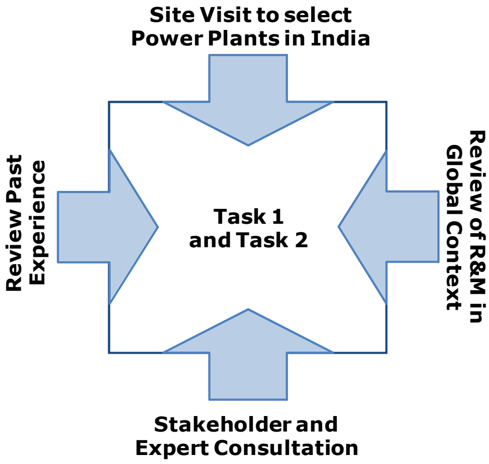
2.1. Approach and Methodology for Task 1 and Task 2[2]

The study team undertook the following approach to undertake this study:

1. Review of the Past experience of R&M in the country.
2. Site Visit to Select Power Plants in India
3. Review of R&M in Global Context
4. Stakeholder and Expert Consultation

All of the above collectively contributed towards development of the risk identification and mitigation guidelines presented as part of this study. Each of the above is explained below:

Figure 3: Approach for the study



2.1.1. Review of past R&M experience in the country

Literature review was undertaken to understand the policy and regulatory framework, the nature of contracts with the entities involved in R&M, experience of past R&M projects, issues and concerns of different stakeholders. This also included review of past studies, review of tariff regulations of various states and previous tariff orders/petitions of the generation utilities.

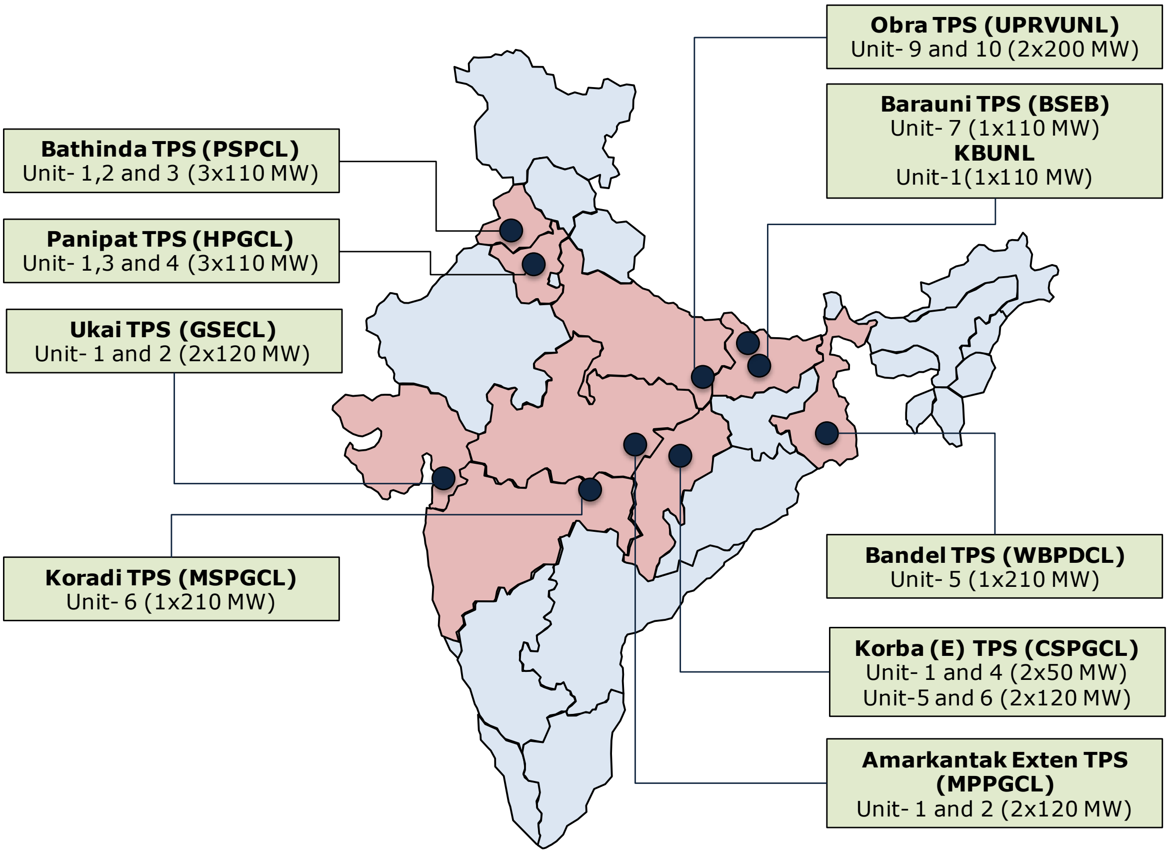
2.1.2. Site visits to select power plants

In order to understand the ground level realities, concerns and barriers constraining the R&M schemes in different states, a case study approach was adopted wherein the ten plants were identified across the country by the CEA for undertaking a detailed study.

Figure below highlights the units/plants considered for review of R&M experience as per the terms of reference

[2] It may be noted that for Task 1 (Guidelines for Risk Identification and Mitigation in R&M Projects in Thermal Power Stations in India) and Task 2 (Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them) similar A&M was adopted.

Figure 4: List of units to be considered for review of R&M/LE works as per the Terms of Reference



*Note: **PSPCL**- Punjab State Power Corporation Limited, **HPGCL**- Haryana Power Generation Corporation Limited, **GSECL**- Gujarat State Electricity Corporation Limited, **MSPGCL**- Maharashtra State Power Generation Company Limited, **UPRVUNL**- Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited, **BSEB**- Bihar State Electricity Board, **WBPDCL**- West Bengal Power Development Corporation Limited, **CSPGCL**- Chhattisgarh State Power Generation Company Limited, **MPPGCL**- Madhya Pradesh Power Generating Company Limited*

Visits were undertaken to all these plants and discussions were held with concerned officials dealing with R&M including plant/unit level engineers, operation and maintenance department and commercial department to understand their experience in planning, tendering, procurement, executing R&M program and O&M of the units subsequent to R&M.

Further, various project specific documents such as DPR, RLA studies, contract documents with the vendors, performance of plant etc. were also collected from the state utilities during the visits to understand the gap if any in the entire R&M process and approaches followed by different states and utilities.

The units visited provided adequate depth to the analysis carried out in the study as these units differed in terms of coverage, current performance, implementation model, mode of funding etc. These factors are explained below:

a) **Coverage of various R&M stages**- Includes representation from all stages of R&M across the selected units.

b) **Current Performance-** Includes the performance of the plant post R&M viz-a-viz that envisaged at the project planning stage. Both, plants that have already completed R&M and those that are undergoing R&M were considered in the sample set.
c) **Implementation Model** – Includes two models generally adopted in the Indian market i.e. (i) OEM initiated; or (ii) Competitive Bidding (National/International).
d) **Mode of Funding**[3] – Includes – (i) Public funds; (ii) Grants; (iii) Soft Loans by Multi-lateral donor agencies
e) **Specific Issues** – Includes specific experience witnessed by a particular plant different from the normal/routine

This enabled the project team to understand the type of risks and technical surprises faced by the utilities, its root causes, its impact on the project, bearer of the risk and way of managing the risks and technical surprises. The table below highlights in brief the unique attributes of the identified plants.

Table 3: Attributes of the identified plants

S. No	Plant Name	Attributes of the identified plants
1	Unit 1,2&3 (3 x 110), Bathinda Thermal Power Station, PSPCL	• R&M awarded on turnkey basis. • Covers entire R&M life cycle – R&M of all three units already completed • Have R&M experience from multiple vendors for different units (NASL, BHEL)
2	Unit 1& 4 (2 x50) and Unit 5 & 6 (2 x 120), Korba (East) TPS, CSPGCL	• R&M experience of multiple units already completed. • Covers entire R&M life cycle – R&M of all the four units already completed. • Post R&M performance of these units have been satisfactory. • RLA included in the scope of the supplier and all the related works needs to be undertaken within the capped overall price of the contract. • O&M supervision post R&M works included in the scope of implementing agency as one of the measure to ensure performance guarantee.
3	Unit 1, 3 & 4 (3x110), Panipat TPS, HPGCL	• Unsatisfactory R&M experience of Unit 1 and 2 led to cancellation of R&M plans for Unit 3 and 4. • Mode of funding- Unit 3 and 4 were proposed to be funded through soft loan from the World Bank

[3] Mode of funding has influence on the level of preparedness and system introduced for robust R&M implementation. While a few funding entities have enforced mandatory lending covenant to be adopted by the utility during the course of design and implementation of R&M in their plants, other entities have not followed such stringent lending criteria.

S. No	Plant Name	Attributes of the identified plants
		• Contractual dispute between vendor and utility leading to prolonged implementation period • Case of unsuccessful contracting at first instance. Project was later rewarded.
4	Unit 1& 2 (2x120), Ukai TPS, GSECL	• Covers entire R&M life cycle – R&M of both units already completed • Initiated directly through OEM • Post R&M outputs achieved have not been in line with the envisaged targets. • Performance Guarantee Test has been delayed incessantly
5	Unit 1&2 (2x120), Amarkantak Extension TPS, MPPGCL	• Frequent change in scope of work due to funding constraints • Covers entire R&M life cycle – R&M of both the units completed. • R&M for different equipments executed through different vendors • R&M executed on discreet basis over a period of time.
6	Unit 9&10 (2x200), Obra TPS, UPRVUNL	• Covers different stages of R&M life cycle – R&M of Unit 9 is completed and Unit 10 is under execution. • Multiple units (5) undertaken for R&M • Initiated directly through OEM • One of the few units wherein R&M works are going on 200 MW plant • Contingency reserves for handling technical surprises included in the overall budget for R&M
7	Unit 7 (1x110), Barauni TPS, BSEB	• Mode of funding- Grant provided by Planning Commission / MOP under RSVY Fund. • R&M initiated through five-party MOU signed among BHEL, NTPC, BSEB, Govt. of Bihar and MoP (Govt. of India).
8	Unit 1 (1x110), Muzzaffurpur, KBUNL, Bihar	• A new company, KBUNL, formed as a Joint Venture (JV) of the State Power Utility (BSEB)/ State Government (Government of Bihar) and public power utility (NTPC). • R&M initiated through five-party MOU signed among BHEL, NTPC, BSEB, Govt. of Bihar and MoP (Govt. of India). • Mode of funding- Part funding through Grant provided by the Planning Commission / MOP under Rashtriya Sam Vikas Yojana (RSVY) Fund and part funding by KBUNL in Debt Equity ratio of 70:30

S. No	Plant Name	Attributes of the identified plants
9	Unit 5 (1x210), Bandel TPS, WBPDCL	• Mode of Funding – through soft loan from World Bank • R&M initiated through international competitive bidding model • High level of preparedness for robust R&M implementation • Contingency reserves for handling technical surprises included in the overall budget for R&M
10	Unit 6 (1X210), Koradi TPS, MSPGCL	• Mode of Funding – through soft loan from World Bank • R&M initiated through international competitive bidding model • High level of preparedness for robust R&M implementation and technical surprise plan prepared in advance to handle potential surprises during the R&M project execution that also required unit rates to be sought from the vendors. • Contingency reserves for handling technical surprises included in the overall budget for R&M • Entire R&M works divided into four different packages.

Further, study of these units also enabled the project team to understand the type of technical surprises faced by the utilities, its root causes, its impact on the project and the way of handling such surprises by the respective utilities.

In addition to the visit to these plants, the project team also participated in the CEA's R&M Planning and Progress Review Meeting with the State and Central Generation Utilities wherein the utilities highlighted the progress of their ongoing R&M schemes and the key issues and concerns being faced in implementing R&M projects.

2.1.3. Review of R&M in Global Context

Having understood the issues and concerns faced in planning and executing R&M projects at the national level, state utility level and the plant level, the study team undertook detailed review of international experience in R&M.

A case study approach was undertaken wherein experience of different countries in implementing R&M works was documented. This includes countries such as Czech Republic, Poland, Turkey, Romania, Indonesia and South Africa. These case studies were prepared on the basis of literature review and visits in some of the countries. The A&M for the same is detailed in the following section.

The above review enabled the team to capture diverse experience being offered by various countries which collectively can be synthesized to offer useful lessons for risk identification and mitigation for R&M of thermal power plants in India. The lessons learned from these experiences are suitably incorporated in the "Guidelines for Risk Identification and Mitigation in R&M Projects in Thermal Power Stations in India" and also in the "Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them".

2.1.4. Stakeholder and Expert Consultations

In order to identify various risks and technical surprises faced by the utilities in execution of R&M project, the team also undertook extensive stakeholder consultation to understand perspectives of various stakeholders. The stakeholder group included the State Generating Stations, Central and State Electricity Regulatory Commissions, Equipment Suppliers, Design Consultants, Implementation Support Consultants, Sector Experts, Funding Agencies and the CEA.

Table below provides a list of entities consulted during the visits made to various states across the country.

Table 4: 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)

S. No.	State	Entities Consulted (State Gencos, SERC, ISC, TC, Suppliers)
		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 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) WAPCOS Limited q) Encotec Energy India Private Limited r) Bureau of Energy Efficiency s) Northern Regional Power Committee t) Tata Consulting Engineers Limited u) KfW v) GIZ w) Central Electricity Regulatory Commission x) L&T Power Limited y) McNally Bharat Engineering Company Limited z) SPML Engineering Limited aa) Deccan Mechanical & Chemical Industries Private

S. No.	State	Entities Consulted (State Gencos, SERC, ISC, TC, Suppliers)
		Limited bb) Central Power Research Institute cc) Black & Veatch Consulting Private Limited dd) L&T-Sargent & Lundy Limited ee) EM Services India Private Limited ff) Stock Redler India Private Limited gg) Tecpro Systems Limited hh) Techfab System Private Limited ii) Assam Power Generation Corporation Limited jj) Andhra Pradesh Power Generation Corporation

In addition to the above, the process of finalisation of the guidelines also involved periodic consultation with the Task Force members. The Task Force has been constituted by CEA for "Promotion of Energy Efficiency R&M in Thermal Power Stations in India" under the Chairmanship of Member (Thermal), CEA.

The Table below provide the list of task force members consulted in various stages of the report.

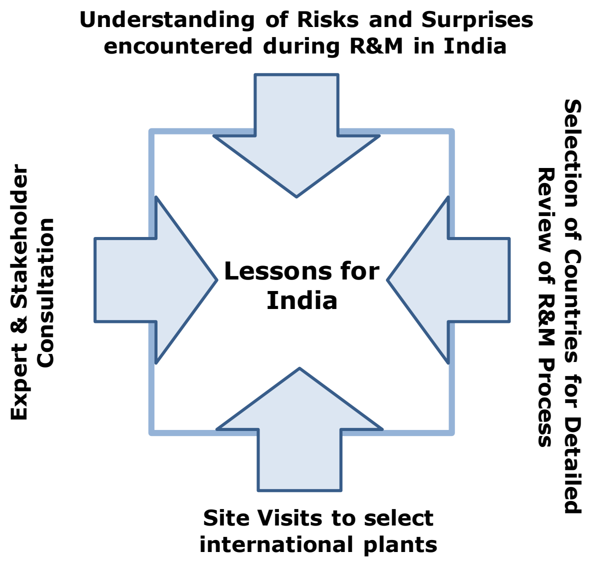
Table 5: List of Task Force Members

S. No	Organisation	Name
1	CEA	Mr. Manjit Singh, Chairman of Task Force
2	APGENCO	Mr. A.Venkateshwara Rao
3	CERC	Mr. S.C. Srivastava
4	DVC	Mr. T.K. Patra
5	HPGCL	Mr. A. K. Sood
6	KfW Development Bank	Arjun Guha
7	MSPGCL	Mr. M. G. Waghmode
8	NTPC	Mr. P. K. Mondal
9	PFC	Mr. Naveen Kumar
10	WBPDCL	Mr. A. K. Ghoshal
11	World Bank	Ms. Surbhi Goyal

2.2. Approach and Methodology for Task 3

Having understood the issues and concerns faced in planning and executing R&M projects at the national level, state utility level and the plant level (in the previous reports undertaken as part of the assignment), the study team undertook the following approach and methodology for a detailed review of international experience in R&M.

Figure 5: Approach and Methodology



a) Understanding of Risks and Surprises encountered during R&M in India
b) Selection of Countries (keeping in mind relevance for India) for Detailed Review of R&M Process
c) Site Visits to select international plants
d) Expert & Stakeholder Consultation

All of the above collectively contributed towards development of this study on international best practices in R&M. Each of the above is explained below:

2.2.1. Understanding of Risks and Surprises encountered during R&M in India

Various risks and technical surprises encountered in implementation of R&M of thermal power plants in India have been identified as part of the Task 1 and Task 2 of this assignment. In order to develop strategies to mitigate or handle such risks and surprises it is important to understand how such risks and surprise are dealt by the international generating companies.

The identified risks and surprises in the Indian context have formed the basis for review of international practises.

2.2.2. Selection of countries for detailed review of R&M Process

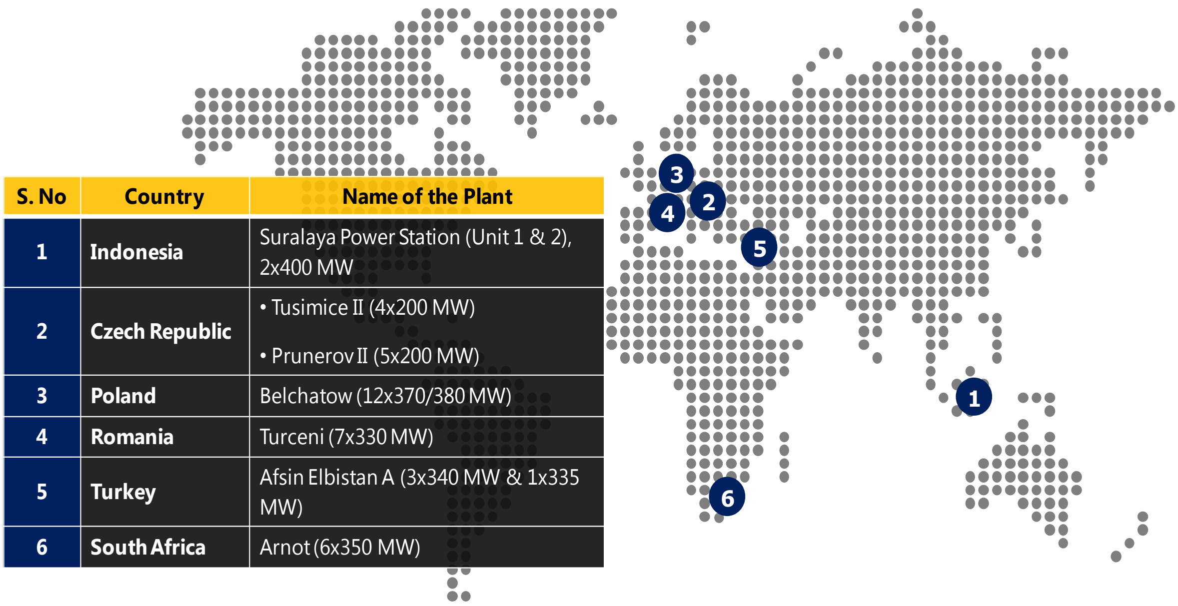
A case study approach was adopted to document the experience of different countries in implementing R&M works. The review included:

a) Context of R&M in the country including key drivers and priorities for R&M.
b) Process adopted for design and implementation of R&M in the country, including the roles and responsibilities of the entities involved.
c) Measures considered for R&M including design of packages, award and execution process.
d) Outcomes of the R&M process, and concerns and barriers faced in R&M.
e) Identification of good practices and lessons for India.

The countries selected for the review included Czech Republic, Poland, Turkey, Romania, Indonesia and South Africa. These case studies were prepared on the basis of literature review and visits in some of the countries. The list of references used for preparation of case studies/review is provided at the end of the report.

Countries and power plants selected for R&M process review are presented in Figure below.

Figure 6: Selected countries and power plants for Review of R&M experience



S. No	Country	Name of the Plant
1	Indonesia	Suralaya Power Station (Unit 1 & 2), 2x400 MW
2	Czech Republic	• Tusimice II (4x200 MW) • Prunerov II (5x200 MW)
3	Poland	Belchatow (12x370/380 MW)
4	Romania	Turceni (7x330 MW)
5	Turkey	Afsin Elbistan A (3x340 MW & 1x335 MW)
6	South Africa	Arnot (6x350 MW)

The following criteria were adopted for selection of the above countries:

a) **Geographical Coverage**
In order to ensure adequate geographical coverage of the worldwide R&M experience, countries from different continents (European, Asian and African continents) were reviewed. Further, experiences of both developed and developing countries were reviewed.

b) **Electricity scenario**
Electricity scenario of respective countries was considered while selecting countries for review. This included review of countries which are surplus in electricity, as well as those that face electricity shortages. Further, consideration was also given to countries using coal as a primary/dominant source for production of electricity.

c) **Coverage of various R&M stages**
Countries were selected so as to include representation from all stages of R&M process across the selected units. Further, countries having adequate experience of completed R&M projects and having fleet of ongoing R&M projects were also selected to understand how feedback from one project is built into the other.

d) **Implementation Model**
Includes models such as (i) OEM initiated; or (ii) Competitive Bidding (National/International)

e) **Mode of Funding**
Includes – (i) Own sources of funds; (ii) Grants; (iii) Soft Loans by Multi-lateral donor agencies

f) **Specific Issues**
Includes specific experience witnessed by a particular plant different from the normal/routine.

Table below highlights in brief the unique attributes of the identified plants reviewed as part of this report.

Table 6: Attributes of the identified plants

S. No	Plant Name	Attribute of the identified plants
1.	Suralaya Power Station Units 1 and 2 (2*400 MW), Indonesia	i. Suralaya is the largest TPP with a total capacity of 4025 MW and plays a critical role in meeting the electricity demand of the country where only 70% of the population have access to electricity ii. Coal is a dominant source of electricity production in the country's energy mix. iii. Covers all stages of the R&M process. iv. Project was funded by JBIC (Japan Bank for International Cooperation). v. R&M led to a reduction in NOx and CO_2 emissions and increase in the efficiency. vi. Project successfully met all the pre-determined objectives.
2.	Tusimice II Power Plant (4* 200 MW), Czech Republic	i. Country has wide range of experience on R&M covering completed and ongoing projects. ii. Coal is the major fuel used for generating electricity. Coal accounts for almost 53% of the installed capacity. iii. R&M experience is recent and comprises mix of plants that have already undergone R&M or plants planning to implement R&M. iv. Occurrence of technical surprises and effective strategy to deal with the same. v. Funded by the utility from its own resources. vi. R&M implemented on EPC contract basis. vii. The technologies used during R&M process are equipped to meet the future emission standards viii. Lessons learnt from R&M of one unit built in

S. No	Plant Name	Attribute of the identified plants
		subsequent units provided a feedback loop.
3.	Prunerov II Power Plant (5*210 MW), Czech Republic	i. Coal is the major fuel used for generating electricity. Coal accounts for almost 53% of the installed capacity. ii. On-going R&M experience iii. Learning from the R&M Experience of Tusimice built into the project preparation work of Prunerov II.
4.	Belchatow Power Plant (12*370/ 380 MW), Poland	i. Country has significant experience on R&M covering completed and on-going projects ii. Largest power plant in Europe and contributes around 20% of the total electricity generated in Poland. iii. Feasibility & diagnostic studies were undertaken for a pre-assessment through consultants iv. Learning from R&M of one unit in built in R&M of subsequent units v. Upward revision in efficiency targets based on continuous learning from R&M works.
5.	Turceni Thermal Power Plant (7*330 MW), Romania	i. R&M for BTG was awarded to Austrian Energy and Environment AG & Co KG (AE&E) on the basis of international tender ii. Funding for the project was garnered from the internal resources of the utility and through loan from KfW iii. Pre-feasibility and feasibility studies were undertaken.
6.	Afsin Elbistan A Thermal Power Plant (3*340+ 1*335 MW), Turkey	i. Project was funded by the World Bank and by the owner of the plant i.e. Electricity Generation A.Ş. (EUAS), the state owned utility company. ii. Due to perceived high risk by suppliers, strategy for bidding revised due to non-participation of vendors. iii. R&M works could not be implemented due to concerns of the bidders with regard to perceived risks of not being able to achieve the functional guarantees. Also, unrelated investigations by the Government into the procurement actions by EUAS led to the cancellation of the project.
7.	Arnot Power Station (6*350 MW), South Africa	i. In 2009, approximately, 12.5 million people had no access to electricity. Overall electrification stood at 75% with 88% of urban and 55% of rural population having access to electricity in the country. ii. Significant energy shortages exist in the country. iii. Detailed studies were undertaken to finalize the scope of work iv. Recent R&M experience on multiple units

S. No	Plant Name	Attribute of the identified plants
		v. Contract was awarded to OEM i.e. Alstom and involved in uprating of the power plant vi. R&M implementation undertaken during phased outages of the plant.

2.2.3. Site Visits to select international plants

Site visits were undertaken to select countries- Poland and Czech Republic to understand the ground level R&M experience in terms of process adopted, barriers or concerns of different stakeholders, strategies adopted to address such concerns and possible lessons for India etc.

In Czech Republic visits were undertaken to Tusimice II Power Plant (4* 200 MW) and Prunerov II Power Plant (5*210 MW). During the site visits discussions were held with concerned officials dealing with R&M at the utility level, at the plant level and also with the EPC contractor i.e. Skoda Praha Invest to understand their experience in planning, tendering, procurement and executing R&M program of different units. Interaction with other sector experts was also undertaken.

In case of Poland, R&M experience of Belchatow Power Plant (12*370/380 MW) was studied. Interactions were held with the officials of Alstom Power, Poland involved in R&M of various units of Belchatow Power Plant (R&M contractor).

2.2.4. Expert & Stakeholder Consultation

As stated above, expert consultations at plant level were undertaken during the site visit to Poland and Czech Republic. In addition to the above, the team also interacted with select international experts and stakeholders to validate the findings and obtain additional perspectives. The consultation process within India also included discussion on global experiences of suppliers and vendors wide cross-border presence.

In addition to the above, periodic consultation with the Task Force constituted under the Chairmanship of Member (Thermal), CEA for "Promotion of Energy Efficiency R&M in Thermal Power Stations in India" was also undertaken before finalising the report.

2.3. Approach and Methodology for Task 4

The approach and methodology adopted for estimating the GHG emissions reduction potential under various technological options of EE R&M of thermal power stations and the possible monetisation framework is elaborated below.

2.3.1. GHG emission reduction potential under various technological options of EE R&M of thermal power stations

Detailed unit level performance analysis has been undertaken to estimate the overall GHG reduction potential of EE R&M. AF-Mercados EMI in its report titled "*Developing Markets for Implementation of R&M Schemes in Thermal Power Stations in India*" has assessed the overall market potential for R&M during the 12th and 13th Five Year Plan[4]. To estimate the GHG potential, these identified coal based units for both state and central sector have been considered (Annexure 3). In addition to the above identified potential, there are certain plants on which R&M/LE works are on-going i.e. the plants that have slipped from 11th to 12th Plan and these plants have also been considered while estimating the GHG potential. Based on the unit level performance data for the identified units under the 12th and 13th Plan, GHG emissions for each of the units has been estimated in pre and post R&M/LE scenario which is then aggregated to estimate the overall GHG emission reduction potential of R&M in the country. Analysis made in this section is based on the performance data for past three years i.e. 2008-09, 2009-10 and 2010-11 and certain assumptions.

2.3.2. Estimation of baseline CO_2 emissions

CO_2 emissions have been calculated separately for both coal and lignite based units since plants based on coal and lignite differ in terms of their heat rate. CO_2 emissions at the unit level can be estimated as follows:

Absolute CO_2 emissions (MT CO_2) at the unit level =	Specific CO_2 emissions for a unit (t CO_2/MWh) * Net Generation (MU) of the unit
Specific CO_2 emissions for a unit (tCO_2/MWh)=	(Fuel Emission Factor (g CO_2/MJ)* Net Station Heat Rate (kcal/kWh)*Conversion Factor (4.1868) (kJ/kcal) + (Specific Oil consumption (ml/kWh) *Specific emissions for Oil (CO_2/ml))

Mt – Million Tonne; tCO_2 – tonne of CO_2; ml – millilitre; gCO_2 – gram of CO_2; kcal – kilocalorie

Wherein,

i. Fuel Emission Factor for different fuels are being provided in the CEA publication titled "CO_2 Baseline Database for Indian Power Sector, Version 8.0, January 2013". Fuel Emission Factor for coal and lignite is considered as 90.6 g CO_2/MJ and 100.5 g CO_2/MJ respectively. Specific emission for oil is being considered as 2.89 g CO_2/ml.

ii. Net Station Heat Rate for each of the state sector unit is calculated based on the average of gross station heat rate and the auxiliary

[4] The report is available on the CEA website.

consumption for past three years. In case of NTPC units, year wise data on Gross SHR is not available. However, CEA in its publication titled "Recommendations on Operation Norms for Thermal Power Stations for Tariff Period beginning 1.4.2009" has worked out the deviation of operating heat rate with the design heat rate for various NTPC plants for different years. This is presented below:

Table 7: Deviation of operating heat rate with the design heat rate for NTPC stations

Weighted Avg. Design Heat Rate (kcal/kWh)	2002-03	2003-04	2004-05	2005-06	2006-07	Average
2267	7.33%	7.29%	6.84%	5.83%	5.46%	6.44%

It can be seen that average deviation of operating heat rate with the design heat rate is reducing over the years indicating improvement in performance. Therefore, for the purpose of analysis of this report average deviation for the year 2006-07 has been considered.

Data for various parameters were compiled from various documents such as tariff orders, tariff petitions of various state utilities, CEA thermal performance review for various years etc.

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.

iii. Net Generation for each of the unit is calculated based on the rated capacity of the unit, average of PLF and auxiliary consumption for past three years.

iv. Specific oil consumption for coal based and lignite based units is considered as 2 ml/kWh and 3 ml/kWh respectively.

From the unit level CO_2 emissions estimated above, total Baseline CO_2 emissions are estimated for the R&M/LE for the 12th and 13th Plan. This is estimated as follows:

Overall CO_2 emissions (Mt CO_2) for the R&M/LE in the 12th and 13th Plan = ∑ Absolute CO_2 emissions (Mt CO_2) at the unit level.

2.3.3. Estimation of unit level CO_2 emissions post R&M/LE

In order to estimate the CO_2 emission reduction potential various scenarios has been built in. These scenarios are based on the literature review of various advance technological options available for EE R&M. Based on the international review, it is observed that on average 3%-5% efficiency improvement potential exists[5]. This is also corroborated by several national examples of R&M, planned and those already executed. The table below presents the pre and post R&M experience of different power plants in the Indian context i.e. the operating station heat rate before R&M, design heat rate, guaranteed heat rate by the supplier and actual/proposed station heat after R&M of some of these plants.

Table 8: Pre Post R&M Experience of different Power Plants

Plant Name	Unit No.	Capacity (MW)	Operating SHR (before R&M)	Guaranteed SHR/Expected SHR as per DPR	Designed SHR	Actual SHR after R&M
Koradi TPS	6	210	3264[a]	2350[b]	2395	R&M under process
Bandel TPS	5	210	2874	2456[b]	2424	R&M under process
Korba (East) TPS	1	50	3270	2650	N.A.	2455[c]
	6	120	N.A.	2434	2398	2381[c]
Ukai TPS	1	120	2899	2,482	2301	2848
Panipat TPS	2	110	3950	N.A.	N.A.	3511
Bathinda TPS	2	110	3030	N.A.	2482	3005

Notes: [a] Figure is for 2009-2010; [b] Figure is based on the option selected in DPR; [c] Achieved as per PG Test; N.A.: Not available

Source: Detailed Project Report for Koradi TPS (Unit 6) and Bandel TPS (Unit 5); Data collected during site visit to Korba TPS, Panipat TPS and Bathinda TPS; CAG Audit Report No.4 (Commercial) for the year ended 31 March 2010 for GSECL; CEA study titled "Mapping of 85 pulverized coal fired thermal power generating units in different states", by Evonik Energy Services India, under Indo-German Energy Program

[5] Refer Standard Menu of Options for Energy Efficiency focused Rehabilitation and Life Extension of 210 MW and above units in TPS in India under Chapter –Lessons for India based on review of international best practices in R&M

Based on the above assessment, the following key observations emerge:

a) In case of Koradi TPS Unit 6, efficiency improvement post R&M is expected to be more than that of design.
b) In case of Bandel TPS Unit 5, efficiency improvement post R&M is expected to be in line with that of design.
c) In case of Korba TPS Unit 1 and 6, SHR achieved after R&M was in line with that guaranteed
d) In case of Ukai TPS Unit 1, improvement in the SHR post R&M was not in line with that guaranteed.
e) In case of Bathinda TPS Unit 2, SHR post R&M improved marginally as compared to pre R&M scenario
f) From the national case studies it can be observed that there are possibilities to improve the operating efficiency of the plant by more than its design.
g) Experience of successful R&M projects has been limited. The actual achievement of R&M needs to be tested on ground.

Based on the observations made above, in order to compute the GHG potential emission reduction for India the maximum achievable heat rate post R&M is being considered as the design SHR. Various intermediate scenarios have also been built in as plant level economics/ cost benefit analysis would guide the number of interventions to be implemented and what could be the possible reduction in the operating SHR or realization of station heat rate vis-à-vis design SHR.

These scenarios are developed considering the fact that different utilities may select different options for R&M depending upon the cost involved, timeframe for shutdown and their priorities.

Scenario 1- Conservative Scenario

In this scenario it is assumed that net station heat rate is improved by 50% from the design value.

For instance, if the plant design net station heat rate is say 2600 kcal/kWh and the operating net station heat rate is 3366 kcal/kWh, according to this scenario, net station heat rate for the calculation purposes would be considered as 2983 kcal/kWh.

Scenario 2- Intermediate Scenario

In this scenario it is assumed that net station heat rate is improved by 75% from the design value.

In continuation to the above example, this scenario would consider net station heat rate as 2792 kcal/kWh.

Scenario 3- Optimistic Scenario

In this scenario it is assumed that net station heat rate is improved to the design value.

In continuation to the above example, this scenario would consider net station heat rate as 2600 kcal/kWh.

It may be worthwhile to mention the following here:

i. Design gross station heat rate for various units is considered as follows:

Table 9: Design SHR and Auxiliary Consumption for various capacity groups

Category	SHR (kcal/kWh)	Auxiliary Consumption
140 MW and less	2,395	9%
200/ 210 MW		
- LMZ units	2,402	8.5%
- KWU units	2,342	8.5%
- Non KWU/LMZ units	2,371	8.5%
250 MW and above	2,297	8.5%

This is based on the CEA study titled "Mapping of 85 pulverized coal fired thermal power generating units in different states", by Evonik Energy Services India, under Indo-German Energy Program.

ii. In cases where average operating heat rate is less than that of design as mentioned above, average operating heat rate is considered. In cases where average operating auxiliary consumption is less than that of design value, average operating auxiliary consumption is considered.

iii. Specific oil consumption for coal based and lignite based units' post R&M/LE scenario is being considered same as 2 ml/kWh and 3 ml/kWh respectively.

Based on the above steps total GHG emission reduction potential for the plants has been estimated under various scenarios.

2.3.4. Data Sources

a) Recommendations on Operation Norms for Thermal Power Stations for Tariff Period Beginning 1.4.2009, CEA, 2008

b) CO_2 Baseline Database for Indian Power Sector, CEA, 2012

c) CEA study titled "Mapping of 85 pulverized coal fired thermal power generating units in different states", by Evonik Energy Services India, under Indo-German Energy Program

d) CEA study titled "Developing Markets for Implementation of R&M Schemes in Thermal Power Stations in India", by AF-Mercados EMI, under India: Coal Fired Generation Rehabilitation Project, financed by the World Bank

e) Performance Review of Thermal Power Stations for various years, CEA

f) Tariff Orders for different years by various State Electricity Regulatory Commission's

g) Tariff Petitions for different years by various state generating companies

2.3.5. Frameworks for Monetizing the GHG Emissions Reduction Potential in the National and International markets

Market assessment of the Global carbon markets was undertaken to suggest the available monetization frameworks for efficiency improvement and emission reduction achieved through implementing EE R&M. This also included review of appropriate methodologies for monetization for different R&M interventions along with suitable international experience/examples.

In addition to the above, analysis has been undertaken to suggest different steps that are required to be undertaken by the utilities to monetize GHG emissions during different stages of R&M process cycle. Further, this section also details out the national level mechanism of Perform Achieve and Trade (PAT).

There are various barriers that may constrain the utilities in monetizing the GHG emission reduction including the evolving market situations. The different barriers along with overall strategies to overcome each of the barriers have also been detailed out in this section.

2.3.6. Expert Consultations

In addition to the above, the process of finalisation of the report also involved periodic consultation with the Task Force members for "Promotion of Energy Efficiency R&M in Thermal Power Stations in India" constituted under the Chairmanship of Member (Thermal), CEA.

AF-Mercados EMI also conducted dissemination workshop in New Delhi where the team presented the key findings and deliberated on the study for reducing barriers for R&M intervention in thermal power stations in India.

Chapter - 3
R&M Process Cycle

In order to identify the risks and surprises experienced during R&M projects and to design strategies to mitigate risk and technical surprises, it is essential to first understand various sub-steps of the entire R&M process, the activities that are undertaken at each step and the stakeholders involved during various stages of the R&M process cycle. Figure 7 maps out the overall R&M process and stakeholders involved during each of the identified stage.

3.1. Identification Stage

During the identification stage the plant units are first identified to be diagnosed further based on certain symptoms. At this stage the plant operators regularly monitor the key plant unit parameters covering at least the following aspects to identify symptoms that may necessitate R&M of power plants: (a) Plant Availability, (b) Plant Load Factor, (c) Auxiliary Consumption, (d) Emission Factors, (e) Level of Outages, (f) Life of the plant etc, (g) Frequency of annual overhaul; (h) frequency of capital overhaul etc.

The diagnosis at this stage is based on available plant records and design data. No inspections and/or testing of material, plant or equipment is involved at this stage. Timely identification and diagnosis of problems is of critical importance and form the foundation for successful R&M of the plant in the future. This obviates the need for a comprehensive R&M in one go (except for BTG) and ensures that necessary up-gradation is carried out during the course of plant operation and annual/capital overhaul and maintenance.

3.2. Assessment Stage

Most of the equipment of a power plant is subjected to high temperature and pressure and are designed for fatigue life of about 25 years of operation.

Due to ageing of the equipments and metallurgical deterioration of the materials after prolonged use, it may become uneconomical or dangerous to operate the unit. However, by undertaking preventive measures such as proper maintenance, refurbishment, rectification or R&M of the plant it is possible to operate the unit safely, reliably and economically for another 15-20 years.

Further, differences in the operational practices from design operation environment may lead to premature equipment failure or lower than expected output. This calls for systematic evaluation of the plant through undertaking of various technical studies and tests. This includes the following:

a) Residual Life Assessment
b) Complete Condition Assessment
c) Energy Audit
d) Performance Evaluation Test

e) Past History of Plant (including maintenance schedules, overhauls and assessment of O&M practices)

The technical evaluation of the plant is followed by the economic evaluation of the plant to decide on the most optimal option. These include:

a) Plant retirement
b) Maintain and operate for extended time and retire subsequently
c) Capital Overhaul and refurbishment
d) R&M and Life Extension (LE)
e) R&M, LE and Up-rating

Detailed Project Report prepared for assessment of above options also includes a detailed technical and economic analysis of the identified option. This also includes assessment of the sources of fund and the phasing required for execution of R&M option.

Several options can be worked out for involvement of private players in the R&M process. Some options often discussed include: (i) Lease, rehabilitate, operate and transfer; (ii) Joint venture between the private player and public/private utilities.

Based on the technical studies and the option selected for R&M, the scope of R&M Project is prepared. The aim here is generally to define scope in as precise terms as possible however often changes and surprises occur when the plant is actually opened up for implementing the R&M. The utility often is faced with the issue of level of detailing that is required at the planning stage itself vs. the time and resources that are available to be committed for achieving marginal improvement in the scope assessment exercise.

Before the tenderization process begins, utility should also submit the details of the assessment to the Appropriate Commission and seek its approval (often "in-principle" approval, with the formal approval obtained post the R&M is executed and actual amount incurred on the same is submitted).

3.3. Planning Stage

Once the scope of the project is finalised, the utility develops the design specification and proposal package and determines the procurement/bidding strategy.

Planning stage covers the entire bid process management i.e. issue of tender(s), pre bid meetings, evaluation of technical and commercial bids, selection of suitable bidder, negotiation of contracts and award of R&M contracts to vendors/suppliers/OEMs.

In India, in certain cases, the bidding stage is omitted. In such cases, the R&M process is directly initiated through the OEM and awarded for implementation.

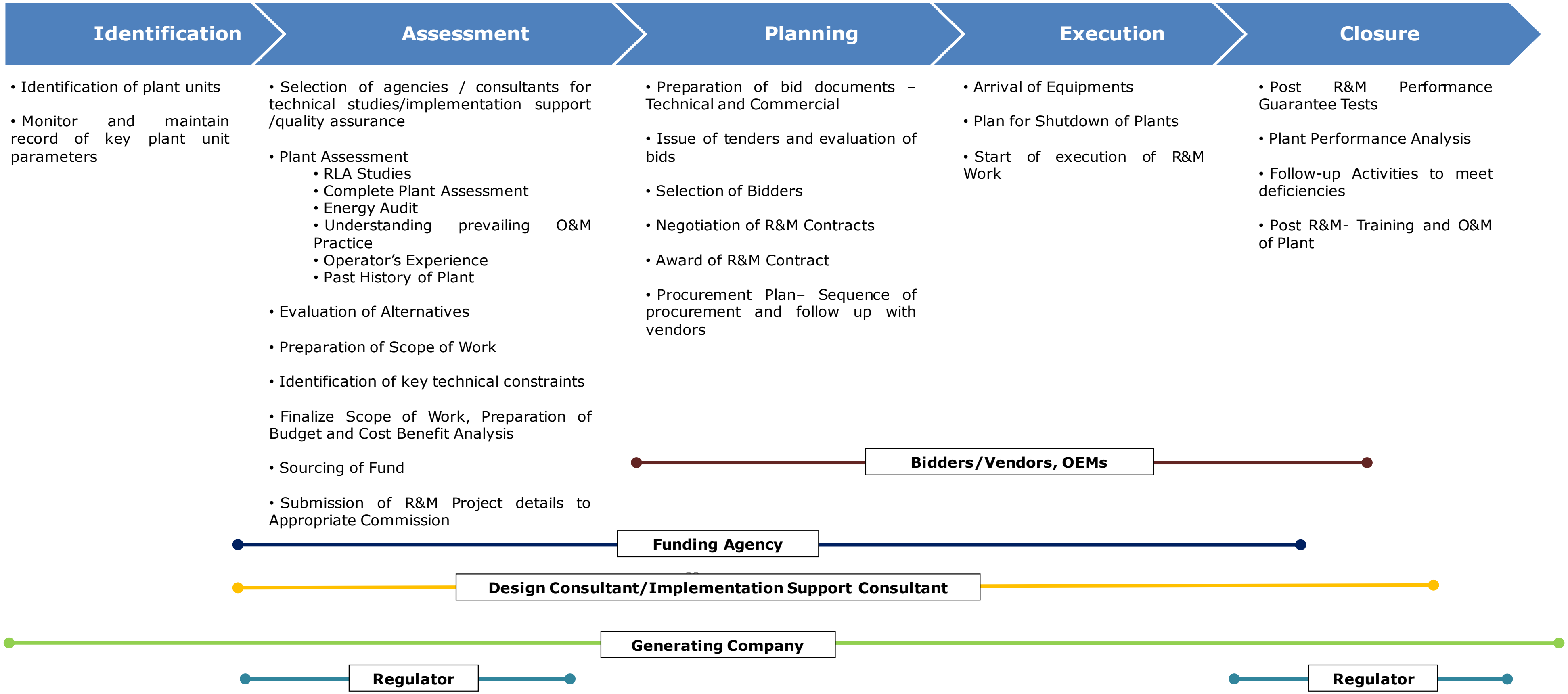
3.4. Execution Stage

This stage covers the entire R&M project implementation stage which begins with the receipt of equipments to the site and planning of shutdown of unit. This stage includes effective monitoring of work, timely decision making on bottlenecks faced, ensuring the quality of work, inspection of material and smooth implementation of work. Implementation support consultant hired by the utility plays a key role in managing all the activities covered under this stage through a structured process.

3.5. Closure Stage

After the R&M work is completed, it is very essential to evaluate whether the goals and objectives of the R&M project was achieved or not. For this post-R&M Performance Guarantee Test is conducted. Further, O&M Training is imparted to engineers for efficient operation of the unit that has undergone R&M. This is very important as there are issues involved in effective interfacing of the new installations with the existing ones, commercial issues linked to change in tariff; actual vs. planned performance outputs etc.

Figure 7: R&M Process Cycle



Indicative timeframe suggested by CEA in the National Perspective Plan for Renovation, Modernisation and Life Extension of Thermal Power Stations (Upto 2016-17) for implementing LE&U schemes:

a) Appointment of consultant by utilities -	*3 months*
b) RLA / Energy Audit -	*6 months*
c) Freezing the scope of work/activities for LE&U -	*3 to 4 month*
d) Preparation of DPR -	*6 to 8 months*
e) Placement of order of LE&U -	*6 to 8 months*
f) Supply of critical spares -	*16 to 20 months from placement of order.*
f) Shutdown of unit -	*6 - 8 months.*

Chapter - 4
Risk Identification and Mitigation Framework

Planning and implementing R&M projects is often witnessed by occurrence of adverse events that can derail the objectives of the project. Identifying and mitigating project risks are crucial to manage R&M projects successfully. Thus, a well-structured and documented Risk Management Framework at each stage of the process is of utmost importance.

This chapter describes the key risk faced in implementing R&M mapped across different stages of the R&M life cycle and the framework for management of such risks.

4.1. Elements of Risk Identification

In order to effectively manage the potential risks that can be encountered in R&M projects, it is important to understand the various elements of the risk which include nature of risk, root causes or factors leading such risk or unfavourable outcomes, bearer of the risk, frequency of occurrence and its severity or impact on the plant/project time/schedule and cost. Each of these elements is explained below.

4.1.1. Nature of Risk

The process of risk identification involves determining which risks are likely to affect the R&M project and documenting the characteristics of each. Risk Identification should address both internal and external risks. Internal risks are those that project team can control or influence whereas external risks are those that are beyond project team's influence and control.

Over the R&M life cycle, there could be various types of risk affecting the effective implementation of R&M project. These include:

i. **Management Risk:** Risks associated with the incorrect/lack/delay in initiating decisions or actions by the management of the company. Such risks may impact the overall project outcome.

ii. **Technical Risk**: Risks associated with inadequate technical assessment of the R&M projects. This includes risks such as occurrence of technical surprises, non-achievement of post R&M guarantees etc.

iii. **Operational Risk:** Risk arising due to internal system processes of the company i.e. due to limited capacity and skills of the personnel of the generating companies in undertaking R&M works.

iv. **Institutional Risk:** Risks associated with weak governance framework. This includes risks related to socio-political considerations that may result in delay in obtaining the shutdown for undertaking both technical studies and execution of R&M projects.

v. **Market Risk:** Risks arising primarily due to the actions or inaction of suppliers in the market and the overall market conditions which are beyond the control of the generating company. This includes risks pertaining to limited participation of suppliers in the bidding for R&M works, higher than expected price discovery, delay in supply of material by the supplier etc.

vi. **Regulatory Risk**: Risks arising due to regulatory uncertainty or change in regulations. This includes risk associated with the disapproval of the investment made by the generating company in undertaking R&M works.

vii. **Contractual Risk:** Risks associated with the uncertainty arising from the contractual disputes or interpretation due to weakly defined scope of works and inability to devise a mechanism to resolve them constraining the overall execution.

viii. **Funding Risk:** Risks associated with mobilization of funds for undertaking R&M project.

ix. **Socio-Environment Risk**: Risks arising due to the insensitivity towards the habitations surrounding the power plant and compliance to the environmental norms.

4.1.2. Frequency and Severity of Risk

Once the risk and its nature have been identified, it is important to assess the frequency or likelihood of occurrence of risk and severity of impact. Frequency and severity of the risk may differ from low to moderate to high leading to different consequences. However, a distinction must be made between: (i) high frequency low impact risk; (ii) high frequency high impact risk; (iii) low frequency low impact risk and (iv) low frequency high impact risk. The concentration of risk mitigation should largely focus around (ii) and (iv) above, as these risk could be catastrophic for the project.

4.1.3. Root Cause Analysis

This step involves identifying the root causes of occurrence of risk or a problem event faced during the course of the R&M life cycle. The practice of root cause analysis is predicated on the belief that problems are best solved by attempting to address, correct or eliminate root causes, as opposed to merely addressing the immediately obvious symptoms. By directing corrective measures at root causes, it is likely that problem recurrence will be prevented.

4.1.4. Bearer of Risk

Identification of risk bearer involves listing out entities that are directly and indirectly affected by the risk event. This helps in design of approaches that enable development of a balanced projects with specific risks allocated to the entities that are best placed to manage them.

4.1.5. International Experience

The international generating companies have adopted multiple practices to manage risks inherent in undertaking the R&M project. Based on the review of the international best practices, lessons that can be learned for managing risks has been suggested. It must be noted that key lessons have been highlighted in this report.

4.2. Strategies for Addressing the Risk

Strategies to address a particular risk involve the following:

4.2.1. Risk Avoidance[6]

Risk avoidance implies not undertaking activities that trigger one or the other risk or involve actions that either completely eliminate or reduce the likelihood of the occurrence of risk. As such, it can be the most powerful technique for managing risk. This may include preventive actions that may be required from the stakeholders involved in the R&M process.

4.2.2. Risk Sharing/Transfer

It involves sharing some or all of the negative impact of the risk with other agency in the form of performance guarantees or a third party in form of insurance. Risk sharing could lead to risk mitigation in certain cases as by sharing the risk with an agency which is able to manage the risk well, can result in minimising the impact of the identified risk.

4.2.3. Risk Mitigation

Risk Mitigation involves reducing the severity of impact of the adverse events. This strategy is used when either the risk cannot be avoided or the cost of avoidance is high, and hence needs to be considered upfront in the project cost estimates.

4.2.4. Risk Acceptance

This strategy is adopted because it is seldom possible to eliminate all the risks. If a risk is identified and its impact or consequences are accepted, it then can also be classified as risk management technique. Acceptance can be active (by developing a contingency reserve to execute should the risk event occur, adjusting the time schedule) or passive (by accepting a lower profit if some activities overrun)

[6] Risk Avoidance can also be defined as Preventive Risk Management. The concept is similar to Preventive Maintenance in a thermal power plant that involves care and servicing by the plant personnel for the purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects.

In order to effectively manage the risks, one or combination of the techniques mentioned above needs to be adopted.

The next chapter of this report provides a description of potential risk events that may be encountered in planning and implementing R&M of thermal power plants. Alongside, the chapter also describes the risk features and strategies to address the risk based on the framework presented above.

Chapter - 5
Risk Management Guidelines

This chapter describes the risks identified across different stages of R&M and the strategies to deal with the identified risk (refer Table 10).

Table 10: Potential Risks involved in R&M Process

S. No	Stage	Category of Risk	Risk
1	**Identification**	Management risk	Reactive approach to identification of plant for R&M
2		Management Risk	Lack of long term generation plan and awareness of available market options
3		Market Risk	Lack of confidence and uncertainty with regard to R&M projects
4	**Assessment**	Institutional Risk	Delay in obtaining unit shutdown for undertaking technical studies
5		Technical Risk	Inadequate technical assessment/studies
6		Management Risk	Weak analytical framework for selection of R&M options
7		Regulatory Risk	Appropriate Commission not apprised of the R&M project plan
8		Operational Risk	Limited capacity of utilities in undertaking R&M works
9		Contractual Risk	Weakly defined scope of work
10		Funding Risk	Utility unable to mobilise funds
11	**Planning**	Market Risk	Low level of participation by the vendors in the bidding process
12		Market Risk	Higher than expected price discovery
13		Market and Operational Risk	Rebidding/Re-award/Delay in award of R&M packages/contract
14		Management Risk	Implementation contract awarded to vendor involved in carrying out technical studies
15	**Execution**	Management	Weak decision-making framework

S. No	Stage	Category of Risk	Risk
		Risk	
16		Technical Risk	Occurrence of technical surprises
17		Contractual Risk	Weak dispute resolution mechanism constraining the execution of work
18		Market Risk	Mismatch (or delay) in supply of critical equipment and the shutdown period
19		Operational Risk	Weak Supervision, Quality Control And Assurance
20		Socio-Environmental Risk	Failure Of the Plant to Achieve Environmental Standards And Plant Is Perceived to Have Negative Social/Environmental Impact on Near-by Villages
21		Institutional Risk	Delay in provisioning of obtaining unit shutdown for executing R&M works
22	Closure	Operational Risk	Sustainability of R&M gains affected by weak O&M practices
23		Technical Risk	Post R&M guarantees not achieved
24		Regulatory Risk	Non-approval of costs incurred during R&M
25		Operational Risk	Absence of ex-post evaluation and feedback loop

The following section details out each of the above risk as per the R&M process cycle along with the risk bearer, impact and strategy to manage the risk.

5.1. Identification Stage

The risk identified across identification stage of R&M process cycle and strategies to handle the identified risks are presented below:

5.1.1. Reactive Approach to Identification of Plant for R&M (Management Risk)

A. Risk Description

This risk arises due to delay in timely decision for R&M works. Ideally decision to undertake comprehensive R&M should be based on the diagnosis of the early warning symptoms. This includes diagnosis of the reasons for deterioration in plant performance parameters such as Plant Availability, Station Heat Rate (SHR), Auxiliary Consumption etc. and the ageing analysis of the unit and critical equipments i.e. the number of remaining years left before the plant completes its economic/designed life of operation.

B. Root Cause Analysis

This risk can be attributed to the weak monitoring processes at the plant and institutional level.

In most of the states in India, it is observed that the decision to undergo R&M is driven by reactive signals (Refer box below) i.e. (i) Units identified by the CEA for undergoing R&M in the plan period during the progress review discussions with the states; (ii) Regulatory signals wherein the petitioned performance parameters are not approved by the Regulator or the generating company has been cautioned by the Regulator; (iii) Tightening of emission norms and notice from the State Pollution Control Board etc.

Box 2: Approach adopted for identification of units for undertaking R&M

Example: Barauni Thermal Power Station (BTPS)

Unit 6 and Unit 7 of BTPS (2X 110 MW) were commissioned in 1983 and 1985 respectively. These units were identified by CEA for R&M works during 11th plan. However, the performance of the plant deteriorated much before the end of economic life of the plant. The cumulative performance of the units from 1998-99 to 2007-08 is given below:

Year	Cumulative Performance						
	Generation (MU)			Auxiliary Consumption (%)	PLF (%)	Heat Rate (Kcal/kWh)	Overall Efficiency (%)
	Unit 6	Unit 7	Total				
1998-99	218	314	532	12.4	28.8	4608	18.8
1999-00	247	80.5	328	10.8	17.7	4681	18.4
2000-01	146	175	321	13.9	17.6	4424	19.7
2001-02	195	124	319	13.1	17.4	5127	16.9
2002-03	145	122	267	16.2	14.5	4637	18.7
2003-04	136	149	276	16.4	15	5050	17.8
2004-05	38.5	115	154	20.0	8.35	5253	16.4
2005-06	83.5	37.5	121	20.8	6.57	5404	16.1
2006-07	0	37.3	37.3	28.6	4.05	5198	16.5
2007-08	132	0	132	12.8	14.4	4450	19.3

Thus, the operational performance of the plant must be regularly monitored and considered as a key parameter for undertaking decisions related to R&M of the plant. The early warning symptoms should be identified and acted upon.

Source:- DPR for R&M of 2X110 MW (Units 6&7) Barauni TPS

In several cases the decision to undertake R&M is taken when either the plant is already shutdown or the performance of the unit has significantly deteriorated or the plant has outlived its economic/useful life.

C. Impact, Frequency and Severity of Risk

This risk leads to continued deterioration in the condition of the plant and its performance. Higher is the delay in the decision to undertake R&M, more adverse is the impact on the performance of the plant which ultimately leads to longer time and higher cost for undertaking R&M of the plant.

The likelihood of occurrence of this risk is high in the Indian context as most of the utilities adopt a reactive approach to R&M.

The severity of risk is moderate if the symptoms of deterioration in performance are identified during the initial stages. However, the severity keeps on increasing with the delay.

D. Bearer of Risk

Utility/Plant Owner is the direct bearer of this risk. However, this also impacts the consumer in the state as it disrupts the quantum of power to be supplied to the discom which then has to resort to purchase of costly power from the short-term market.

E. Strategy to Manage the Risk

Strengthening of internal data acquisition, monitoring and alert systems to track unit performance (Risk Avoidance)

Early diagnosis of the symptoms requires strengthening of data acquisition, monitoring and alert system (Management Information System) within the plant level. This system then interfaces with the Digital Control System (DCS) for automatic generation of management reports. These reports then form the basis of tracking of performance and R&M decisions.

Based on the above, this risk can be completely avoided or its impact can be significantly minimized. Some of the critical actions involve:

a) Adherence to the annual maintenance/overhaul schedule and capital overhaul schedules. This should also be accompanied by updating the maintenance log, recording the history of such overhauls, key issues faced and resolutions implemented.

b) Regular collection of unit level data pertaining to key performance parameters such as Load Factor, Availability, Turbine Heat Rate, Secondary Fuel Oil Consumption, Auxiliary Consumption, Emissions (So_x, NO_x etc.); reliability and condition of individual components; and flagging of warning signals in the management reports.

c) Identification of the components/factors causing forced outages along with reasons for such failures

For this, input from O&M department is critical and recording of routine data such as material properties, geometries, crack sizing, hardness, operational parameters etc. during operation, annual/ capital maintenance, will be useful for undertaking technical studies/R&M in future.

The overall mitigation strategy described above is based on proactive approach of the utility towards performance improvement.

5.1.2. Lack of Long Term Generation Plan and Awareness of Available Market Options (Management Risk)

A. Risk Description

Key priorities of the state in the context of energy sector are: (i) to provide adequate and affordable power to the consumers; (ii) be energy secure and environmentally benign; and (iii) ensure financially sustainable utilities. The states and the power utilities in the country must have long-term plan (Optimal Generation Plan) for achieving the above mentioned goals. The decisions related to R&M must be a consequence of this long-term plan.

The risk arises when decisions related to R&M are taken up in isolation without considering other available options.

B. Root Cause Analysis

The root causes for the above behaviour are as follows:

a) Lack of power sector vision at the state level and vision at the utility level
b) Conventional focus on augmentation of new supply as a means to meet the increasing power demand
c) Lack of awareness of possible market options

C. Impact, Frequency and Severity of Risk

The risk results in sub-optimal investment decisions. In addition, this risk directly impacts the long term sustainability of the plant affecting its performance and availability. As a consequence, this also affects the financial performance of the generating company.

This trend has been observed in several states reviewed as part of this study. Hence, the frequency of occurrence of this risk is high. The risk impacts the plant and utility performance gradually, hence severity is moderate.

D. Bearer of Risk

Utility/plant owner is the direct bearer of the risk. However, non-performance also impacts the consumers in terms of higher tariff (if pass through under the regulatory mechanism).

E. Strategy to Manage the Risk

The rationale for R&M of a project should be established at the state level taking into account all the alternative competing options. (Risk Avoidance)

R&M decision should take into account all the available market options including new power plants (at same site or at a different location), procurement of power through medium and long-term Case I bids, availability of supply from renewable energy sources, purchase from open market etc. This should form the basis of the decision i.e. whether to: (i) Retire; (ii) Maintain and Operate for few years and eventually retire; (iii) Capital Overhauling and Refurbishment; (iv) R&M and Life Extension; and (v) R&M, LE and Uprating.

The final decision of R&M should also be considered in consultation with the Discoms, wherein the refurbished plant should fit with the Discoms long-term power procurement plan and merit order schedule.

5.1.3. Lack of Confidence and Uncertainty with Regard to R&M projects (Market Risk)

A. Risk Description

Due to limited experience sharing and success stories in India, a number of generating companies are uncertain about the outcomes of the R&M. Hence, appreciation of benefits associated with R&M is limited.

This leads to a risk wherein the utility may not consider R&M as an option, even though it makes economic sense.

Box 3: Lack of confidence and uncertainty in taking up R&M

Uncertainty with regard to R&M projects

Example: Ukai Thermal Power Station Unit 1, Gujarat State Electricity Corporation Limited (GSECL)

The post R&M performance of Ukai TPS unit 1 has not been in line with that envisaged in DPR. The performance of the unit during Pre and Post R&M and as envisaged in DPR is given below.

Ukai TPS Unit 1	Norm as per DPR	Pre-R&M (2005-06)	Actual Post R&M (2009-10)
Auxiliary consumption (%)	9.20	10.70	10.85
Heat Rate (in Kcal/ Kwh)	2,482	2899	2848
PLF (%)	80	54.53	50.68

Under performance was due to high vibration of turbine and excessive boiler tube leakages which led to delay in stabilisation of operation of Unit I of Ukai TPS (which was subsequently addressed by BHEL). Although, the performance improved thereafter but it still has to achieve sustainable benefits as provided in the DPR.

Source:- CAG Audit Report No.4 (Commercial) for the year ended 31 March 2010 and discussion with the utility

Non completion of R&M work by selected vendor

Example: Obra A Thermal Power Station, Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited (UPRVUNL)

UPRVUNL entered into an agreement (February 2003) with M/s Techno Prom Export (TPE), Russia for the refurbishment of 5 units of 50 MW capacity each of Obra 'A' TPS for Rs 479.50 Crore, work being divided in three phases. TPE started the refurbishment of Unit No.1 & 2 under Phase I (July 2003) but stopped the work (February 2006) mid-way without completing the contract. A MOU was further signed (April 2006) with TPE for completion of work of Phase I by November 2006. TPE again failed to complete the work within extended period up to January 2008. Agreement was terminated (March 2008) and remaining work of Phase-I was got completed (May 2009) by other vendor.

Source:- CAG Audit Report

Uncertain outcomes have created apprehensions about viability of R&M among the utilities.

B. Root Cause Analysis

The root causes include:

a) Limited experience of R&M related to larger size plants especially 210 MW and above. This is critical as going forward 500 MW fleet shall also require R&M.
b) In certain cases, post R&M performance of the plants has not been in line with that envisaged at the planning stage leading to the negative outlook of the utility towards R&M.
c) Limited dissemination of successful cases
d) Success of R&M has been limited in case of earlier installed 120 MW sets in the country due to their inherent design problems.

C. Impact, Frequency and Severity of Risk

This risk either results in delay or discarding of R&M as an option even when it would have made economic sense. This also adversely impacts the R&M market in the country.

The severity of the above risk depends on case to case basis, however may range from low to moderate. The frequency of the above risk is moderate to high.

D. Bearer of Risk

This risk impacts the entire R&M market including potential generating companies, equipment suppliers, design consultants etc.

E. Strategy to Manage the Risk

a) *Need for Experience Sharing (Risk Mitigation)*

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.

Box 4: Need for Experience Sharing

Example: Korba (East) Thermal Power Station- Unit 1 to 4 (4x50 MW) and Unit 5& 6(2x120 MW)

In case of the above plants, the achievement post R&M viz-a-viz the contracted parameters has been encouraging. This is tabulated below:-

PERFORMANCE PARAMETERS (4X50 MW) KORBA EAST							
		As Per Contract Agreement					
		Pre-Rehab	Post-Rehab	Achieved as Per PG Test Results			
		All Units	All Units	U#1	U#2	U#3	U#4
1	Rated Capacity(MW)	40 MW	50 MW	50MW	50MW	50MW	50MW
2	TG Heat Rate kcal/kWh	2714	2319	2186.12	2257.4	2253	2188.1
3	Boiler Efficiency	83%	87.50%	89.03%	88.39%	88.97%	90.30%
4	Station Heat Rate kcal/kWh	3270	2650	2455.54	2553.85	2532.31	2423.145

PERFORMANCE PARAMETER (2X120 MW) KORBA EAST					
		Guaranteed Parameters		As per PG Test Results	
		U#5	U#6	U#5	U#6
1	Rated Capacity(MW)	120MW	120MW	120 MW	120MW
2	TG Heat Rate kcal/kWh	2087	2087	2096.96	2097.97
3	Boiler Efficiency	86.3(+/-1%)	85.75(+/-1%)	89.40%	88.13%
4	Station Heat Rate kcal/kWh	2418	2434	2346	2381

It is important that the generating companies and other stakeholders should share their experience of implementing R&M so that other plants can also

take benefit of such experiences. This also results in confidence building towards R&M interventions.

Source: Interaction of AF Mercados EMI team with the officials of CSPGCL

Pilot demonstrations in Bandel TPS Unit-5 (210 MW) and Koradi Unit 6 (210 MW) have already been initiated through the support of the World Bank. It is expected that the experience from these pilots would help in better design and implementation of R&M programs in future.

b) Need to Develop Market for R&M in the Country (Risk Avoidance)

The CEA needs to facilitate development of R&M market in the country through appropriate signals. This includes:

i. Communicating the overall R&M market size to various stakeholders. This will promote vendor development and interest in the R&M market from India and outside.
ii. Initiate measure to address concerns of the stakeholders including bidders/suppliers and technical consultants.

CEA has already initiated the above study with support from the World Bank. The result of these will be available during 2013-2014.

5.2. Assessment Stage

The risks identified across assessment stage of R&M process cycle and strategies to manage the identified risks are presented below:

5.2.1. Delay in Obtaining Unit Shut down for Undertaking Technical Studies (Institutional Risk)

A. Risk Description

Robust baseline assessment through technical studies is the foundation for the success of R&M project. In order to carry out comprehensive assessment of the remnant life and condition of the plant, various standardised tests are required to be performed (destructive and non-destructive) involving a shutdown of approx. 2 to 3 months.

This risk arises if the utility is unable to obtain requisite approvals from the relevant authorities (State Government or Regulatory Commission) for shutdown of the plant for carrying out such studies.

B. Root Cause Analysis

Significant energy and peak deficit scenario in most of the states coupled with lack of planning for procurement of power from other sources inhibits shutdown of state owned units especially for carrying out such studies.

In certain cases this is driven by socio-political consideration that results in delay in obtaining the shutdown.

C. Impact, Frequency and Severity of Risk

The above risk leads to the following:

a) Delay in initializing the R&M activity, causing further deterioration in the plant condition and performance
b) Shorter shutdown period results in inadequate assessment of the condition of the plant and residual life of various components derailing/impacting the entire R&M project.

The likelihood of the occurrence of this risk is low to high depending upon the number of units requiring simultaneous shutdown. It may not be difficult to obtain requisite approval for one unit but in case more units are scheduled for such shutdown, obtaining requisite approvals/permissions may be difficult.

The severity of the risk is low.

D. Bearer of Risk

Generating company is the direct bearer of this risk.

E. Strategy to Manage the Risk

This risk can be avoided through a combination of measures that should be initiated from the Central Government, the Generating Company and the Distribution Utility. These are explained below:

a) Advance Planning for Scheduling of Technical Studies (Risk Avoidance)

The following steps are required at the plant level:

i. Efforts should be made to coincide the time period of technical studies with that of annual maintenance/overhauling of the unit. Thereby, a separate shutdown may not be required for carrying out technical studies.

ii. In case a separate shutdown is required, it must be planned well in advance and distribution utilities must be informed accordingly. This would provide sufficient time to the distribution utility to arrange for additional power to meet the shortfall on account of the above. In addition current power market provides several avenues for procurement of power in the short and medium term, which should be considered.

iii. Further, efforts should be made to plan such studies during off-peak demand months when the stress on the generating systems is low. This however, should be considered in view of the market conditions. As in certain cases it is noticed that when multiple plants undergo R&M during off-peak periods, the stress on the suppliers increases resulting in delays. Hence, availability of the vendors should be assessed before actual commencement.

b) ***Additional Allocation of Power to States from Unallocated Quota of Central Pool for carrying out the studies (Risk Avoidance)***
In order to obviate this risk the following is required:

i. As per clause 6.2 (ix) of the MoP Guidelines for R&Min National Perspective Plan for Renovation and Modernisation and Life Extension of Thermal Power Stations (upto 2016-17), 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.

5.2.2. Inadequate Technical Assessment/Studies (Technical Risk)

A. Risk Description

Technical assessment is the most important and a resource intensive activity in terms of time and manpower. It involves performance testing, destructive and non-destructive evaluation of equipment, to diagnose the key concern areas in the power plant. This risk arises on account of the following:

a) Requisite studies or tests not performed
b) Assessment undertaken only for major components of the plant
c) Proxy Assessment in case of multiple units, wherein studies are undertaken only for one unit to finalise scope for other units

B. Root Cause Analysis

The root causes for the above are:

a) ***Studies undertaken only for the major components of the plant***
It is observed that in many cases RLA/CA study is undertaken for boiler and turbine but no detailed study is undertaken to diagnose critical areas in BoP and auxiliaries. Further, studies such as energy audit may not be undertaken at all, inhibiting identification of energy efficiency measures for improved performance and also comparison of performance of different components of plants in pre and post R&M scenario.

b) Due to lack of past operating and performance data with the utility, it may difficult to identify improvement areas for certain components in the unit/machine as every component cannot be tested.

c) Utilities may also not be keen to undertake detailed assessment as they generally underestimate the importance of data or in interest of time these studies may be omitted.

d) Scope of work prepared for carrying out technical studies may be weakly defined especially for critical plant components operating in creep and fatigue range. Further, deliverables based on such technical studies are not defined appropriately by the utilities

e) In case of multiple units, it is sometime assumed that since both units are operating under same condition, assessment of any one of the units would suffice the purpose. This is often done to save time and cost during the initial stages (Refer box below).

Box 5: Inadequate Assessment for R&M

During interactions with various officials both at the utility headquarters and the plant level, it was observed that most of the utilities do not undertake comprehensive assessment, and studies are being undertaken for the main plant only (BTG). In addition, in case of multiple units undergoing R&M, studies are conducted only for one of the units and scope for all units is prepared based on the same (Proxy Assessment).

One of the examples is Barauni Thermal Power Station (Unit 6 and 7) wherein the RLA study for Boiler & Auxiliaries and Turbine & Auxiliaries was undertaken for only Unit 6. No RLA/CA study was conducted for Electrical and C&I Systems or for common facilities. Further, no such assessment was undertaken for Unit 7.

Based on the limited assessment scope of work was prepared for both the units.

Source: Interaction of AF Mercados EMI team with the officials of various utilities and DPR for R& M of 2X110 MW (Units 6&7) Barauni TPS.

C. Impact, Frequency and Severity of Risk

The impact of this risk is reflected in the form of surprises or additional scope of work at the project execution stage leading to increase in cost and time of the project. The impact on the project could be high as identification of additional scope not only increases the cost of procurement but also leads to delay in execution leading to significant generation loss and hence revenue to the utility.

The frequency of occurrence of this risk is high.

D. Bearer of Risk

The above risk impacts all the parties involved in the R&M activity including generating company, supplier(s) and the Implementation Support Consultant (if applicable).

E. Strategy to Manage the Risk

Comprehensive Studies for the unit planned for R&M should be mandatory. The scope of the study should cover both the Main Plant Equipment as well as the Balance of Plant. (Risk Avoidance)

A comprehensive R&M assessment should aim to undertake the following for each unit being considered for R&M or LE: (i) Data Gathering; (ii) Plant Walk-down; (iii) Energy Audit; (iv) Pre-R&M Performance Testing; (v) Residual Life Assessment; (vi) Steam Path Audit; (v) Stress Analysis of Critical Piping; (vi) Potentially Non-destructive and Destructive Evaluation; and (vii) Review of O&M Practices[7]. (Refer Table below)

Table 11: Technical Study of Thermal Plants

Boiler	Turbine/Generator	Balance of Plants/Auxiliaries
• RLA Study • Condition Assessment Study • Performance Testing	• RLA Study • Performance Testing • Finite Element Analysis • Steam Path Audit	• Condition Assessment Study • Performance Testing

Additionally, diagnostic studies should also review the procedures, training system and other similar aspects.

Further, in order, to minimize the impact of this risk it is advisable to undertake comprehensive R&M assessment for each unit planned for R&M, and review both the main plant equipment and the BoPs. The depth of the studies between different units or plants could vary depending upon the condition of the plant, availability of historical operation and maintenance records etc. For example, if regular maintenance of the plant is being undertaken by the utility and comprehensive maintenance records have been well kept in that case in-depth testing may not be required for all the components of the plant. Also, it is suggested that project financiers should consider submission of the reports/results of such studies as a pre-requisite for funding the project.

In this regard CEA has prepared standard documents for carrying out RLA/CA/EA studies which may be used by the utilities.

5.2.3. Weak Analytical Framework for Selection of R&M Options (Management Risk)

A. Risk Description

Post the technical studies have been undertaken, the decision to repair/improvement/replace/retrofit or combination of these measures (or

[7]In certain cases, wherein the assessment of O&M practices has revealed serious gaps, funding agencies have insisted on development of an O&M improvement action plan that is accepted by the Board of Directors by the generating company, and proposed for implementation as soon as the R&M is completed.

retire) is based on assessment of available options. This also includes economic evaluation or comparison of options with regard to R&M, retirement or setting up of new power plant etc.

This risk arises if the utility is not able to identify and/or evaluate different options and select the best possible option depending upon the conditions of the plant, financial constraints, etc.

B. Root Cause Analysis

The root causes of the above behaviour are:

a) Poorly defined objectives for undertaking R&M
b) Inability to identify alternative option or combination of options
c) Focus only on the technical criteria, with limited focus on financial and economic returns
d) Limited project appraisal skills

C. Impact, Frequency and Severity of Risk

The above risk leads to selection of sub-optimal option that may result in unmet objectives and outcomes, and/or higher time and cost.

The likely occurrence of the risk is high and severity is moderate.

D. Bearer of Risk

The ultimate bearer of this risk would be consumers as the suboptimal decision would lead have relatively high cost viz-a-viz benefit resulting in high consumer tariffs.

E. Strategy to Manage the Risk

Comprehensive Identification and Assessment of Options including computation of financial returns, payback period, shutdown time required and conformance to the set objectives. (Risk Avoidance)

R&M should be goal oriented. Hence, objective for undertaking R&M should be decided upfront. The objective for undertaking R&M could be any one or a combination of the following (i) Availability improvement i.e. increased electrical output; (ii) efficiency upgrading i.e. reduced fuel consumption, (iii) environmental control upgrading i.e. emissions within new norms, (iv) life extension i.e. improved reliability. Based on the identified objective/(s), options for R&M should be evaluated and selected.

A detailed cost benefit analysis by estimating the net present value (NPV), rate of return (IRR), payback period and cost-benefit ratio, should be undertaken by the utility for different 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 justification of the R&M project needs to be established clearly demonstrating that the R&M project is competitive against all feasible power generation supply options (Refer Box below).

It must be noted that there is no benchmark cost for R&M. The actual cost depends on a variety of factors including:

a) Periodicity and quality of regular maintenance and overhauls.
b) Overdue maintenance works imply a larger scope of R&M works
c) Age, technology and condition of the plant.
d) Higher Costs of Energy Efficiency Measures and Modernization

Hence, net financial returns should be the determining factor rather than capital expenditure incurred on R&M. Independent specialized entities could be considered for undertaking such assessments.

Box 6: Evaluation of different R&M options

Example: Unit 6 of Koradi Thermal Power Station (KTPS) (210 MW), Maharashtra State Power Generation Corporation Limited (MSPGCL)

Table below indicates the options considered for R&M by MSPGCL for KTPS Unit 6. Based on the assessment Option D was selected.

Description/ Option	A	B	C	D	E	F	G
Scope	One to one replacement for life extension of the plant for up to 20 years with the present operating capacity without modification for existing coal quality, with improvement in heat rate	Option B, along with life extension, aims for restoration for design capacity and restoration of the design Unit Heat rate with Boiler modification for existing coal quality and Turbine refurbishment	Option B plus LP retrofit for Increase in Plant Capacity up to 215 MW and Improvement in Unit Heat Rate beyond design Heat	Option B plus replacement of complete turbine with new reaction type turbine for increase in Plant Capacity up to 215 MW, and Improvement in Unit Heat Rate beyond design Heat Rate	Option D plus Generator modification to achieve 220 MW capacity	complete replacement of the main plant with new plant of 250 MW capacity at adjacent location	Insitu replacement of the main plant with new plant of 250 MW capacity at same location.
Unit Capacity (MW)	**196**	**210**	**215**	**215**	**220**	**250**	**250**
Unit Heat Rate (kCal/kWh) PG Test value	2476	2400	2370	2350	2350	2350	2350

Project Capital cost Rs. Cr.	**309**	**403**	**456**	**486**	**536**	**984**	**849**
Cost per MW (Rs. Cr/MW)	1.57	1.92	2.12	2.26	2.43	3.93	3.39
Cost of Generation (Rs/kWh)	2.27	2.27	2.23	2.21	2.24	2.59	2.36
FIRR % at minimum cost of Generation	11.74	11.65	12.86	13.2	12.39	7.82	8.28
Pay Back period	4.5	4.6	4.6	4.6	4.6	6.6	6.7
Shut down period months	5	6	6	6	6	4	18

Source: Detailed Project Report for KTPS (Unit 6)

Thus, various options for R&M should be comprehensively identified and evaluated, and best option be selected.

5.2.4. Appropriate Commission not apprised of the R&M Project Plan (Regulatory Risk)

A. Risk Description

R&M project involves capital investment and hence regulatory approval for such investment is essential to enable the generating company to recover the amount through tariffs. It is thus, essential that the appropriate regulatory commission is apprised well in advance about the plan for undertaking the R&M. In addition, the plan should be in accordance with the regulations notified by the Commission from time to time.

The risk arises when the Appropriate Commission is not apprised about the R&M project.

B. Root Cause Analysis

This risk can be attributed to complacency resulting in oversight or lack of awareness of regulatory requirement.

C. Impact, Frequency and Severity of Risk

The impact of this risk would be that the generating company may not be able to recover the investment or the cost it incurs on undertaking R&M of the plant. This will also impact the financial position of the generating company.

The likelihood of this risk is moderate and the severity is moderate.

D. Bearer of Risk

Utility is the bearer of the risk.

E. Strategy to Manage the Risk

Practice of obtaining in-principle approval from the Appropriate Commission should be encouraged. (Risk Avoidance)

Review of the tariff regulations notified by various states indicate that in-principle approval of R&M investment is not a mandatory requirement; however experience suggests that it is a desirable practice that helps avoid controllable risks at a later stage.

In accordance with the above, the generating company must provide all required information to the regulator for obtaining such approval.

5.2.5. Limited Capacity of Utilities in Undertaking R&M Works (Operational Risk)

A. Risk Description

The risk arises due to the limited skills and expertise of the generating company to plan and implement R&M. In addition, absence of dedicated cell/department at the company level also contributes to the risk.

B. Root Cause Analysis

The risk arises on account of the following:

a) Limited training of utility professionals in the area of planning and execution of R&M projects
b) Inadequate exposure of the utility staff with regard to experience of other states in India and outside in implementing R&M
c) Adequate personnel not dedicated to the R&M activity. It is often seen that most of the available manpower is dedicated to the already on-going and large new capacity augmentation programs.
d) People working in R&M project get transferred to other departments in the middle of the project.

Box 7: Limited capacities of the Utilities in undertaking R&M works

During interactions with various utilities undertaking R&M, it was observed that *"Adequate staff is not deployed for the project and Maintenance Engineers from running plants are utilised as and when need arises diluting the efficacy of work."*

Adequate dedicated personnel is a pre-requisite for effective implementation of R&M projects

Source: Interaction of AF Mercados EMI with officials of various utilities.

C. Impact, Frequency and Severity of Risk

Every stage of the R&M process cycle is impacted leading poor execution of project. The frequency of this risk is high and severity is moderate.

D. Bearer of Risk

Besides the utility, vendors also bear this risk as they would not be able to perform their work effectively.

E. Strategies to Manage the Risk

Creation of dedicated R&M Cell and Engaging Specialised Consultants (Risk Avoidance)

In order to effectively deliver a successful R&M project, the following steps are required:

a) Creation of dedicated R&M cell by the utility at the headquarter and the plant level

In order to effectively deliver on the R&M project it is important to create a separate R&M cell with adequate and dedicated manpower for the project. This team should involve a mix of plant level officials dealing with the different plant level departments like Boiler, Turbine, Electrical, C&I, CHP, Milling system and AHP etc.

Further, officials having prior R&M experience should also be included in the team. To ensure timely decisions and approvals within the organization it is important that this team is formed at both headquarter and plant level.

b) ***Engaging of design and implementation support consultants***
Specialized agencies should be engaged by the utility (on the basis of competitive bidding) covering assistance on all works from design to implementation. This could be either one agency or multiple agencies.

The role of design consultants is to assist the utility in tasks related to conduct of different studies, identification and selection of best feasible option for R&M, preparation of DPR, scope finalization, preparation of tender documents, bid evaluation and selection of vendor etc.

The role of implementation consultant includes review and approval of drawings, coordination between the vendors and the utility, monitoring the progress of work as per approved schedule, assistance to Owner in dealing with statutory authorities such as Boiler Inspectorate Directorate, Pollution Control Board etc, monitoring of day to day progress of the work, review of PG Test Report etc.

Further, to build the requisite capacity of the utility officials, scope of work of consultants should also include training of utility/R&M cell officials on each of these components/fields.

c) ***Avoidance of transfer of personnel involved in R&M Project in the middle of R&M work***
Abrupt transfers of personnel in an ongoing R&M project create unnecessary distress and slow down the progress till the new personnel gets acquainted with the project. It is imperative to involve people selected for R&M Cell to work from the beginning to end of the project so that timely decisions can be taken.

5.2.6. Weakly Defined Scope of Work (Contractual Risk)

A. Risk Description

This risk arises if the scope of work is broad and does not clearly define the role and responsibility of different stakeholders including the works to be performed by each party.

Further, if the scope of work or design specifications is prepared in a way to favour a particular supplier or include propriety items.

B. Root Cause Analysis

The risk arises due to the lack of proper and detailed assessment of the requirement of works at the start of the project by carrying out limited technical studies. It needs to be acknowledged that the nature of R&M work is such that exact scope cannot be defined but efforts are required to bridge this gap as much as possible. However, instead of bridging this gap by specifying the scope as precise as possible, utilities prefer to insert clauses the following clauses to safeguard their interest (such as):

> *"Any item essentially required for system completion and commissioning of the units shall be treated as included in the scope of works without any extra cost on this account"*

Such clauses although included in the contract, in reality are not acceptable to the vendors. It is also difficult for the utilities to make vendors adhere to such clauses. Further, scope is kept broad or are prepared in manner to favour a particular supplier in cases where in there exists a potential conflict of interest i.e. same organisation or consultant is involved in the entire process of undertaking the technical studies, preparation of scope and its ultimate execution.

C. Impact, Frequency and Severity of Risk

Lack of clarity in the roles and responsibilities of the involved parties in the scope of work leads to contractual disputes causing delay in project execution. Also, such risk arises when the actual execution of the project starts leading to increased shutdown period and hence loss in revenue to the utility.

Further, ill defined scope of work and specifications tailored to favour a particular vendor lead to increased cost of procurement of the works for the utility and discourages other vendors in the market ultimately hampering the overall market development in a broader context.

Contractual delays also impact the bottom line of the vendor and opportunity cost for the utility. The likelihood of the occurrence of this risk is high and severity differs from moderate to high.

D. Bearer of Risk

Both utility and vendor are the bearers of this risk.

E. Strategy to Manage the Risk

Scope of Work to be as precise and comprehensive as possible (Risk Mitigation)

In order to mitigate this risk a multi-pronged approach is required which is explained below:-

a) Role of Design Consultants- Besides their role in undertaking the technical studies, it is required that design consultants should also be involved in preparing the final scope of work for the study.

b) Involvement of plant level officials- It is required that officials/engineers involved in the operation and maintenance of the plant should be involved while finalizing the scope of work as they have deeper knowledge of the condition of the plant.

c) Involvement of engineering team-Engineering team of the utility should also be involved while finalizing the scope of works.

d) Discussions with vendor/s- Suppliers (especially the original equipment suppliers) should be consulted in the early planning process to understand the viability of options for R&M envisaged including new technologies which can be used. However, it is required that scope should not be biased towards any one or more supplier. Further, in case of bidding, the bid clarification stage would provide the opportunity to bidders to flag biases if any and would help in strengthening of the scope of works. In case of nomination basis, direct discussion with the vendor can provide inputs in finalization of scope.

e) Avoid proprietary items in the scope of work- While preparing specifications for different components efforts should be made to avoid proprietary items. For e.g.: - in case of C&I systems, it is important to select Open System to minimize proprietary hardware and software; and ensure compatibility with existing systems. In addition, the customer support and service policy should also be taken into account during assessment.

Involvement of multiple agencies as suggested above and conducting comprehensive R&M studies are vital components for preparation of best possible specifications of the project.

5.2.7. Utility Unable to Mobilise Funds (Funding Risk)

A. Risk Description

This risk arises when the utility is unable to arrange adequate funding for undertaking R&M of the project or faces constraints in raising funds for the project.

Box 8: Lack of funding for undertaking R&M (Thermal Power Station - BTPS)

Example: Barauni Thermal Power Station (BTPS)- Unit 4 and 5

Unit 4 and Unit 5 of BTPS (2x50 MW) were first identified by the CEA for R&M works in 1989 and 1991 respectively. However, due to lack of sufficient funds R&M works could not be taken up at that stage.

These units were later shutdown in 1995-96. Finally, in 2008, the Bihar State Electricity Board (BSEB) decided to take up these units for R&M. However, these were declared unviable by the CEA, and considered for retirement under the 11th five year plan.

Thus, due to funding constraints R&M plans could not materialize as per expected schedule.

Source: CAG Report – 2009-10

B. Root Cause Analysis

The risk arises due to the poor financial condition of state utilities that makes it difficult to obtain financing especially from commercial sources. Further, due to declining profitability, it is difficult for state utilities to even arrange equity funds from their internal reserves.

In addition to the above, most of the utilities are unable to justify the benefits envisaged from R&M to the potential financiers. This occurs on account of three factors: (i) lack of robust analysis of various possible options; (ii) lack of confidence of financiers on R&M due to limited success stories in the country; and (iii) overwhelming focus of financiers on new capacity addition (until recently).

C. Impact, Frequency and Severity of Risk

The overall impact is that utility is unable to materialize its plan for undertaking R&M. The consequent delay on account of the above results in further deterioration in the plant performance. This also has a cascading affect on the overall R&M market and leads to creation of a vicious cycle, wherein projects do not get financed on account of limited success stories and vice versa.

The likelihood of occurrence of this risk is low to moderate and severity of risk is high.

D. Bearer of Risk

Utility is the direct bearer of this risk. This also impacts the suppliers as they may not receive timely payments for their works.

In the long run, this risk has repercussions on the entire R&M market.

E. Strategy to Manage the Risk

Use of innovative financing approaches/models (Risk Mitigation)

In order to attract public or private investment for R&M projects different financing models should be taken up by the state utilities. These include:

a) **Lease, rehabilitate, operate and transfer (LROT):-**
Under this option, the 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. However, legal title and ownership of the plant remain with the utility. 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.

b) **Joint Venture between Power utility and public or private**

company:-
In this option, a new company would be formed as a joint venture (JV) of the state power utility/ State Government and selected private/public collaborator. The JV Company would then undertake the R&M/ LE works and also own, operate and maintain the power station. The private collaborator could also be an equipment supplier. Each partner shall hold minimum 26% equity in the JV Company. For e.g. 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, the actual implementation of such models has been limited. It is important that utility should undertake a robust analysis of alternative approaches, cost benefit analysis and computation of financial returns. Also for increased participation of the financial institutions it is important to safeguard the interest of financers by clearly defining the roles and responsibility in the event of shortfall/ non achievement of required operational parameters and financial returns along with the suitable mechanism for recovery of investment.

Therefore, it is required that such models must be actively considered by the generating company for financing R&M projects.

In addition, awareness campaigns and outreach activities to communicate benefits of R&M provide certainty on the market size, and involving potential vendors in the process is of critical importance. Demonstration of successful pilots will also provide a strong fillip to the R&M market in India.

The Indian power market particularly the new thermal capacity addition is 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 inflexible contractual structure for pass through of variation in the coal prices is resulting in slow down of the new capacity addition. Thus, there is likely to be a very strong focus on increasing the efficiency of the existing generation fleet of the country. R&M market is likely to gain momentum in the near future, with financiers also preferring to finance projects that demonstrate visible improvement in the performance in short time.

5.3. Planning Stage

The risks identified across planning stage of R&M process cycle and strategies to manage the identified risks are presented below:

5.3.1. Low Level of Participation by the Vendors in the Bidding Process (Market Risk)

A. Risk description

This risk arises when the utility adopts the bidding process for selection of vendors and receives a poor response to its bid(s).

B. Root Cause Analysis

The risk occurs due to the following reasons:-

a) Limited firms involved in the R&M market as most of the domestic and foreign companies have focused on new capacity addition in comparison to R&M projects.
b) Limited new vendor development initiatives - Insufficient/inadequate market signals to the prospective vendors. Most of the utilities in the past have preferred to execute R&M projects on nomination basis.
c) Stringent qualification requirements and guarantees impending larger participation.
d) Prohibitive contractual conditions.

C. Impact, Frequency and Severity of Risk

The utility is forced to select vendor from the limited pool of options available. Low competition also results in a higher price discovery. The risk has a broader market impact in terms of the development of competitive R&M market in the country.

The likelihood of occurrence of this risk was high in the past but with more utilities resorting to competitive bidding framework as opposed to only OEM based model, situation is now gradually changing. With the increase in the participation of international players in the Indian R&M market, the likelihood of this risk is expected to be low. The severity of risk is moderate.

D. Bearer of Risk

Utility is the direct bearer of this risk. This also impacts the potential vendors who are discouraged from entering into the R&M market.

E. Strategy to Manage the Risk

Focussed efforts should be taken up to involve potential players in the R&M market by the utilities and the CEA. (Risk Mitigation)

The following interventions should be taken up:

a) Qualification requirements in the tender documents should be designed in a manner that encourages participation of players including the new players. These should not be overly stringent.

b) The level of guarantees should not be excessive and should be based on fair balance between risk and rewards. Review of contractual documents and interaction with stakeholders indicates that 'performance specifications' are preferred as target parameter over 'design specifications' experience. This permits defining the target performance relative to the present operating and design conditions and provide flexibility to the bidder to investigate alternatives for achieving (or overachieving) the targets. In certain cases, a combination of design and performance specifications has also been used.

c) Pre-bid meetings and two stage bidding process can be adopted by the utility to address the concerns of the suppliers prior to submission of price bid. Any concern related to scope of work or technical specifications or quantities or performance requirements or guarantees etc should be clarified during the pre-bid stage. The bid documents should be easily accessible and available for the bidders to examine.

d) Utilities should make efforts to reach out to the potential vendors and disseminate information about the bid.

e) In this regard CEA has prepared standard bid documents which may be used by the utilities.

Box 9: Vendor Participation in R&M Bidding Process

Example 1: Vendor Participation for Koradi TPS Unit 1 & 2 (2005) Vs Koradi TPS Unit 6 (2012) – Maharashtra Power Generation Corporation Ltd. (Mahagenco)

During 2004, Mahagenco had planned to undertake R&M works for Unit 1 and 2 of Koradi Thermal Power Station. A global tender was floated for participation of vendors for R&M for Unit-1&2 R&M and LE Works in January 2005. Around four companies purchased the tenders but only 2 companies finally submitted the bids. Subsequently, the process was scrapped since for all units below and equal to 110 MW since investment in new capacity was considered to have better returns.

In case of Koradi Unit 6 (210 MW), participation of the vendors have been encouraging. The process has been supported by the World Bank with robust assessment and analysis of options. A participatory process has been undertaken for finalization of specifications. Also, two stage bidding process has been involved to address concerns of all the potential vendors.

All of the above have enable to create a balanced risk profile of the project resulting in higher vendor participation. In case of BTG around 8-10 companies purchased the tender and around 4 companies finally submitted the bids. In case of Electrical package around 5 companies purchased the tender and around 2 companies finally submitted the bids. Similarly, large number of BoP vendors purchased and participated in the bid for BoP works.

Source: Interactions of AF Mercados EMI with the officials of the KTPS, Mahagenco

Example 2: Stringent Qualification leading to low Vendor participation – Case of Bandel TPS (Unit 5), West Bengal Power Generation Corporation Ltd.

In case of BTG package only one out of the four bidders qualified after the first stage bid opening. Based on the discussions with the bidders, further refinements in technical design and performance requirements were made and a decision was undertaken to re-bid on a single stage basis. The single stage bids attracted two bids.

***Qualification requirements should be such that it encourages wider participation and further refinements may be made if the need arises* during the bidding stage.**

Source: Interactions of AF Mercados EMI with the officials of the Bandel TPS, WBPDCL

5.3.2. Higher than Expected Price Discovery (Market Risk)

A. Risk Description

This risk arises if the price discovered through competitive process or through nomination basis is significantly higher in comparison to that envisaged during the Planning Stage.

B. Root Cause Analysis

The risk arises due to the following factors:-

a) Lower vendor participation or selection of vendor through nomination basis, lead to limited bargaining power of the utility resulting in high procurement cost

b) Unrealistic assessment of cost of various components at the DPR stage.

c) Weakly defined scope of work and uneven sharing of risks between the utility and vendor. 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" i*ncrease the risk perception leading to increased risk premium or price for absorbing/sharing higher risk.

d) Stringent performance guarantees imposed/expected from the vendors ultimately leads to high prices for the project.

e) Pre-R&M condition of the equipment is not well-established. Usually, the information provided is not enough to determine clearly the design of the equipment and its performance, and its operating history.

f) Time gap between the technical studies and commencement of actual implementation, as the units do not get maintenance priority in the interim resulting in deterioration in plant performance.

g) Lack of drawings and historical data of the plant discourages vendors and/or increases their risk perception towards the proposed R&M of the unit/plant as they are not able to sufficiently familiarize with the condition of plant before bidding. This is ultimately reflected in the price of R&M.

C. Impact, Frequency and Severity of Risk

The impact of the above risk results in the following:

a) **Compromises on the scope of work** - In order to reduce the price discovered the earlier set scope of work may be reduced. This includes dropping uprating option, or dropping of up-gradation of BoP or other similar measures.
b) **Re-evaluation of option** – In view of the high price discovery, the utility may re-evaluate the options and may drop R&M of the plant.

The likelihood of occurrence is moderate. With increase in participation the likelihood of occurrence of this risk may be low. The severity of the risk is moderate to high.

D. Bearer of Risk

This risk is borne by the Utility and Vendor.

E. Strategy to Manage the Risk

The contracts should aim at balancing the risk and benefits between the utility and the implementation vendor. Adequate flexibilities in the contract should be provided to accommodate reasonable/acceptable changes. At this stage, the decision to go ahead for R&M should be re-evaluated and considered in the light of proposed changes. (Risk Mitigation)

In order to mitigate this risk following steps are required:-

a) **Discussions with Vendors**-

Suppliers should be consulted during the preparation of DPR (and cost estimates) to understand the viability of options for R&M envisaged including new technologies which can be used and to understand the market prices of various components.

b) **Proper Communication with the Vendors**-

This is the most important step as this would enable the vendor to realistically evaluate its cost and benefit and associated risks involved in the project. This includes the following:

i. Provision of previous year data pertaining to plant performance, results of technical studies etc. to the prospective vendors along with the bidding documents.
ii. Suppliers interested in bidding for the project should be

encouraged to undertake plant visits to understand or review the site conditions.

iii. Conduct of pre-bid meetings and two stage bidding process can be adopted to address the concerns of the suppliers prior to submission of price bid.

c) While preparing DPR of the project some contingency should be provided for price discovery and scenario analysis should be undertaken to understand the maximum price increase that can be allowed so that the identified/selected option remain the best possible option. If the price discovered is such that it makes the option unviable, utility should try to select the second best possible option. Thus, at this stage, the decision to go ahead for R&M should be re-evaluated and considered in the light of proposed changes.

d) Utility may also decide for rebidding (although it has its own risks) the project with suitable modifications i.e. changes in qualification criteria to increase participation, change in the selected R&M option etc. However, efforts should be made for suitable negotiations with the lowest bidder before resorting to such option.

e) Striking a right balance between the performance guarantees and penalties- There should be adequate sharing of risks between the utility and the supplier, shifting additional risk (beyond what the supp lier has direct control on) only increases the overall price of the contract.

Box 10: Higher than expected price discovery

Example 1: Koradi TPS Unit 1 and 2 (2x120MW), MSPGCL

MSPGCL re-evaluated the R&M Option for Unit 1 and Unit 2 of KTPS after the price discovered was higher than the expected price.

MSPGCL planned to undertake R&M works for Unit 1 and 2 of Koradi Thermal Power Station in 2004. The Feasibility report of Unit-1&2 was approved by the CEA with cost estimation of Rs. 128 and 132 Crores respectively. The erstwhile MSEB accorded its approval for Unit-1&2 for total estimated cost of Rs. 260 Crores with 15% variation above the estimated cost, under single tender for both the Units.

Accordingly, KTPS published a global tender for Unit-1&2 R&M and LE Works in January 2005.BHEL and NASL submitted the bids. Price bids were opened in September2005 wherein the total cost of the project was Rs 492 Crores (Rs. 2.05 Crores per MW) with a payback period of 18 years and Life extension of 15 years.

With these facts MAHAGENCO appointed a financial consultant for economic study in respect of Expenditure on LE works of Unit 1 to 4 Vs setting up of a new 500 MW power project. The following results were obtained:

Particular	Unit	R&M of Unit-1&2	R&M of Unit-1 to 4	New 500 MW Unit
Project IRR	%	11.62	9.78	12.97
NPV	Rs Cr.	69	28	250

Accordingly, the plans to undertake R&M for Unit 1 & 2 of KTPS were abandoned.

Example 2: Barauni TPS Unit 6 and 7(2x110 MW), BSEB

The initial price offer submitted by BHEL was considered high and therefore in order to accommodate the R&M activity within the sanctioned (available grant/budget), the scope of R&M was adjusted wherein the option of uprating (planned initially) and modernization of certain BoP items was dropped.

Source: Interaction of AF Mercados EMI team with the officials of BSEB

5.3.3. Rebidding/Re-award/Delay in Award of R&M Packages/Contract (Market and Operational Risk)

A. Risk Description

This risk arises if the utility consumes significant time in awarding the contract or has to rebid any of its contract or packages. There are examples wherein this risk has originated from the vendor side as well as from the utility's side.

Box 11: Rebidding of R&M Package

Example 1: Amarkantak TPS, Chachai (Power Station), Power House II(Unit 3 and 4), Madhya Pradesh Power Generating Company Limited

Units 3 and 4 of Power House II (2x120) were commissioned in 1977 and 1978 respectively. Comprehensive refurbishment of the PH-II was initiated in 1996. The contract was awarded in 1999 to Ansaldo Energia, Italy, which was terminated in 2002 on account of non-performance.

Fresh tenders were invited in 2002 for major R & M works. Due to high cost of main package (TG and boiler), the project was considered techno-economically unviable and was, thus, dropped. Subsequently, the scope was reframed and it was decided in late 2003 to split the work into smaller packages and administrative approval was provided by the erstwhile State Electricity Board in 2004.

The Company invited tenders (April 2004) from BHEL on single tender basis, against which BHEL offered (on 6 June 2005) to do the work at Rs.105.96 Crore. The Company reduced (between February 2005 and November 2005) the scope of work, in view of fund constraint. The negotiations were held

(November/ December 2005) and BHEL agreed to do the work at a reduced cost.

In the meantime, another firm NTPC Alstom Limited (NASL) on their own expressed (November 2005) their interest to participate in the R & M of TG sets and quoted a lower price. The Company, however, decided (January 2006) to invite fresh tenders. The Company invited (March 2006) fresh tenders, against which BHEL did not participate and the only tender received was from NASL. Letter of Intent was issued (May 2007) to NASL at a total cost of Rs.59.80 Crore.

Thus, the repeated revision of scope of work coupled with several negotiations resulted in delayed award of R & M work of TG sets.

Source: CAG Report Audit Report and interaction of AF Mercados EMI with officials of MPPGCL

Example 2: Panipat TPS- 1 (Unit 4x110 MW), Haryana Power Generation Corporation Limited (HPGCL)

Comprehensive R & M Scheme was adopted by the erstwhile Haryana State Electricity Board for rehabilitation of the four Units of 110MW each at PTPS. Competitive bids were invited (August 1995) and the contracts were awarded (23 May 1997) to ABB Kraftwerke Berlin GmbH (now Alstom Power). However, the work could not be completed as planned due to dispute, wherein the contract was terminated by the vendor. Several attempts were made to resolve the dispute however all of them were unsuccessful. Subsequently, the pending works were completed through another vendor.

Source: HPGCL Petition for Approval of Tariff for the year FY 2012-13

Example 3: Delay in Award of Contract- Case of Obra B (5x200MW),UPRVUNL

In 1998, UPRVUNL invited bids for refurbishment of 5 x 200 MW units of Obra 'B' TPS Power plant Performance Improvement Limited (PPIL), was found to be the lowest bidder and it was decided (November 2001) to issue Letter of Intent to the firm. In the meantime second lowest bidder M/s Alstom Power India Limited reduced (December 2001) its earlier offer to less that offered by the PPIL. The decision was hence deferred and subsequently the work was awarded to BHEL at a higher cost than that originally offered by the vendors.

Source: CAG Report Audit Report (Commercial) for the year ended 31 March 2009

B. Root Cause Analysis

The risk arises due to the following factors:

a) Qualification requirements, specifications desired or scope of work etc. are not clearly specified or utility has been constantly reassessing its options and changing the scope.
b) Bid responses are in a manner wherein comparison of different bids is not possible.

c) Discovery of higher than expected prices and subsequent modification in scope, qualification requirement etc.
d) Supplier issues - Delay in start of work or non-availability of manpower or dispute among sub-contractors.

C. Impact, Frequency and Severity of Risk

This risk leads to significant delay in execution of project, cost overruns and risk of change in baseline parameters. Likelihood of occurrence is moderate to high, and severity is high.

D. Bearer of risk

This risk is borne by both the Utility and the Vendor.

E. Strategy to Manage the Risk

a) Rebidding should ideally be avoided through robust project preparation, however in cases where it still emerges as the only option, potential bidders should be encouraged to assess the current plant condition and assume the responsibility of the task. (Risk Acceptance)

Further, the following should be considered:

i. The specialized design and implementation support consultants should be accountable and responsible for clearly examining the qualification requirements, scope of work etc, and must flag these issues at the start to avoid such situations.

ii. Pre-bid meetings and two stage bidding process can be adopted by the utility to address concerns of the suppliers and incorporating their suggestions to improve specifications.

iii. Requisite safeguards should be adequately provided for in the contract through bank guarantees and liquidated damages.

iv. Potential conditions that may lead to rebidding/re-award should be comprehensively assessed and incorporated in the next bidding round. In cases where work has been partially performed (by the earlier selected bidder), the information should be shared with potential bidders so that they assume the responsibility of the work. In such cases, the potential bidders should also be encouraged to visit the site for undertaking their own assessment.

b) Management should undertake timely decision for award of contract by formulating qualification requirements and evaluation procedures along with appropriate timelines before seeking interest from the vendor (Risk Avoidance)

To avoid such situations, it is required that qualification requirements and evaluation procedures along with appropriate timelines should be clearly formulated before seeking interest from the vendor. Role of design consultant in clearly specifying such requirements becomes essential. Further, ISC should facilitate timely decision by providing advice with regard to evaluation and selection of successful bidder to enable decision making at the utility's end.

5.3.4. Implementation Contract Awarded to Vendor Involved in Carrying out Technical Studies (Management Risk)

A. Risk Description

This risk arises if the same entity is involved in formulation of technical specifications/scope of work and execution of R&M project.

B. Root Cause Analysis

The Original Equipment Manufacturer (OEM) is generally the first point of contact in case of any R&M based requirement on account of various reasons – availability of engineering drawings and familiarity with the plant. In India, this risk is accentuated from the fact that only a select few OEM were responsible for commissioning of power plants during 1980s and 90s (those that will require R&M).

Directly initiating the process with the OEM is considered safe, convenient and saves time and effort of the utility.

C. Impact, Frequency and Severity of Risk

Lack of independent assessment and presence of potential conflict of interest may not lead to the best possible outcome for the utility. The likelihood of occurrence is high, with moderate severity.

D. Bearer of Risk

The utility is the direct bearer of this risk.

E. Strategy to Manage the Risk

A single entity should generally be avoided to assume both the role of design consultant as well as the supplier. (Risk Avoidance)

Independent assessment through specialized agencies to develop the technical specifications and the scope of work should be mandatory. Further potential conflict of interest wherever possible should be avoided.

5.4. Execution stage

The risks identified across execution stage of R&M process cycle and strategies to manage the identified risks are presented below:

5.4.1. Weak Decision-Making Framework (Management Risk)

A. Risk Description

This risk arises if there is significant delay in undertaking decisions to resolve issues faced during the execution of the work. This could be related to the possible surprises upon the opening of machines which may require contract modifications; difference in the interpretation of scope and responsibility by vendors and employer etc.

B. Root Cause Analysis

The risk arises due to the following:

a) Lack of planning and ownership of the R&M project by the utility officials due to frequent change in the officials handling R&M works, lack of technical and professional management skills to address the issue/situation, lack of accountability structure etc.
b) Lack of authority of the officials involved

C. Impact, Frequency and Severity of Risk

This leads to contractual disputes and delay in execution of the work. The frequency of occurrence is moderate and severity of this risk is high.

D. Bearer of Risk

This risk affects all the parties involved in the R&M implementation including the utility, supplier and the implementation support consultant.

E. Strategy to Manage the Risk

Creation of clearly defined decision making and reporting structures with nominated officials authorized to undertake decisions (Risk Mitigation)

Decision making and reporting structure should be clearly specified. This should include roles, responsibility and authority to various officials involved in R&M. For timely decision making it is important that these structures should be defined in a way wherein relatively smaller issues (could be defined in terms of value of money involved) or issues involved in day to day execution with the vendor can be undertaken at the plant level and larger issues can be reported to the top management for their action.

Further, contract review meetings to assess the progress and deviations if any from the schedule of work should be held weekly. The minutes of the meetings prepared should clearly specify the responsibility and the timelines to address the issues. Requisite follow up of the actions should also be undertaken regularly.

Here in the role of Implementation Support Consultant is of utmost important as it is required to facilitate smooth coordination and timely action for resolving of pending issues.

Alongside, empowered team of both the utility and the suppliers should be nominated to ensure timely resolution of disputes and issues, as and when they arise. 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, a collaborative atmosphere needs to be created wherein both the utility and the supplier work as partners.

5.4.2. Occurrence of Technical Surprises (Technical Risk)

A. Risk Description

A thermal power plant undergoing R&M, despite undertaking comprehensive prior plant assessment might face unforeseen events once the unit is shut down and opened up for R&M. Such unforeseen events are called Technical Surprises. As the units are very old or nearing the useful life of operation, such technical surprises are quite common. The utility due to such surprises is faced with unexpected change or unforeseen additions in the scope of work leading to cost and time overruns. In order to address this risk it is suggested that CEA guidelines for "Early Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them" may be referred.

B. Root Cause Analysis

The risk arises due to the following:

a) Inadequate assessment and weak scope of work. RLA and other tests are conducted for main plant and equipments whereas in case of rest of areas like Balance of Plant (BoP) the scope is generally derived, without any actual condition assessment for BoP items.

b) Huge time lag between the technical studies (RLA, DPR preparation) and actual award of contract (and commencement of R&M work). This entire process normally takes ~3-4 years. The units in the interim get low maintenance priority leading to rapid deterioration in the plant condition not captured in the studies and hence the scope of work. In case of units that are already shutdown, cannibalization of the material/spares to other unit has also been observed as a common practice.

Box 12: 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
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	January 2005	February 2012

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

c) Refurbishment of old equipment or spares may not be possible due to technological obsolescence. This is true especially in case of old units of 110/120 MW units wherein the manufacturers have stopped manufacturing the spares (especially electrical) due to technological obsolescence.

d) Identification of additional scope of work at the execution stage not in the nature of surprise but required for better operation of plant at the later stage.

e) Due to nature of R&M certain surprises are encountered when the machine is actually opened. Even with careful planning and implementation, some unforeseen situations are likely to arise. In most cases, the strategy to deal with such surprises is not planned for leading to distress.

C. Impact, Frequency and Severity of Risk

The above risk results in the following:

a) Scope deviation: Additional scope of work to be addressed.
b) Contractual disputes due to weakly defined scope of works, and non-agreement between the utility and vendor.
c) Situation of indecisiveness due to inflexible contracts making it difficult for any alteration at the execution stage.
d) Delay in execution of work and increase in cost of the project.

In addition to the above, the finances of the utility are directly impacted in absence of any strategy to deal with such surprises.

The frequency of occurrence and severity of this risk is high.

D. Bearer of Risk

Both Utility and Vendor are affected by this risk.

E. Strategy to Manage the Risk

In order to mitigate this risk a multi-pronged approach is required. This includes:

a) Undertaking comprehensive assessment through technical studies with clearly defined scope of work (Risk Mitigation)

Effective assessment at the start of the project is the key to minimise technical surprises. The nature and occurrence of technical surprises depend upon the depth with which technical studies are undertaken. In order to minimize technical surprises, the foremost step is to undertake comprehensive assessment of both main plant equipment and the BoP through studies for each unit planned for R&M. Based on the studies, efforts should be made to define the scope as clear and comprehensive as possible along with the roles and responsibilities of each stakeholder.

b) *Creation of technical surprise plan (Risk Acceptance)*

A well-defined technical surprise plan should be prepared for effectively handling technical surprises, as and when they occur[8]. The design consultant involved in undertaking comprehensive assessment, DPR and subsequent scope of work should also prepare a technical surprise plan. This is required as replacement/repair of some components may come up at the time of execution as everything cannot be analysed / tested during the studies. This should be prepared in consultation with the plant level officials involved in operation, repair and maintenance of the plant to understand the potential surprises as they have the experience of the actual condition of the plant. This includes a list of possible surprises, ensuring availability of spare parts to minimize delays, addressing upfront the likely contractual aspects of additional supplies and works etc.

Further, this should also include the unit rates for equipment/parts and total financial implications of the same. In this regard CEA has prepared standard documents for Detailed Project Report which may be considered by the utilities.

c) *Establishing a clear decision making framework (Risk Mitigation)*

After the occurrence of technical surprises the indecisiveness of the utility can result in significant delay in the execution of work. It is important to specify the decision making process with clearly defined roles and responsibilities along with requisite authority of different officials to enable timely resolution of the issues encountered.

Box 13: Occurrence of Technical Surprises

Example1: Muzaffarpur TPS, KBUNL

Low Temperature Super Heater (LTSH): Only 50% coil replacement was mentioned in the DPR and R&M work order. This was done to reduce cost. Replacement of LTSH supply tubes was not included in the DPR and in the work order. While executing R&M it was found that about thirty nos. of LTSH supply tubes were missing. Discussions were held with the contractor and ultimately it was decided that KBUNL would place separate purchase orders for these tubes.

Thus, comprehensive assessment of the plant is essential for understanding the exact condition of equipment before placing the order or preparation of specifications.

Turbine Side Valves: As per R&M contract, all valves were to be refurbished by the contractor. However, requirement of spares for refurbishment of valves was unknown during the contracting stage. When the valves were opened by contractor

[8] The first aim in all earnest should be to minimize the occurrence of technical surprises.

it was found that additional spares were required.

An associated issue was that most of the valves were obsolete and now not being manufactured by the contractor or their sub-vendors. Hence, replacement was the only option.

Example 2: Obra B TPS (Unit 9 to 13) , UPRVUNL

Only main plant equipment has been considered for undertaking R&M while majority of the auxiliaries i.e. motors and cables have not been refurbished or changed impacting the quality of R&M works.

Site accessibility and space constraint are important factors for delay of R&M works in Obra, which were not considered before the start of the project. Due to space constraints crane cannot move between the units and therefore R&M works for Unit 10 & 11 were taken together. ESP of unit 11 had to be dismantled so that the crane could move and work on Unit 10 can be undertaken. This was not envisaged at the assessment stage.

Thus comprehensive assessment and planning before the execution of R&M works is necessary to avoid technical surprises.

Example 3: Additional Scope of Work in Ukai TPS (Unit 1 and 2), GSECL

In case of Ukai TPS additional work over and above R&M work was identified such as (i) Rewinding & Recaging of HT motors, (ii) Supply of IP Inlet Gland Box & Accessories, (iii) Supply of spares for ESP fields 1&2 of Unit 2 etc. Since these works were considered essential for future performance of the plant and there was no provision for addition/alteration of R&M, separate purchase orders were placed by the company.

Source: Interaction of AF Mercados EMI with officials of various utilities

5.4.3. Weak Dispute Resolution Mechanism Constraining the Execution of Work (Contractual Risk)

A. Risk Description

This risk arises due to occurrence of disputes including contractual disputes that affect the execution of work.

B. Root Cause Analysis

The risk arises due to the following:

a) Misinterpretation of the scope of work by either party i.e. utility or supplier.
b) Delay by supplier or claim of compensation by the supplier for any additional work outside the scope of work.
c) Delay in decision making by the utility or delay in providing shutdown of the plant.

C. Impact, Frequency and Severity of Risk

The risk impact the harmony in work and results in halting or delay of the work. The frequency of occurrence of this risk is moderate and severity is high.

D. Bearer of Risk

Both Utility and Vendor are affected by this risk.

E. Strategy to Manage the Risk

Creation of Dispute Resolution Committee at the start of project to address disputes between the Utility and the Contractor in a timely manner (Risk Mitigation)

In order to resolve disputes between the contractor, sub-contractor and utility, it is important to create a Dispute Resolution Mechanism. Under this mechanism a Dispute Resolution Committee (DRC) should be formed at the start of the project with fair participation from both utility and contractor. The institutional set up, powers and roles along with the time schedule (within which case can be referred from the occurrence of the dispute, hearing of the dispute and the final decision) of the DRC should be specified in the tender document itself. Any dispute which cannot be amicably settled between the parties can be referred to the DRC. However, until the dispute is resolved, the contractor should proceed with the work and contract in discussion with the utility and implementation support consultant.

5.4.4. Mismatch (or delay) in Supply of Critical Equipment and the Shutdown Period (Market Risk)

A. Risk Description

Various sub-activities within the R&M have to be planned and timed according to the available shutdown period. Accordingly, the schedule of supply of critical equipment has to be synchronized with the shutdown period to ensure completion of work in the minimum possible time. This risk arises when there is delay in supply of key components and equipments by the supplier and delivery schedule of the equipments is not in sync with the shutdown period of the plant.

Box 14: Delay in Supply of Material during Execution

Example1:Ukai TPS, Unit 1 (110 MW), GSECL

There were significant delays in supply of material by the vendor during the execution of the project leading to increased shut down period. Also, material with regard to Mainsteam and Hot-Reheat System was not supplied by the contractor until the end of the shutdown period and hence it could not be replaced. The material during the interim period was kept as inventory since it required a separate shutdown (outage) for installation.

Thus, supply of key components/material should be ensured before the shutdown of the plant and should be according to a proper project schedule.

Source: Interactions of AF Mercados EMI with the officials of the GSECL

Example2: PTPS, Unit 1 (110 MW), HPGCL

There was significant delay in supply of material by the contractor leading to delay in execution of the project. As per the schedule, R&M and up-rating of Unit-I was to be taken up from November 2006 but due to the delay in supply of material it could be taken up from September 2007.

Accordingly, applicable Liquidated Damages were levied on the contractor for delay in completion of works.

Source: CAG Audit Report and Interactions of AF Mercados EMI with the officials of the HPGCL

Example 3: Mismatch between the delivery of material and the shutdown period: Case of Obra B Units 9 to 13, (5X200 MW), UPRVUNL

R&M work for Obra B Units 9 to 13 was awarded to BHEL in May 2006 with a completion period of 30 months. However, till August 2012, work on only Unit 9 has been completed and work on Unit 10 and 11 is still in progress.

Since the delivery of material was not linked with the shutdown period of the units, the Contractor had supplied the entire material for all the five units during 2006 to 2010 leading to expiry of Warranty Period of material (24 months) even before the work on different units could commence. This is expected to have significant repercussion on the overall quality of execution of R&M project.

Thus, supply of material must be linked with the shut down schedule of units.

Source: CAG Audit Report and Interactions of AF Mercados EMI team with the officials of UPRVUNL.

B. Root Cause Analysis

This risk arises due to the following:

a) One of the major issues faced by the suppliers is the difficulty in procurement of sub-vendor items. This difficultly stems from the following: (a) non-existence of original vendors for such items; (b) non-availability of original equipment details, specifications etc; (c) obsolete design and (d) inadequate information available about modification done/spares used earlier. This leads to delay in supply of material on a timely basis.
b) Non-performance or underperformance of the vendor due to its overbooked manufacturing capacity.
c) Technological obsolescence may require customized manufacturing for certain components leading to delay in supply of components.
d) In-adequate planning on part of the utility.

C. Impact, Frequency and Severity of Risk

The impact of the above risk results in:

a) Delay in implementation of project and hence longer shutdown period.
b) Non-installation of certain components impacting the performance and quality of R&M works executed.

The frequency of occurrence and severity of this risk is high.

D. Bearer of Risk

Both Utility and Vendor are affected by this risk.

E. Strategy to Manage the Risk

a) Availability of key components should be ensured before the start of the project and should be in accordance with the pre-defined plan finalized before the commencement of work (Risk Mitigation)

The planning for pre-shutdown activities should be done meticulously. Availability of key components along with the sequential delivery of the components should be ensured before start of implementation/before shutdown is provided. Further, delivery of materials should be linked to the shutdown period of the plant.

b) Provision of Penalties for delay in completion of work (Risk Sharing/Transfer)

Adequate penalties should be built into the contracts for delay in completion of works by the vendor. This would provide right signals to the vendor for timely completion of work and would also compensate the utility to some extent for the potential loss[9].

Box 15: Lack of Penalty Clause for Delay in Completion of Work

Example:- Obra 'A' TPS (Unit No 1&2), UPRVUNL

Instrumentation Limited (I.L), Kota was awarded the work of upgrading C&I system for Obra 'A' TPS (Unit No 1&2) however the company could not complete the work as per the planned schedule.

The delay on the part of I.L, Kota in completing the work of unit No.1 &2 as per the schedule (October 2008) resulted in potential loss of generation to the utility for the delayed months (work completed in January 2009). Further, due to absence of the penalty clause in the agreement no penalty could be imposed on I.L., Kota such delays.

[9] A review of supply contracts of various plants indicates that such penalties are generally included in the contract, however in some cases omissions have also been observed.

> ***Thus, penalty clauses related to delay in completion of work should be included in the contracts by the utilities to ensure adherence to timely completion of work and to safeguard its financial interest.***
>
> *Source:- CAG Audit Report*

c) Sequential delivery of materials to the R&M site (Risk Mitigation)

Sequential delivery of materials should be agreed upon by both the utility and vendor and built into the contract. In the contract clauses, provision for non-acceptance and disallowance of material to the project site if not delivered sequentially should be included in order to avoid unnecessary delay in R&M work.

5.4.5. Weak Supervision, Quality Control and Assurance (Operational Risk)

A. Risk Description

The process of quality control involves setting up the specification of equipment and service upfront and ensuring that the delivered material/service is in compliance with the stated targets. This is often performed through random inspections and test.

The process of quality assurance involves reviewing the practices adopted by the vendor supplying the material or service to examine the extent to which the quality will be, is being or has been controlled.

This risk arises if material supplied or work performed by the vendor is of substandard quality. This risk also arises due to the weak quality review procedures of contractor to review quality delivered by the subcontractors.

B. Root Cause Analysis

The risk arises due to the following:

a) Lack of expertise in assessing the quality of material/service supplied by the supplier
b) Quality audits not performed by the utility at the supplier’s site
c) Lack of assessment of the vendor’s quality procedures with regard to its sub-vendor
d) Lack of appreciation on the necessity of formal quality control and quality assurance procedures

C. Impact, Frequency and Severity of Risk

Substandard equipment and installation service has a direct impact on the long term performance and life of the plant.

The frequency of occurrence and severity of this risk is moderate.

D. Bearer of risk

Utility is the direct bearer of this risk.

E. Strategy to Manage the Risk

Approval of detailed Quality Plans and Engaging Quality Control and Quality Assurance Consultants by the Utility (Risk Mitigation)

The detailed Quality Plans for both manufacturing and field activities should be submitted separately by the contractors to the utility for approval before the start of the project. The approved quality plan should then form as an integral part of the Contract document. The contractor must submit the quality plan for the project including the Quality Plan proposed for each sub-contracted item along with the procedures followed by the contractor to finalize and assess the quality assurances of the sub-contractors.

Implementation Support Consultants (ISC) or Independent Quality Assurance Consultants (QAC) should be appointed to confirm that implementation is as per the design requirements and that the documented quality plans are being adhered to. Consultants would also certify quality of materials and works before the payments are made as per contractual milestones. The QAC would also be responsible for the inspection of material quality at the workshop/facility of supplier.

Box 16: Need for Quality Control and Quality Assurance

Example 1: Quality Issues Encountered During the R&M

One of the utilities visited by AF Mercados EMI complained 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.

Example 2: Case of Koradi TPS (Unit 6), Maharashtra and Bandel TPS (Unit 5), West Bengal

The R&M project plan for the above plants indicates the following:

"Independent Implementation Support and Quality Assurance Consultants, working in collaboration with the concerned power generation utility, would be appointed for monitoring implementation progress as well as quality. These consultants would act as owner's engineers for the power generation utility and validate all design details, material supplies and works executions. The consultants would also support decision making process to handle surprises during the course of R&M implementation"

Thus, the process of having independent QAC has been considered and ensured as part of the implementation process.

Source: Interactions of AF Mercados EMI with the Utility Officials and Review of documents collected during the site visits

5.4.6. Failure to Comply with Environmental Standards and Perceived Negative Externalities (Socio-Environmental Risk)

A. Risk Description

Thermal power plants lead to gaseous emissions containing carbon dioxide, oxides of sulphur and nitrogen, and solid particulate matter (ash). Besides, the waste water discharges contains the pollutants. These power plants, thus results in air, water, noise pollution and land degradation.

The risk arises if the units undergoing R&M are not able to achieve the target emission standards even if efficiency gains are achieved. Further, the risk also arises if rehabilitation work is perceived to have adverse environmental and social impact on the habitants in the project vicinity.

B. Root Cause Analysis

This risk arises due to the following:

a) Inadequate environmental and social impact assessment by the utility.
b) Most of the units do not have requisite infrastructure for environmental monitoring and some are unable to install/ replace existing Electrostatic Precipitators (ESPs) due to paucity of funds or lack of space
c) Environmental norms are increasingly becoming stringent.

C. Impact, Frequency and Severity of Risk

The above risk leads to the following:

a) Non- compliance of environmental regulations, which in turn may lead to closure of the plant.
b) Delayed execution/ or abandonment of R&M due to agitation or demonstration from the community or civil societies.

The frequency of occurrence is high and severity is moderate as it may lead to closure of the generating unit/plant.

D. Bearer of Risk

Both generating company and supplier are direct bearers of the risk.

E. Strategy to Manage the Risk

a) Renovation of ESP system of the power plant (Risk Mitigation)

In order to meet the statutory environmental regulations there is a need to renovate ESP system of the power plant. This includes the following:

i. Retrofitting of existing ESPs with additional pass in parallel or additional fields in series to enhance the collection area within the available space.
ii. Renovation of the existing ESPs by increasing their height and

increasing the electrode spacing wherever the existing ESP height is 9 mtrs.

iii. Application of moving electrode type ESP

iv. Retrofitting of ESPs with bag filters.

v. Periodic environment audit of power plant

vi. Timely renewal of "consent to operate" from statutory authorities as per prevailing requirements.

b) *Undertaking socio-environment impact assessment to assess the impact of the project (Risk Mitigation)*

i. Utility should carry out Rapid Social Impact Assessment Study to identify potential adverse impacts of the Thermal Power Plant on the immediate habitations and screening or the social development issues of the immediate habitations. Further, Environmental Audit and Due Diligence Studies should also be carried out to improve environmental performance of the plant (pollution prevention and control measures, waste minimization, occupational health and safety) and develop strategies to mitigate environment risk and liabilities.

ii. Appropriate CSR framework or policy should be formulated by the generating company for the sustainable development of the inhabitants surrounding the power plant and to address negative externalities from the plant, if any.

iii. Generating company should engage with the local community and efforts should be undertaken to disseminate project impact assessments and benefits to nearby villages by deploying an appropriate strategy for communication.

Box 17: Formulation of CSR policy

Example: Formulation of CSR policy by Rajasthan Rajya Vidyut Utpadan Nigam Limited (RVUN)

RVUN, Government of Rajasthan has framed a CSR policy with an aim to contribute to the socio-economic development of the local community and society surrounding the power generating stations.

As per this policy, fund for carrying out CSR activities for power stations for new/extension projects will be Rs. 2.5 lakhs, 2lakhs and 1.5 lakhs per MW (one time) for coal based thermal power projects on supercritical technology, subcritical technology and gas based thermal projects respectively. Further, fund for power stations in operations will be 0.25% of the total annual Operation and Maintenance charges/cost allowed by Rajasthan Electricity Regulatory commission.

Thus, such policy should be framed by other generating stations also.

Source:- CSR Policy, 2011, RVUN

5.4.7. Delay in Provisioning of Unit Shut down for Executing R&M Works (Institutional Risk)

A. Risk Description

This risk arises if the utility is unable to schedule timely shutdown for executing R&M either due to grid conditions or delay in obtaining timely approvals from the relevant authorities (State Government or Regulatory Commission) for shutdown of the plant.

B. Root Cause Analysis

Significant energy and peak deficit scenario in most of the states coupled with lack of planning for 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.

C. Impact, Frequency and Severity of Risk

The above risk leads to the following:

i. Contractual disputes and delay in execution of work.
ii. Change in baseline parameters due to time gap between the studies and actual execution.
iii. Deterioration in the material quality already supplied by the vendor

Box 18: Delay in obtaining shutdown for R&M works during execution

Example: Amarkantak Thermal Power Station, Chachai (Unit 3 and 4)

While the material for boiler was supplied by the vendor, delay in providing shutdown for the unit led to deterioration of the new equipment which further delayed the execution of R&M.

Source: Interactions of AF Mercados EMI with the officials of MPPGCL

iv. Deterioration in condition of plant and occurrence of technical surprises

The likelihood of the occurrence of this risk is low to high depending upon the number of units requiring simultaneous shutdown. It may not be difficult to obtain requisite approval for one unit but in case multiple units are scheduled for such shutdown, obtaining requisite approvals/permissions may be difficult.

Severity of risk varies from low to high depending upon the delay in obtaining the approvals for shutdown.

D. Bearer of Risk

Both generating company and supplier are the bearers of the risk.

E. Strategy to Manage the Risk

This risk can be avoided through a combination of measure that should be initiated from the Generating Company and the Distribution Utility. These are explained below:

a) ***Advance Planning for Scheduling of Shutdown for Execution of Works (Risk Avoidance)***

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 to arrange 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.

b) ***Additional Allocation of Power to States from Unallocated Quota of Central Pool (Risk Avoidance)***

As per clause 6.2 (ix) of the MoP Guidelines for R&M, 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 clause/guideline.

c) ***Implementation of partial R&M activities during Annual shutdown periods (Risk Avoidance)***

R&M can also be implemented during planned shutdown for annual maintenance over two to three years' time period especially if the work does not include opening of steam turbine and significant repairs in the boiler and the generator. In case of Tanda (4x110 MW) and Talcher thermal power station (4x60, 2x110 MW) of NTPC, R&M was taken up during annual shutdowns over 3-4 years without substantially enhancing the routine shutdown period.

5.5. Closure stage

The risks identified across closure stage of R&M process cycle and strategies to manage the identified risks are presented below:

5.5.1. Sustainability of R&M Gains (Operational Risk)

A. Risk Description

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 by team corroborate the above fact.

Another reason which could affect the sustainability of R&M gain is the non-availability of spares or poor after sales services by the vendor.

This risk arises when the performance gain become difficult to sustain due to weak O&M practices and poor support services by the vendor after R&M has been completed.

Box 19: 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

B. Root Cause Analysis

This risk arises due to the following:

a) Lack of proactive approach in operating and maintaining the plant
b) Lack of awareness about the new techniques, processes and procedures
c) Lack of sufficient funds due to which mandatory spares are not being purchased and stocked in advance by the utility
d) Weak recognition of support services as an important parameter during evaluation of bids and formulation of contract
e) Difficulty in obtaining unit shut down for annual maintenance or periodic capital overhaul due to significant energy shortages in the state

Box 20: Delay in capital overhaul post R&M of the unit

Example:- Korba East TPS Unit 5 (120 MW), CSPGCL

The capital overhaul of the unit is yet to be undertaken (as on October 2012) after the completion of R&M of the unit in 2005.

Source: Interaction of AF Mercados EMI with officials of CSPGCL

C. Impact, Frequency and Severity of Risk

The above risk leads to the gradual deterioration of the condition and performance of the plant and hence the gains expected from undertaking R&M may not be achieved over a longer period of time.

The likelihood of the occurrence and severity of this risk is high leading to suboptimal utilisation of R&M investment.

D. Bearer of Risk

Generating company is the direct bearer of the risk.

E. Strategy to Manage the Risk

a) Preparation and implementation of O&M action plan on priority basis and engaging specialised agency for O&M of the plant, post R&M. (Risk Mitigation)

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.

Box 21: Adequate skills to undertake O&M, post R&M of the plant

During interactions with various officials both at the utility headquarters and the plant level, it was observed that most of the utilities lack adequate skills and expertise in operation and maintenance of plant. The schedules are not followed, there are no documented processes, and limited up-gradation has happened over the years. In certain cases, this has resulted in degradation of plant performance post R&M. Thus, it is important to ensure that O&M practices are strengthened and a robust plan is developed upfront and followed.

Source: Interaction of AF Mercados EMI with officials of various utilities

i. Contractor should revise the existing O&M manual as per the new system/unit requirements.

ii. Adequate training should be provided by the contractor before handing over the plant to the utility.

iii. The list of mandatory spares along with its unit prices should be included in the total price of the R&M contract. This mitigates the financial risk related to procurement of mandatory spares post R&M of the project.

iv. Generating company can also outsource O&M of the plant; post R&M to a specialized agency. There are models available for participation of private players in O&M.

Box 22: Experience of Engaging Specialised Company for O&M of Coal based Power Plant in India

Example 1: Sterlite Energy engaged Evonik Energy Services India (now Steag Energy Service India Ltd.) for their 4x600 MW TPS at Jharsuguda, Orissa

As per the agreement signed between the parties, Steag would be responsible for smooth and reliable operations and maintenance for 4x600 MW Coal based Power Plant at Jharsuguda. Further, as per the contract Steag would also bring in its proprietary plant management system and latest fault prediction systems which would ensure that the downtime for maintenance is reduced to a minimum. Health, Safety and Environmental systems would also be given high priority. Thus, the contract not only enables the company to ensure better O&M practices but also enables access to the state of the art technologies, systems and processes.

Example 2: Comprehensive O&M services by DESEIN

DESEIN is currently handling total Operation & Maintenance of many plants in India & Abroad. This includes :

i. 1 x 29.4 MW and 1 x 19 MW Coal / Lignite based Power Station at Dalmiapuram, Trichy, Tamil Nadu of Dalmia Cement Bharat Ltd., (contract continuing since 2005

ii. 2 x 15 MW Coal based Power Station at Butibori, Nagpur of Indorama Petrochemicals Ltd., (contract of O&M continuing since 2007)

iii. 2 x 43 MW coal fired power plant for Action Ispat & Power Pvt. Ltd. at Jharsuguda, Orissa (continuing since 2011)

Source: Compiled from various sources and media articles[10]

v. Generating company can also include O&M supervision in the contract of executing agency. However, a right mix of balance

[10] http://www.business-standard.com/india/news/vedantaevonik-ink-rs-14000-crore-omdeal/392724/, last accessed on 12th September 2012

http://steag.in/pdf/STEAG%20Energy%20Services%20(India)%20Pvt.%20Ltd.%20%20%20Profile.pdf, last accessed on 12th September 2012

http://www.desein.com/Services/om-services.php, last accessed on 12th September 2012 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.

Box 23: O&M supervision included in the contract of executing agency

Example: Korba East Thermal Power Station, CSPGCL: Unit 1 to 4(4x50 MW) and Unit 5 and 6 (2x120 MW)

Table below presents the post refurbishment performance of units in O&M guarantee period.

The Post Refurbishment performance of units (Plant Utilization Factor - 80%)			
O&M guarantee period	**First Year**	**Second Year**	**Third Year**
Unit 1 to 4(4 X50 MW)	93.02%	90.47%	93.58%
U# 5 (120 MW)	73.91%	83.65%	79.64%
U# 6 (120 MW)	80.17%	77.37%	74.55%

Source: Interaction of AF Mercados EMI with officials of CSPGCL and data collected during the visits

b) After sale services to be made an integral part of the contract (Risk Mitigation)

After sale services provided by the vendors should be considered as an important element during the bidding stage and support services for some specific period of time (say one to two years) should be incorporated in the contract.

5.5.2. Post R&M Guarantees not Achieved (Technical Risk)

A. Risk Description

Performance guarantee test are conducted to test the performance of the plant viz-a-viz the guaranteed parameter, within a specified period of time after commissioning of the plant. A review of contract indicates that in most cases the following guaranteed parameters have been adopted: (i) plant availability; (ii) ESP outlet emission level; (iii) boiler efficiency; (iv) turbine heat rate, and (v) rated capacity.

This risk arises if the performance test fails and the requisite performance guarantees are not achieved or if the performance guarantee test is not conducted or delayed incessantly.

B. Root Cause Analysis

The root causes for the above are as follows:

a) Failure of supplier to meet the commitments.
b) Lack of confidence on the achievement of the requisite targets

leading to delay in conducting of PG test.

C. Impact, Frequency and Severity of Risk

The risk results in the following impacts:

a) Envisaged R&M benefit not achieved during the assessment stage.
b) Contractual disputes
c) Levy of performance guarantee penalties on the supplier
d) Problems in regulatory approval and recovery of costs incurred on the R&M of the plant
e) Consequent financial loss to the utility.
f) Non-achievement of performance post R&M may lead to cancellation of future R&M works by the utility

The frequency of occurrence is moderate and severity of this risk is high.

D. Bearer of Risk

Both generating company and supplier are the bearers of this risk.

E. Strategy to Manage the Risk

Rectification or replacement of components to meet guaranteed parameters at no extra financial cost to utility and Levy of Liquidated Damages for shortfall in performance (Risk Mitigation)

a) Guaranteed Performance Parameters with Liquidated Damages should be included in the contract document.
b) Supplier should be asked to rectify/replace the components affecting the performance of the plant at no extra financial cost to the utility.
c) In case of non-achievement of performance guarantees, utility should levy the requisite penalties as provided in the contract.
d) Performance Guarantees Test should be a critical milestone defined in the contract.

While the impact of this risk is seen towards the end of the R&M exercise a number of actions indicated in the previous sub-sections also contribute towards non-achievement of the guaranteed parameters. Hence, preventive actions as indicated earlier in this chapter are critical to avoid such situations.

Box 24: Post R&M Guarantees Not Achieved

Example 1: Performance Guarantee Tests not Performed by the Contractor (Ukai TPS - Unit 1 and 2), GSECL

R&M works of Unit Nos.1 & 2 have been completed and units have been handed over to GSECL. However, Unit 1 and 2 have not been able to operate at the rated capacity of 120 MW and guaranteed parameters are yet to be achieved. Further, PG tests are yet to be performed by the contractor, which have been pending for a long time (approx. 1.5 years). There have been several efforts to facilitate this including assistance of the CEA, however still the PG test remain pending.

Source: Interaction of AF Mercados EMI with officials of GSECL

Example 2: Under Achievement of Guaranteed Parameters (PTPS Unit 1), HPGCL

The R&M and up-rating of Unit – I from 110 MW to 117.8 MW was awarded in August 2005. The Unit was synchronized in November 2008 and was declared for commercial operation in April 2009.

However, the desired improvements in the performance of the unit have not been achieved post R&M. The annual heat rate of Unit 1 was 3342 kCal/kWh for FY 2006-07 before refurbishment and after R&M, heat rate of 2916 kCal/kWh could be achieved against the contracted provision of around 2346 kCal/kWh.

Year	Plant Load Factor (%)	Specific Oil Consumption (ml/kWh)	Aux. Power Cons. (%)	Heat Rate (Kcal/kWh)		Availability factor (%)	No. of Tripping
				HERC Norm	Actual		
Pre R&M							
2002-03	58.09	6.26	11.66	-	3718	72.88	100
2003-04	63.09	4.5	11.04	-	3479	82.54	142
2004-05	52.59	5.13	12.2	3500	3554	71	112
2005-06	59.4	4.97	12.05	3450	3508	80.5	75
2006-07	62.63	3.11	11.67	3450	3342	89.16	55
Post R&M							
2009-10	79.08	1.95	10.37	2930	3047	83.67	70
2010-11	48.90*	4.08	10.09	2750	3112	54.68	28
2011-12	79.27	2.89	11.24	3050	2916	93.91	32

**Unit 1 was shut down from 1/3/2010-23/8/2010.*

Note: Unit has been up-rated from 110 MW to 117.8 MW w.e.f. 07.04.200 and unit was under shutdown for R&M from Sept. 2007 to Oct 2008

Source: Interaction of AF Mercados EMI with officials of HPGCL.

5.5.3. Disapproval of Costs Incurred During R&M (Regulatory Risk)

A. Risk Description

The capital cost incurred during the R&M is considered as part of the overall regulatory asset base of the utility wherein the regulator admits the cost based on prudence check and approves a tariff to be charged from the consumer for recovery of such costs. This risk arises if the regulator does not approve the expenditure incurred by the utility for undertaking R&M works on account of gaps/inadequacies in the submission.

B. Root Cause Analysis

The root cause of this risk is that the expenditure incurred by the utility is high as compared to what was in-principally approved by the regulator or in the DPR of the project. Also, the utility is unable to justify that the excess expenditure incurred is not due to the inefficiency of the generating company but due to factors non-attributable to the generating company.

C. Impact, Frequency and Severity of Risk

This risk would lead to under recovery or non-recovery of cost incurred by the generating company leading to financial losses.

The likelihood of occurrence of this risk is low if adequate planning is undertaken. The severity is high if the risk goes unaddressed.

D. Bearer of Risk

Generating company is the direct bearer of the risk.

E. Strategy to Manage the Risk

Involvement of Regulator should be ensured from the inception of the project with regular updates about the progress of the project. (Risk Avoidance)

The need for apprising the regulator about the R&M plan is important as the recovery of the cost incurred towards R&M is approved by the Regulator. This involves:

a) Obtaining in-principle approval from the Regulator during the initial stages for upfront commitment on the capital cost and plant performance
b) Updating the regulator on progress and achievement of critical milestones
c) Updating the regulator in case of abnormal or unexpected changes leading to cost and time overruns
d) Ensuring coordination with the distribution company (through the Regulator) since it is the primary off-taker of the power from the project.
e) Obtaining the final approval for admittance of the capital cost
f) Sharing of information about the outcomes, performance achieved vis-à-vis the guaranteed parameters with the regulator.

5.5.4. Absence of Ex-Post Evaluation and Feedback Loop (Operational Risk)

A. Risk Description

Post evaluation of R&M works is essential to understand the impact/effectiveness of the program. Such evaluations though largely missing would not only facilitate stakeholder feedback towards the scheme, but also enhance understanding of the ground level barriers, implementation challenges besides facilitating designing of effective R&M programs in future.

This risk arises if the generating company does not undertake ex-post evaluation of the R&M works and fails to incorporate the experience or unable to improve upon the execution of R&M works for its ongoing units. Also, this leads to lack of institutional memory when the staff involved in R&M moves out.

B. Root cause analysis

Undertaking post evaluation of projects is not considered as a standard practice by the generating companies in India.

C. Impact, frequency and severity of risk

The impact of this risk is that the generating companies would be unable to improve upon the execution of R&M projects based on its learning or experiences.

The likelihood of occurrence of this risk is high. Severity of this risk is low and it would also impact future R&M projects of the company.

D. Bearer of risk

Generating company is the direct bearer of the risk.

E. Strategy to manage the risk

Experience gained must be documented and incorporated in subsequent units planned for R&M works (Risk Mitigation)

Generating companies must undertake ex-post evaluation of the R&M works and should document its experiences. This is important especially in cases where multiple units are taken up for R&M. The learning/experiences gained from the first unit must be incorporated in the implementation plan of the subsequent units even if it requires modification in the scope of work of other units.

In addition to the above, dissemination of ex-post evaluation provides experiential learning to other utilities as well, and enables them to design their R&M program effectively. CEA may provide a platform/ methodology for such information sharing between the utilities

Box 25: Absence of post evaluation of R&M works

During interactions with various officials both at the utility headquarters and the plant level, it was observed that most of the utilities do not undertake ex-post evaluation or document their experience of the works.

Source: Interaction of AF Mercados EMI with officials of various utilities.

Chapter 6
Risk Heat Matrix and Management Plan

This chapter presents the risk heat matrix and the risk management plan emerging from the assessment in the preceding chapter.

6.1. Risk Heat Matrix

The risk heat matrix is divided into four tiers wherein:

- **Tier 1:** presents risks which have high likelihood of occurrence and also have high severity. This is the most important Tier as the risks identified in this tier are the most critical once. Highest priority should be accorded for managing these risks else it would be difficult to implement R&M project effectively.

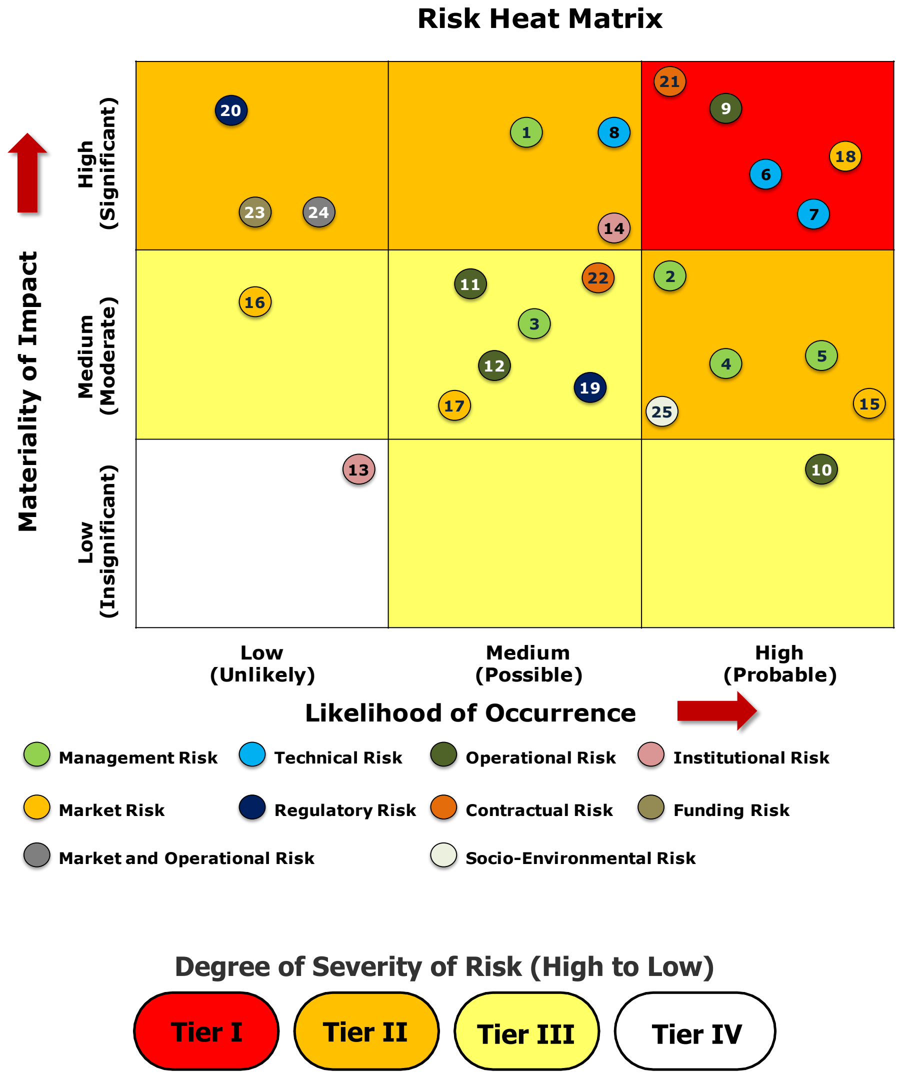
- **Tier2:** presents risks which have high severity with low or moderate likelihood of occurrence. This also includes risks which have high likelihood of occurrence with moderate severity. Tier 2 category risks are second priority risks which also needs to be attended as any change in operating environment can activate these risks towards Tier 1.

- **Tier 3:** presents risks which have moderate severity with low or moderate likelihood of occurrence. This also includes risk with high likelihood of occurrence with low severity.

- **Tier 4:** presents risks which have low severity with low likelihood of occurrence. These risks are of least importance for the project and do not have material impact on the project.

Figure below presents the risk heat matrix for a typical R&M project.

Figure 8: Risk Heat Map for a typical R&M Project



Note: The risk profile will vary from project to project.

S. No	Risk Type	Risk	Code
A	Management Risk	Weak decision-making framework	1
		Reactive approach to identification of plant for R&M	2
		Lack of long term generation plan & awareness of available market options	3
		Implementation contract awarded to vendor involved in carrying out technical studies	4
		Weak analytical framework for selection of R&M options	5
B	Technical Risk	Inadequate technical assessment/studies	6
		Occurrence of technical surprises	7
		Post R&M guarantees not achieved	8
C	Operational Risk	Sustainability of R&M gains affected by weak O&M practices	9
		Absence of ex-post evaluation and feedback loop	10
		Limited capacity of utilities in undertaking R&M	11
		Weak Supervision, Quality Control And Assurance	12
D	Institutional Risk	Delay in obtaining unit shutdown for undertaking technical studies	13
		Delay in provisioning of unit shutdown for executing R&M works	14
E	Market Risk	Lack of confidence and uncertainty with regard to R&M projects	15
		Low level of vendor participation in the bidding process	16
		Higher than expected price discovery	17
		Mismatch/delay in supply of critical equipment and the shutdown period	18
F	Regulatory Risk	Appropriate Commission not apprised of the R&M project plan	19
		Disapproval of costs incurred during R&M	20
G	Contractual Risk	Weakly defined scope of work	21
		Weak dispute resolution mechanism constraining the execution of work	22
H	Funding Risk	Utility unable to mobilize funds	23
I	Market &Operational Risk	Rebidding/Re-award/Delay in award of R&M packages/contract	24
J	Socio-Environment Risk	Failure to Comply with Environmental Standards & Perceived Negative Externalities	25

6.2. Risk Management Plan

Table below summaries the key risk, the category of risk, the bearer, frequency, severity and the strategies proposed to deal with such risk.

Table 12: Risk Management Plan

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
IDENTIFICATION STAGE						
1	Management Risk	Reactive approach to identification of plant for R&M	High	Moderate if symptoms are identified during the initial stages. However, the magnitude of impact increases as the delay increases.	Utility/Plant Owner is the direct bearer. Also, impacts the consumers.	Strengthening of internal data acquisition, monitoring and alert systems to track unit performance and diagnose early warning symptoms. For this input from O&M department is critical and recording of routine data such as material properties, geometries, crack sizing, hardness, operational parameters etc. during operation, annual/ capital maintenance, breakdown maintenance can useful for undertaking RLA in future. (Risk Avoidance)
2	Management Risk	Lack of long term generation plan and awareness of available market options	High	Moderate	Utility/Plant Owner is the direct bearer. Also, impacts the consumers.	The rationale for R&M of a project should be established at the state level taking into account all the alternative competing options. The decision should involve multiple stakeholders including the Discoms (Risk Avoidance)
3	Market Risk	Lack of confidence and	Moderate to high.	Depends on case to case basis,	Entire R&M market	A. Need for Experience Sharing and Dissemination (Risk Mitigation)

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
		uncertainty with regard to R&M projects		may range from low to moderate	including potential generating companies, equipment suppliers, design consultants etc.	B. Need to Develop Market for R&M in the Country by communicating the overall market size and address concerns of various stakeholders (Risk Avoidance)
ASSESSMENT STAGE						
4	Institutional Risk	Delay in obtaining unit shut down for undertaking technical studies	Low to high depending upon the number of units requiring simultaneous shutdown	Low	Generating company	A. Advance Planning for Scheduling of Technical Studies so as to either coincide the timing with the annual/capital overhaul or provide advance notice to the discom for such shutdown (Risk Avoidance) B. Additional Allocation of Power to States from Unallocated Quota of Central Pool for carrying out the RLA studies, Condition Assessment and Steam Path Audit (Risk Avoidance)
5	Technical Risk	Inadequate technical assessment/studies	High	High	Impacts all the parties including generating company,	Comprehensive Studies for the unit planned for R&M should be mandatory. The scope of the study should cover both the Main Plant Equipment as well as the Balance of Plant. The assessment should cover review of O&M processes as well. Proxy

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
					supplier(s) and the Implementation Support Consultant (if applicable).	assessment i.e. in case of multiple units undergoing R&M, studies are conducted only for one of the units and scope for all units is prepared on the basis of the same, should be avoided. In this regard CEA has prepared standard documents for carrying out RLA/CA/EA studies which may be used by the utilities. (Risk Avoidance)
6	Management Risk	Weak analytical framework for selection of R&M options	High	Moderate	Consumers	Comprehensive Identification and Assessment of Options including computation of financial returns, payback period, shutdown time required and conformance to the set objectives.(Risk Avoidance)
7	Regulatory Risk	Appropriate Commission not apprised of the R&M project plan	Moderate	Moderate	Utility	Practice of obtaining in-principle approval from the Appropriate Commission should be encouraged.(Risk Avoidance)
8	Operational Risk	Limited capacity of utilities in undertaking R&M works	High	Moderate	Utility and Vendors	Creation of dedicated R&M Cell by the utility at the headquarter and the plant level. The nominated officials should be exposed to the current practices and must be trained on R&M aspects through specialist entities. (Risk Avoidance) Engaging Specialised Consultants especially design and implementation support consultants. (Risk Avoidance) Avoidance of transfer of personnel involved in R&M

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
						Project in the middle of R&M work
9	Contractual Risk	Weakly defined scope of work	High	Moderate to high	Utility and Vendor	Scope of Work to be as precise and comprehensive as possible including roles and responsibilities of each entity involved in the contract. General statements should be avoided. The scope of work should be built on the comprehensive studies conducted and strengthened by root cause analysis. (Risk Mitigation) Based on above study, appropriate run- repair-replace decisions with back up information to be given. Special attentions to components operating in creep / fatigue regime for residual life assessment.
10	Funding Risk	Utility unable to mobilise funds	Low to moderate	High	Utility is the direct bearer. Also impacts the suppliers. In the long run, this risk has repercussions on the entire R&M market.	Increased proliferation of innovative financing approaches /models coupled with creation of awareness about benefits of R&M through pilot studies to be taken up. Alongside, the assessment of R&M should involve robust analysis of alternative approaches, cost benefit analysis and computation of financial returns. Suitable mechanism needs to be worked out for responsibility assigning in event of shortfall/ non achievement of required operational parameters and financial returns and recovery of investment. (Risk Mitigation)

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
PLANNING STAGE						
11	Market Risk	Low level of participation by the vendors in the bidding process	Low	Moderate	Utility is the direct bearer. Also impacts the potential vendors.	Focussed efforts should be taken up to involve potential players in the R&M market by the utilities and the CEA.(Risk Mitigation)
12	Market Risk	Higher than expected price discovery	Moderate, with increase in participation the likelihood may be low	Moderate to high	Utility and Vendor	The contracts should aim at balancing the risk and benefits between the utility and the implementation vendor. The price is an outcome of inherent risks in the contract. Adequate flexibilities in the contract to be provided to accommodate reasonable/acceptable changes. The utility should re-evaluate R&M scope and make necessary modification considering proposed changes.(Risk Mitigation)
13	Market and Operational Risk	Rebidding/Re-award/Delay in award of R&M packages/contract	Moderate to high	High	Utility and Vendor	A. Rebidding should ideally be avoided through robust project preparation, however in cases where it still emerges as the only option, potential bidders should be encouraged to assess the current plant condition and assume the responsibility of the task.(Risk Acceptance) B. Management should undertake timely decision for award of contract by formulating qualification requirements and evaluation procedures along with appropriate timelines before seeking interest from the vendor. (Risk

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
						Avoidance)
14	Management Risk	Implementation contract awarded to vendor involved in carrying out technical studies	High	Moderate	Utility	To avoid conflict of interest, a single entity should generally be avoided to assume both the role of design consultant as well as the supplier. (Risk Avoidance)
EXECUTION STAGE						
15	Management Risk	Weak decision-making framework	Moderate	High	Affects all the parties including the utility, supplier and the implementation support consultant.	Creation of clearly defined decision making and reporting structures with nominated officials authorized to undertake decisions related to R&M (Risk Mitigation)
16	Technical Risk	Occurrence of technical surprises	High	High	Utility and Vendor	A. Undertaking comprehensive assessment through technical studies with clearly defined scope of work (Risk Mitigation) B. Creation of technical surprise plan including unit rates for specific items, contingency fund allocation to deal with exigencies. (Risk

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
						acceptance) C. Establishing a clear decision making framework.(Risk Mitigation)
17	Contractual Risk	Weak dispute resolution mechanism constraining the execution of work	Moderate	High	Utility and Vendor	Creation of Dispute Resolution Committee at the start of project to address disputes between the Utility and the Contractor in a timely manner (Risk Mitigation)
18	Market Risk	Mismatch (or delay) in supply of critical equipment and the shutdown period	High	High	Utility and Vendor	A. Availability of key components should be ensured before the start of the project and should be in accordance with the pre-defined plan finalized before the commencement of work.(Risk Mitigation) B. Provision of Penalties for delay in completion of work. (Risk Sharing/Transfer) C. Sequential delivery of materials to the R&M site (Risk Mitigation)
19	Operational Risk	Weak Supervision, Quality Control And Assurance	Moderate	Moderate	Utility	Approval of detailed quality plans and Engaging Quality Control and Quality Assurance Consultants by the Utility. (Risk Mitigation)
20	Socio-	Failure to	High	Moderate	Generating	A. Renovation of ESP system of the power

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
	Environmental Risk	comply with environmental standards and perceived negative externalities			company and supplier	plant. (Risk Mitigation) B. Periodic environment audit of power plant (Risk Mitigation) C. Timely renewal of "consent to operate" from statutory authorities as per prevailing requirements. (Risk Mitigation) D. Undertaking socio-environment impact assessment to assess the impact of the project. (Risk Mitigation)
21	Institutional Risk	Delay in provisioning of obtaining unit shut down for executing R&M works	Low to high depending upon the number of units requiring simultaneous shutdown	Low to high depending upon the delay in obtaining the approvals for shutdown.	Utility and Vendor	A. Advance Planning for Scheduling of Shutdown for Execution of Works (Risk Avoidance) B. Additional Allocation of Power to States from Unallocated Quota of Central Pool (Risk Avoidance) C. Implementation of partial R&M activities during Annual shutdown periods. (Risk Avoidance)
CLOSURE STAGE						
22	Operational Risk	Sustainability of R&M gains	High	High	Generating Company	Preparation and implementation of O&M action plan by preparing O&M manuals including preventive, capital and breakdown maintenance procedure / guidelines for units undergoing R&M. This should be adopted through a Board Resolution and followed thereafter. (Risk Mitigation)

S. No	Category of Risk	Risk	Frequency of Occurrence	Severity of Impact	Bearer of the risk	Strategy to Manage the Risk
						Engaging specialised agency for O&M of the plant, post R&M. (Risk Mitigation) After sale services to be made an integral part of the contract (Risk Mitigation)
23	Technical Risk	Post R&M guarantees not achieved	Moderate	High	Generating company and supplier	Rectification/replacement of components to meet guaranteed parameters at no extra financial cost to utility. (Risk Mitigation) Levy of Liquidated Damages for shortfall in performance. (Risk Mitigation)
24	Regulatory Risk	Disapproval of costs incurred during R&M	Low	High	Generating Company	Involvement of Regulator should be ensured from the inception of the project with regular updates about the progress of the project. (Risk Avoidance)
25	Operational Risk	Absence of ex-post evaluation and feedback loop	High	Low	Generating company	Experience gained must be documented and incorporated in subsequent units planned for R&M works. CEA may provide a platform/ methodology for such information sharing between the utilities (Risk Mitigation)

A holistic assessment of the risks has been made (in the earlier chapter) by identifying risks occurring in different stages of R&M cycle i.e. in identification, assessment, planning, execution and closure stage and by understanding the impact of the risk, its frequency of occurrence, its severity and the bearer of the risk.

It is essential that the identified risks in these guidelines are evaluated by each generating company before implementing R&M projects and appropriate strategies are formulated in line with these suggested in these guidelines to manage the identified/evaluated risks.

Chapter - 7
Framework for Early Identification and Addressal of Technical Surprises

A thermal power plant undergoing R&M, despite undertaking prior plant assessment through Residual Life Assessment (RLA), Condition Assessment (CA), Energy Audit (EA) and Performance Evaluation Test (PET) of units; might face unforeseen events after the unit has been shut down and opened up for R&M. Such unforeseen events are defined as Technical Surprises. As the units are generally very old or nearing the useful life of operation, such technical surprises are quite common. The utility due to such surprises is faced with unexpected change in scope or unforeseen additions in the finalised scope of work leading to unexpected cost escalation which may not be incorporated in the final approved budget.

Occurrence of technical surprises can have adverse impact on scope, schedule, cost and quality of R&M projects. Therefore, it is important to devise strategies for the early identification of technical surprises to address them at its nascent stage. In addition, it is equally important to develop a framework that provides the utility, the ability to manage the surprises that are difficult to obviate, as and when they occur during the course of R&M project. The aim of this chapter is to describe the framework for the assessment of technical surprises in R&M projects and ways to address them effectively.

7.1. Elements of Technical Surprises

In order to effectively handle the potential surprises that may be encountered in R&M projects, it is important to understand the type of technical surprise, root causes or factors leading such surprises and its severity or impact on the plant/project time/schedule and cost. Each of these elements is explained below:

7.1.1. Type of Technical Surprises

Potential surprises have been identified for each of the key components of the plant system. Component wise identification of technical surprise enables effective planning and management of these surprises by the utilities.

7.1.2. Root Cause Analysis

This step involves identifying the root causes of occurrence of technical surprises during the course of the R&M life cycle. The practice of root cause analysis is based on the belief that problems are best solved by attempting to address, correct or eliminate root causes, as opposed to merely addressing the immediately obvious symptoms. By directing corrective measures at root causes, it is likely that problem recurrence will be prevented.

7.1.3. Impact of Technical Surprises

Once the potential surprises and its root causes are identified, it is important to understand the impact of these surprises on scope, cost, schedule and quality of R&M project. This will enable the utilities in assessing the impact of technical surprise as one of the elements while undertaking cost-benefit analysis and preparation of budgets for execution of R&M projects.

7.2. Strategies for Addressing the Technical Surprises

In order to address technical surprises, different actions/strategies need to be undertaken/ executed during different stages of R&M process cycle i.e. from the identification stage/start of R&M project until the closure stage/end of R&M project. These strategies/actions for addressing technical surprises can be categorised into the following categories:

7.2.1. Preventive Strategies

This involves undertaking actions/strategies by the utilities that either aim at reducing or eliminating the likelihood of the occurrence of such surprises. Preventive actions in general should be preferred as they aim to address the issue when the magnitude of the problem is controllable.

7.2.2. Managing Surprises

This is essential because it is seldom possible to eliminate all the surprises and the utilities are bound to face certain surprises. The only possible way is to identify potential surprises, accept it and create provisions to minimise its impact.

In order to effectively handle the surprises combination of the strategies mentioned above need to be adopted.

Chapter - 8
Identification of Technical Surprises along with its Root Cause and Impact

This chapter provides a description of potential surprises that may be encountered during implementation of R&M of thermal power plants. Alongside, it also describes the root causes and impact of such surprises based on the framework presented in the preceding chapter.

8.1. Type of Technical Surprises

Different type of surprises encountered for various systems and/or subsystems of the power plant have been briefly presented in table below (refer Table 17 for further details). The visits to select power plants, interactions with the officials of the generation utility, and consultation with sector experts has been the basis of development of the following table.

Table 13: Technical Surprises encountered during R&M Intervention

S No.	Plant System	Areas of Potential Surprises
Boilers and Auxiliaries		
1	Boiler Tubes	Boiler tube failure is quite common in thermal plants; the quantity requirement may change due to the time lag between the assessment and execution of R&M works. This may result into additional requirement of boiler tubes than those listed in the contract.
2	Wind Box	In case of replacement of the wind box chamber, the size of the new chamber may change. In such cases, problems may be encountered in fitment of new chamber.
3	Furnace	In the interim period between RLA study and actual R&M execution, bulge in the furnace may occur due to minor explosion resulting in increased vulnerability of furnace to failure. Additionally, problem in buck stay system may be overlooked during the time of technical studies.
4	Boiler Drum	Leakages in manhole, handhole gaskets and in safety valves may be overlooked during the studies. This impacts the overall boiler efficiency.
5	Super Heater	In R&M, to increase the efficiency and to improve the performance of boiler, the coils of the Super Heater needs to be replaced. Additionally problem and assessment of Superheater safety valves may be overlooked during the time of technical studies.

S No.	Plant System	Areas of Potential Surprises
		While preparing scope of work exact requirement for replacement of coils for Low Temperature Super Heater (LTSH) and Platen Super Heater may not be clearly specified by the utility. During the designing stage, aspects related to shape, gauge, material and size of the new coil fabrication may be overlooked.
6	Reheaters	a) Deterioration of coils and sagging of assembly due to constant high temperature and pressure, developed during the time gap between RLA study and commencement of R&M works. b) Specific details of coil replacement for reheaters may not be clearly mentioned in the scope of works. In addition, condition assessment of reheater safety valves is normally overlooked.
7	Economiser	In case of replacement of economizer tubes, size shape and gauge of tubes may differ from those installed initially, resulting in problem of fitment.[11]
8	Superheater and Reheater Safety Valves	There may be cracks in the seat and spindle of the safety valves which may be overlooked during the studies
9	Air Pre-heater	Due to high corrosive nature of boiler flue gases, there is corrosion in the Air Pre-heater which leads to loss of effective support of the plates in the basket and bents in tubes. Diagnosis of the actual condition may be overlooked during technical studies.
10	Soot Blowers	Diagnosis of condition of the soot blowers is often ignored during the scope assessment and finalization stage. In case of replacement, space constraints may be encountered which may not have been assessed at the time of placing of the order.
11	Fuel Oil / Oil Firing System	Pipe rerouting for Heavy Furnace Oil (HFO) and Light Diesel Oil (LDO) Pump may be required which may be overlooked during the assessment.
12	F.D. Fan	Improper assessment of the foundation and capacity of Forced Draft Fans in case of increase in the size of the boiler furnace. Further, there can be damages in the coupling and

[11] This problem is non-existent when one to one replacement of the entire economizer is taken up.

S No.	Plant System	Areas of Potential Surprises
		impeller assembly and blades of the fans during the interim period between RLA studies and R&M execution.
13	I.D. Fan	a) Over the years, many leakages develop in the system and the utility instead of analyzing the root cause of the leakages, generally decides to increase the size/capacity of I. D. Fan which may not be the requisite solution. b) Surprises related to shaft cracks due to excessive stress and damages in coupling assembly may be observed if it is not properly diagnosed during the studies. Further, there may be deterioration of ID Fan during the interim time period between the studies and execution of R&M works.
14	P.A. Fan	a) If the utility decides to increase the boiler capacity, the required new rating for the new P.A Fans may not be assessed by the utility. b) Further, typically the Primary Air Fan faces damages in shaft, coupling assembly and in the impeller which sometimes is overlooked during the plant assessment.
15	Scanner Fan	In case of complete replacement of Scanner fans compatibility issues may be observed.
16	Electrostatic Precipitator	Electrostatic Precipitator is an integral part of coal fired thermal plants to control particulate emissions and with increasingly stringent norms for emission, renovation and modernization of ESP is an important part of the scope of work. Some of the technical surprises observed are: a) Space constraint for installing additional ESP may not be considered at the time of designing of the project, b) Unavailability of spares due to technological obsolescence,
17	Mill and Burner	a) In case of increase in capacity of the boiler, the revised size required for the mill and burner may be overlooked. b) Due to improper assessment of long term calorific value of coal, the size of mill and burner planned for installation may be inadequate. c) Possible technical surprises can arise due to improper assessment of calorific value of coal which has deteriorated over the years the unit was in operation.

S No.	Plant System	Areas of Potential Surprises
		d) Improper Condition Assessment /Performance Evaluation Test along with time gap between the studies and actual execution.
	Turbine & Auxiliaries	
18	Steam Turbine	In Steam Turbine, potential technical surprises observed are given below: - Cracks in rotors and discs, - Corrosion and fatigue of blades and pitting - Technological obsolescence of spare parts especially in case of turbine valves, - Failure on part of vendor to up-rate turbine efficiency due to improper design and - Lack of timely decision by the utility with regard to finalization of turbine design
19	Condenser	a) Further weakening of condenser performance due to deterioration of tubes, leakages and insufficient heat transfer during the large time gap between RLA studies and actual R&M implementation. b) Non-availability of condenser spare parts due to technological obsolescence. c) Non-specification of exact number of coils to be replaced in the scope of work.
20	Circulating Water Pump	Circulating Water Pump (CWP) faces damages in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Lack of capacity assessment of CWP in case utility decides to increase the capacity of the plant, may lead to technical surprise at later stages as the old CWP may not be able to circulate the water throughout the system efficiently.
21	Low Pressure Heaters	There can be space constraint in case of installation of new one and compatibility issues in case of new spares.
22	High Pressure Heaters	There can be mismatch of the outlet and inlet flanges and the new HP heater may not fit to the existing heater space later during R&M execution. HP Heater extraction Non Return Valve (NRV) is also normally ignored by the utility which may create problem later on.

S No.	Plant System	Areas of Potential Surprises
23	Boiler Feed Pump (BFP)	BFP is the interface with the Feedwater system, the Deaerator, and the steam condensate return system. Improper design of BFP can have cascading effect if the utility decides to go for up-rating of the unit and do not assess the capacity and ability to provide feed water to boiler drum at the required temperature and pressure. Moreover detailed requirements of its spares may not be assessed leading to additional requirement during execution.
24	Drip Booster Pump (DBP)	Usually DBP suffers problems in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Moreover proper size, capacity and its compatibility with the existing connected system like valves and piping system may be overlooked.
25	Condensate Extraction Pump (CEP)	CEP suffers problems in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Moreover proper size, capacity and its compatibility with the existing connected system like valves and piping system may be overlooked.
Balance Of Plant (BoP)		
26	Coal Handing Plant	Possible technical surprises which the utility might face are: a) Replacement of few hammers may be mentioned in the scope of work but during execution more units may need to be replaced. b) Replacements of few crushers may be mentioned in the scope of work but during execution entire unit may need to be replaced. c) Weak foundation strength of coal crushers d) Usually the building structure and pressure house is in dilapidated condition and is not part of scope. e) Increase in size of marshalling yard for accommodating additional Wagon Tippler is given in DPR but space constraints may not be considered. f) Inadequate assessment of coal bunkers supporting structure strength g) The scope may be for replacement of few

S No.	Plant System	Areas of Potential Surprises
		rollers and idlers of conveyer belt however later additional replacements may be required during execution. h) Replacement of metal detectors and magnetic separators are usually not part of RLA studies and may need replacement during R&M execution. i) Further there can be more deterioration during the interim period after RLA studies.
27	Compressed Air System	a) Lack of proper assessment of the compressed air system. b) Additional installation of auxiliary pipes may be required.
28	Cooling Water System	While planning for installing new higher capacity Cooling Water Pump, compatibility of associated components may not be taken into account due to which pump cannot be operated at rated capacity.
29	Control And Instrumentations System	Significant technological advancement is observed in case of C & I. Most of the utility therefore prefers to undertake complete replacement of C&I system and hence may not face any significant technical surprises. In case entire system is not replaced, there may be reliability and compatibility issues of the new system with the old one.
30	Ash Handling Plant	Ash Hopper over time develops cracks in supporting columns and in some cases there are bents in balancing bolt which the utility may overlook during studies. Further, there may be space constraints for installation of new Ash Hopper which may be overlooked.
Civil Work		
31	Civil works	Proper evaluation of the foundations of all major equipments like boiler, turbine, ESPs etc. is sometimes overlooked which may lead to technical surprises during the execution.
		Site accessibility and space constraint are important factors for delay of R&M works which are generally not considered before the start of the project. Lack of planning with regard to the movement of crane at the start leads to the occurrence of technical surprises and delay in execution of work.

S No.	Plant System	Areas of Potential Surprises
Electrical System		
32	Generator	Technical surprise arises due to lack of design documents and information of the sub-vendor with regard to generator and its auxiliaries.
33	Stator	Damages in the generator stator may be observed during the execution stage which may get overlooked at the time of studies or may develop during the interim period between RLA studies and execution.
34	Rotor and Excitation System	There can be cracks in overhang portion of the rotor which might be overlooked during RLA studies or may develop during the interim period between RLA studies and execution.
35	Transformers (Generator Transformer, Unit Auxiliary Transformer, Station Transformer, HT and LT Transformer)	Insulation strength of paper (Furfural Test) of transformer is normally not conducted in RLA studies and there may be possibilities of flashovers. Another possibility of technical surprise is that connections from bus duct to transformer may be damaged which may be overlooked during assessment.
36	Motors (HT and LT Motors)	Technical surprise may arise due to improper assessment with regard to compatibility of HT/LT motors with the up-rated system.
37	Cables (HT and LT Cables)	In most cases the old cables are usually replaced with new ones. Cable tray fowling with the existing structure may need rerouting during execution. Although the scope may include replacement of paper insulated cable and some PVC cables having multiple joints with XLPE cables but exact requirement (in kms) may not be provided.
38	UPS, Battery and Battery Charger	Scope of UPS, battery and battery chargers may not be clearly defined. During the plant assessment the condition of battery and battery charger can be found to be operating properly but due to time lag between studies and actual R&M execution, the deterioration may set in.
39	Plant illumination	Energy efficiency opportunities in illumination system of the plant (i.e. replacement of bulbs with CFL, LEDs etc.) may not be assessed.

In addition to the above, there are other equipments/components where technical surprises may occur (Refer Table below) and it is suggested that the utilities should also assess the condition of these equipments to avoid technical surprises based on the framework provided in this guidelines[12].

Table 14: Other components/equipments for potential technical surprises

Boiler Island	Turbine Island	Balance of Plant	Electrical Systems
- Super Heater Attemperator - Safety Valves - Expansion Bellows - Fuel oil / Oil Firing System	- Vacuum Pump - Low Pressure Heaters - Deaerator - Gland Steam Coolers - LP Dozing Pump - Turbine Governing System and valves - Shaft Turning Gear/Barring Gear - Coolers (Hydrogen Coolers, Seal Oil Coolers, Lubricating Oil Coolers) - Oil Pumps (Oil pumps include jacking, starting, seal, DC) - Steam Jet Ejectors - Pressure Reducing and De-superheating System (PRDS)	- Air Conditioning System - Fuel Oil System - Water Treatment Plant - Demineralisation Plant - Control and Instrumentations System	- Switchyard

8.2. Root Cause Analysis for Occurrence of Technical Surprises

Technical surprises occur due to the following:-

a) **Weak data monitoring, reporting and maintenance procedures at the unit level**

Most of the utilities do not maintain data related to key performance parameters of the unit, reliability of the unit and its individual components etc. Even if such data is maintained, it is done at the plant level only and not for all the unit level. Due to the lack of historical data it becomes difficult to understand the exact condition of the unit and this acts as one of the primary reasons for occurrence of technical surprises (arising due to lack of information

[12]No major technical surprises were observed for these equipments/components during the visits to select power plants, interactions and consultation held with the officials of the generation utilities and sector experts.

for any third party invited for R&M of the unit). Lack of overhauling records with the utility is another related aspect. Due to the lack of such records suppliers are unable to comprehensively understand the exact condition of various equipments i.e. components that were replaced during the operating life of the plant, replacement time and history and remaining useful life of such equipments.

b) **Unavailability of original design drawings with the utilities**
Absence of design drawings with the utilities makes it difficult for both the utility and suppliers to undertake R&M and leads to technical surprises at the execution stage. Additionally, it also makes it difficult for the equipment suppliers especially non-OEMs to effectively assess the requirements of the plant as the equipments/components to be supplied have to fit the existing/old plant system averaging around 25-40 years of operation. For example, after 25-30 years of operation of boiler and number of start-ups, the hangers and supports may become jammed and non-operative. The original drawing/design parameters of these hangers and supports are not available with the utility which makes it difficult for the vendor to re-engineer and design the hangers and supports as the supplier may not know the loading and the expansion range of the hangers.

c) **Inadequate Assessment**
RLA and other tests are conducted for main plant and equipments only whereas in case of rest of areas like Balance of Plant (BoP) the scope is generally derived, without any actual condition assessment for BoP items. Lack of planning/assessment of BoP was found to be the one of the most common issues faced by the utilities. Lack of well chalked out path for cranes to reach the sites, space constraints etc. are some of the important issues generally overlooked during the planning stages.

Further, proxy assessment is undertaken in case of multiple units. It is sometimes assumed that since both units are operating under same condition, assessment of one of the units would suffice the purpose and thus scope of work is prepared for both the units based on such limited assessment. This although results in saving of time and cost for the utility in the initial stages, leads to occurrence of technical surprises at the later stages due to non-exhaustive scope of work.

d) **Weak/inadequate Scope of Work**
Inadequate/weak scope of work is also one of the factors leading to technical surprises. This is primarily due to inadequate assessment/technical studies wherein the exact requirement for R&M is not established. Another reason for weak/inadequate scope

of work is the financial constraints of the utility. In order to keep the financial budget under control, the utility may not include certain important works as part of R&M exercise and plans to cover that under O&M head at the later stage. However, this may lead to compatibility issue of old system with the new one leading to surprises at later stages or may impact the overall quality of works. For example: In case of R&M works of Obra TPS, some of the motors were replaced whereas the rest were refurbished by re-winding it and by renewing the insulators. However, the refurbished motors may not be able to provide rated output and there are chances that it may not be able to perform in sync with the new system. Obra TPS also increased the capacity of ID fans for the plant to operate at 216 MW but the motor was not changed and only rewinding was undertaken. Due to lack of funds, UPRVUNL didn't include it in the scope of work although all heavy HT motors and continuous running motors which have no standby should have been changed with new one with higher capacity.

e) **Huge time lag between the technical studies (RLA, DPR preparation) and actual award of contract (and commencement of R&M work**)
This entire process normally takes ~3-4 years. The units identified for R&M in the interim period get low maintenance priority leading to rapid deterioration in the plant condition not captured in the studies and the scope of work leading to surprises at the execution stage. In case of units that are already shutdown, cannibalization of the material/spares to other unit has also been observed as a common practice.

Table 15: 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
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	January 2005	February 2012

Source: CEA Quarterly Review Reports on R&M and LE of Thermal Power Stations and interaction of AF- Mercados EMI with various utilities

f) **Mismatch in plant shutdown period and supply of critical equipments**

The schedule of supply of critical equipment has to be synchronized with the shutdown period to ensure completion of work in the minimum possible time. However, this mismatch can be on account of both suppliers and utility. There could be a delay in supply of key components and equipments by the supplier on account of absence of original vendors for such items; non-availability of original equipment details, specifications etc.; obsolete design and inadequate information available about modification done/spares used earlier. This leads to delay in supply of material on a timely basis. Further, due to energy shortages in the state and the prevailing grid conditions, utility may not be able to provide for timely shutdown of the plant. Larger the mismatch or gap higher are the chances of occurrence of technical surprises.

g) **Technological Obsolescence**

Refurbishment of old equipment or spares may not be possible due to technological obsolescence. This is true especially in case of old units of 110/120 MW units wherein the manufacturers have stopped manufacturing the spares (especially electrical) due to technological obsolescence.

h) **Genuine uncertainty in R&M**

Even with careful planning and implementation, some unforeseen situations are likely to arise. Most of the units being very old and functioning beyond their operating life coupled with poor O&M practices of the utility, it is common to find few technical surprises which cannot be anticipated at early stages. Also, with careful assessment and undertaking of studies some gaps in condition assessment of the plant/unit may remain leading to technical surprises at later stage. For e.g. in case of RLA study of the critical piping system, the NDT (Non-destructive Test) are done at few selected location of pipes and not on the overall length of the critical piping system. Such studies do not reflect the true status of the component as RLA is undertaken at specific points and those points may not have any problem whereas during execution certain other parts of piping may turn up as technical surprise which may lead to change in scope of work during R&M execution stage. However, with expected procedure and norms, such surprises can be minimized.

Also in most cases, the strategy to deal with such surprises is not planned leading to distress for utilities.

8.3. Impact of Occurrence of Technical Surprises

The impact of the occurrence of technical surprises is as follows:

a) **Scope Creep**

The primary impact of occurrence of technical surprises is the additional scope of work which needs to be addressed by the supplier. This additional scope of work leads to cost escalation, time delay and sometimes contractual disputes between the utility and suppliers. The effectiveness with which utility decides the fair allocation of additional work to the supplier, minimises the contractual dispute and time taken by the supplier in delivering to this additional work are the key factors which govern the magnitude of the impact of the scope creep due to technical surprises. It has been observed that in most of the cases suppliers are being made solely responsible for addressing these surprises within the given/capped contract value/amount without being adequately compensated. A balanced arrangement is likely to go a long way in contributing towards success of R&M market.

b) **Cost Escalation**

Any additional work discovered in the form of surprise has a cost associated with it. This could be both direct as well as indirect. Direct costs include the cost of additional work and increase in IDC cost of the utility. Indirect cost include the loss in potential generation and hence revenue of the utility due to additional time required to address these surprises. Lack of ownership/active participation by the utility in acknowledging such additional work and deciding an acceptable course of action are key issues faced during implementing R&M. Both suppliers and utility are bearers of this risk. While the loss of supplier is limited to the cost of addressing the surprise, utility suffers/bears a large proportion of the cost in form of both direct as well as significant indirect cost caused due to loss in potential generation. Moreover utility might also face regulatory risk wherein recovery of these costs may not be allowed by the state electricity regulatory commission while determining generation tariffs.

c) **Non-adherence to the project schedule timelines**

Another related impact of technical surprise is the delay in the project schedule due to additional time required to address the technical surprise. The reasons for delay from the project schedule includes the following: a) situation of indecisiveness, b) non-availability of slots for repair, testing at various production/manufacturing units of the supplier, c) non-existence of original vendors for such items, d) customized manufacturing of a particular component/spare due to obsolete design, e) practical time required in transportation of material for repair from the utility place to the workshop of the supplier and back at the utility place etc. All these factors may have adverse impact on the utility revenues as it can lead to months of shutdown of the unit.

d) **Quality Deviation**

Technical surprise may also impact the quality of R&M works and non-achievement of overall R&M benefits. One of the most concurring technical surprises seen is non-availability of spares or incompatibility of older system with the new system envisaged in R&M project. Due to such surprises, the expected outcome of the scope cannot be met and the utility has to look for other alternatives which affect the quality of the system. This situation arises due to improper assessment of the relationship and interaction between different components/equipments in a thermal plant. Further, to minimise the delays/shutdown period certain non-priority items are not given due importance during the R&M process which may affect the overall quality of work.

e) **Contractual Dispute**

Disagreement between supplier and utility regarding additional scope on account of technical surprise and incomplete interfacing between components and instruments may lead to contractual dispute causing delay or slow execution of the work. This dispute also arises from the fact that in most of the contracts, scope of work is vague and to safeguard its interest utilities generally include clauses such as:

"Any item essentially required for system completion and commissioning of the units shall be treated as included in the scope of work without any extra cost on this account"

Such clauses although included in the contract, give rise to contractual disputes at later stages which may not be in the best interest of the R&M project.

Chapter - 9
Strategies for Early Identification of Technical Surprises and Ways of Addressing Them

Occurrence of technical surprises is an important element/component of the R&M project and un-preparedness or absence of strategies to handle these surprises could derail the entire objectives/outcome of R&M project. For early identification of technical surprises and to minimise its impact on the project, planning/actions/ strategies to handle such surprises needs to be initiated right from the inception/start of the R&M project.

A multipronged strategy is required to be undertaken covering different stages of R&M process cycle. These strategies could be further classified depending upon the nature of the impact of these strategies. While preventive strategies aim to minimise occurrence of technical surprises, strategies for managing surprises aims to minimise its impact on the project in case of its occurrence. These are presented in detail below.

9.1. Identification Stage

The identification stage includes execution of preventive strategies by the utility to handle technical surprises. This includes strengthening of O&M practices in the plant and strengthening of internal data maintenance, acquisition and reporting in the plant. These are explained below:

9.1.1. Strengthening of O&M practices in the plant (Preventive)

Development of preventive maintenance manuals and adherence to the annual maintenance/overhaul schedule and timely/periodic capital overhaul schedule are pre-requisite for preventing occurrence of technical surprises during R&M of the project. By undertaking regular O&M, utility is constantly updated about the actual condition of the plant and wear and tear of different components of the plant is addressed on regular intervals minimising the probability of occurrence of technical surprises.

9.1.2. Strengthening of internal data maintenance, acquisition and reporting in the plant (Preventive)

Internal data maintenance includes regular monitoring and data collection of key operating and performance parameters such as heat rate, specific coal and oil consumption, auxiliary consumption at the unit level (besides the station level). Compilation and analysis of historical data enables accurate identification of gaps; important for resolution of problems. Therefore, it is required that utility should undertake the following steps:-

a) The utilities must properly maintain documents related to Operating Procedures, Manuals, Technical Handbooks and Instructions supplied by Original Equipment Manufacturers

(OEMs).

b) Documentation of key engineering diagrams/drawings and other critical plant diagrams in centralised technical library in both hard and soft format. This is one of the most critical requirements for designing the components/equipments that are to be replaced and made compatible with the existing system.

c) Operation Engineers should maintain day to day parameter data of the units and generate monthly performance report.

d) Overhaul records (as stated above) along with complete details of repair/replacement of plant equipments/components.

In most of the utilities majority of the above mentioned data is not compiled/maintained in a usable format or is unavailable. It is important that plants/units that are expected to undertake R&M in near future should try to start compiling and collecting the above mentioned data to the extent possible. Also, for the recently commissioned units, it is important that utility should implement above suggestions in its day to day operation of the unit so that such problem does not arise in future.

The above mentioned strategies coupled with good management practices play an important role in minimising the surprises. The availability of good quality information also enables the suppliers to acclimatise themselves to the plant conditions in a better manner and hence permit proper design, specifications and estimation of bills of quantities of the required equipments within the project schedule time period.

Further, compilation of data mentioned above (especially performance data) is also important from the viewpoint of estimation and monetization of GHG emissions reduction through implementation of energy efficient R&M.

9.2. Assessment Stage

The assessment stage includes execution of both preventive strategies and strategies for dealing with surprises. Preventive strategies include comprehensive assessment and clearly defined scope of work. Strategies related to dealing with technical surprises include development of technical surprise plan and dispute resolution mechanism, establishing a clear decision making framework and providing for contingency fund. These are explained below:-

9.2.1. Undertaking comprehensive assessment through technical studies with clearly defined scope of work (Preventive)

Effective assessment at the start of the project is the key to minimising technical surprises. The nature and occurrence of technical surprises depend upon the depth with which technical studies are undertaken. In order to minimize technical surprises, the foremost step is to undertake comprehensive assessment of both main plant equipment and the BoPs through technical studies for each unit planned for R&M. In this regard, CEA has prepared standard documents for carrying out RLA/CA/EA studies which may be used by the utilities.

Based on the technical studies, efforts should be made to define the scope as clear as possible along with the roles and responsibilities of each of the stakeholder. This includes clarity in the scope with regard to the following:-

a) **What needs to be done:** The specification should clearly define the R&M requirements and desired outputs on the basis of the plant assessment
b) **Who will do what:** The division of work, roles and responsibilities of the utility and the contractor/vendor must be clearly specified along with the timelines
c) **When should it be done:** The utility must specify the schedule and duration of shutdown of the unit along with the sequential delivery of various equipments

9.2.2. Creation of Technical Surprise Plan (Managing Surprises)

A well-defined technical surprise plan should be prepared for effectively handling technical surprises, as and when they occur[13]. The design consultant involved in undertaking comprehensive assessment, DPR and subsequent scope of work should also prepare a technical surprise plan. This is required as replacement/repair of some components may come up at the time of execution as everything cannot be analysed / tested during the studies. This should be prepared in consultation with the plant level officials involved in operation, repair and maintenance of the plant to understand the potential surprises as they have the experience of the actual condition of the plant. This includes a list of possible surprises, ensuring availability of spare parts to minimize delays, addressing upfront the likely contractual aspects of additional supplies and works etc.

Further, this should also include the unit rates for equipment/parts and total financial implications of the same. In this regard CEA has prepared standard documents for Detailed Project Report which may be used by the utilities.

9.2.3. Creation of Dispute Resolution Mechanism (Managing Surprises)

Due to the occurrence of technical surprise there may be disagreement between the utility and vendor on certain aspects which may translate into disputes and affect overall execution of work. Therefore, in order to resolve disputes between the contractor, sub-contractor and utility, it is important to

[13]The first aim in all earnest should be to minimize the occurrence of technical surprises.

create a Dispute Resolution Mechanism. Under this mechanism a Dispute Resolution Committee (DRC) should be formed at the start of the project with fair participation from both utility and contractor. The institutional set up, powers and roles along with the time schedule (within which case can be referred from the occurrence of the dispute, hearing of the dispute and the final decision) of the DRC should be specified in the tender document itself. Any dispute which cannot be amicably settled between the parties can be referred to the DRC. However, until the dispute is resolved, the contractor should proceed with the work and contract in discussion with the utility and implementation support consultant.

In this regard CEA has prepared standard bid documents which may be used by the utilities.

9.2.4. Creation of dedicated R&M Cell and Engaging Specialized Consultants (Preventive)

In order to effectively deliver a successful R&M project, the following steps are required:

a) **Creation of dedicated R&M cell by the utility at the headquarter and at the plant**

In order to effectively deliver on the R&M project it is important to create a separate R&M cell with adequate and dedicated manpower for the project. This team should involve plant level officials dealing with the different departments like Boiler, Turbine, Electrical, C&I, CHP, Milling system and AHP etc. Further, officials having prior R&M experience should also be included in the team.

To ensure timely decisions and approvals within the organization it is important that a dedicated R&M cell should also be formed at the headquarters level.

b) **Engaging of design and implementation support consultants**

Specialized agencies should be engaged by the utility (on the basis of competitive bidding) covering assistance on all works from design to implementation. This could be either one agency or multiple agencies.

The role of design consultants is to assist the utility in tasks related to conduct of different studies, identification and selection of best feasible option for R&M, preparation of DPR including technical surprise plan, scope finalization, preparation of tender documents, bid evaluation and selection of vendor etc.

The role of implementation consultant includes review and approval of drawings, coordination between the vendors and the utility, monitoring the progress of work as per approved schedule, assistance to Owner in dealing with statutory authorities such as

Boiler Inspectorate Directorate, Pollution Control Board etc, monitoring of day to day progress of the work, review of PG Test Report etc.

Further, to build the requisite capacity of the utility officials, scope of work of consultants should also include training of utility/R&M cell officials on each of these components/fields.

9.2.5. Establishing a Clear Decision Making Framework (Managing Surprises)

Once the technical surprises occur, the indecisiveness of the utility can result in significant delay in the execution of work. It is important to specify the decision making process with clearly defined roles and responsibilities, and requisite authority of different officials to enable timely resolution of the issues encountered during the R&M. This includes internal reporting structures and decision making authority for its timely addressal.

9.2.6. Pre-approved Contingency Fund (Managing Surprises)

As discussed earlier, occurrence of technical surprises has a direct impact on the cost of the project. Lack of funds or approval of additional funds at a later/advanced stage of execution may become difficult for the utility. Further, it might happen that the unaccounted cost of such surprises may even change/impact the entire cost-benefit analysis of the selected R&M option. Therefore, it is required that some contingency fund may be provided for handling technical surprises and must be incorporated in the final budget of the project.

Based on the interaction with utilities and other stakeholders including suppliers and technical consultants this fund can be capped around 5%-10% of the total project cost. There is no specific percentage that can be prescribed as contingency budget as this would depend upon the plant specific condition such as level of preparedness of the utility through detailed studies, timely execution of project etc.

Provision of contingency fund provides sufficient flexibility to the utilities to undertake activities not envisaged earlier (surprises) and copes with the surprises, as and when they occur.

Further, such pre-approved budget also reduces regulatory risk of the utility at the closure stage.

9.2.7. In principle approval from the Regulatory Commission for additional capital requirement for handling Technical Surprises (Managing Surprises)

Appropriate regulatory commission should be apprised well in advance about the technical surprise plan and contingency fund for provisioning of additional costs for dealing with surprises. It is thus suggested that the technical surprise plan and contingency fund be incorporated in the Detailed

Project Report (DPR).

9.3. Planning Stage

The planning stage includes execution of both preventive strategies and strategies for managing surprises. Preventive strategies include minimising time gap between assessment and award of contract and preparation of interim O&M action plan (O&M plan during the time gap between RLA study and commencement of R&M) by the utilities and provision for self studies by the suppliers before bidding for the projects. Managing strategies include unit price contract for certain items in the bidding document and submission of action plan by the utilities for addressing technical surprises. These are explained below:-

9.3.1. Minimizing time gap between assessment and award of contract and preparation of interim O&M action plan by the utilities (Preventive)

One of the major reasons for occurrence of technical surprises is the time gap between the assessment and the actual execution of the project. After undertaking assessment of the plant and preparation of DPR, utility has to undergo several approval procedures including approval from its own Board of Directors, State Government (due to the requirement of equity capital), regulatory commission etc. which may lead to significant lapse in time. Weak contracting capabilities of the utilities may further add to the time delay.

Thus, it is required that specialised design and implementation support agencies or consultants must be engaged by the utilities for assisting in undertaking detailed assessment, preparation of DPR, selection of R&M option and later seeking approvals from various authorities. While, this may minimise the time gap to an extent, still some time gap is expected to lapse between the assessment and actual execution of work by the selected vendor. Therefore, it is suggested that an interim O&M action plan must be prepared by the utility which identifies the urgent requirements or actions that must be undertaken by the utility during this interim time period. This would minimise the chances of occurrence of technical surprises at the execution stage. Further, disclosure/sharing of such plan with the potential suppliers would reduce the risk and thereby risk premium by suppliers which is ultimately reflected in the price of the contract.

9.3.2. Provision for access of potential suppliers to the site (Preventive)

Access to the site should be provided to the bidders for carrying out due diligence. The access to the site may be provided by the utility either at the pre-bid stage or before the submission of financial bid by the supplier. This is important as this would enable the suppliers to acclimatise to the actual condition of the plant and enable them to bid accordingly. The access to the plant site along with providing results of past studies undertaken by the utilities would not only minimise surprises but would also lead to more realistic price discovery for the utility.

9.3.3. Bid documents should seek unit price of various components (Managing Surprises)

In the bid documents the utility should seek unit rates for such components/works which are expected or anticipated based on the prepared technical surprise plan. This is important as additional spares/components may be required beyond those specified in the scope at the execution stage. Further, upfront specification of additional requirements provides sufficient flexibility in the contract to the utility for handling the additional requirements during R&M of the plant. This would also ensure quick decision making as no new contracting is to be undertaken for the additional supplies.

9.3.4. Understanding supplier strategy to deal with Technical Surprise as an important evaluation criteria (Managing Surprises)

At the tendering stage, suppliers must be asked to provide their understanding of potential surprises based on their past experience, results of the plant studies provided by the utility, their own assessment and the potential technical surprise plan prepared by the utility. Any additional requirement may disrupt the overall production schedule of the supplier and it may be difficult for the utility to make available slots for manufacture, repair or testing of components at manufacturing/service centre/workshop of the supplier leading to further delay. Therefore, it is important to understand the suppliers plan for handling surprises.

Submission of strategy for dealing with the technical surprises by the suppliers would provide some certainty and commitment to the utility of ability of the supplier to deal with anticipated surprises.

9.4. Execution Stage

Actual technical surprises are observed at the time of opening up of the machine for R&M. In order to minimise the impact of technical surprises it is important to timely identify and report technical surprises to the relevant decision making authorities. This is explained in detail below:-

9.4.1. Timely identification and reporting of surprises (Managing Surprises)

In order to timely identify surprises, it is important that robust communication and periodic review of R&M project be undertaken by the utility. An indicative communication and review matrix is given below:-

Table 16: Communication and Review Matrix

Communication Type	Objective of Communication	Medium	Frequency	Participants
R&M Cell Meetings	Review status of the project with the R&M Cell.	Face to Face	Daily/Weekly	R&M Cell-Plant Level officials, implementation support consultants

Communication Type	Objective of Communication	Medium	Frequency	Participants
				along with the suppliers
Technical Meetings	Discussion over the technical issues / surprises for the project.	Face to Face	Weekly	R&M Cell-Plant Level officials, implementation support consultants along with the senior officials of suppliers
Project Status Reports	Report the status of the project including activities, progress, costs and issues, key action points.	Email	Weekly	R&M plant cell to Headquarter (HQ) Cell and subsequently to higher authorities
Monthly/Quarterly Project Status Meetings	Report on the status of the project to management. Approval/decision on key issues	Face to Face	Monthly/Quarterly	Board of Directors 3.4. R&M HQ Cell

9.5. Closure stage

The occurrence of technical surprises has an adverse impact on the overall cost of the project. It is therefore important for the utility to obtain approval from the regulatory commission to capitalise the additional cost of the project in order to safeguard its financial interest.

9.5.1. Submission of details to the Regulatory Commission detailing out the occurrence of technical surprises and strategies adopted to minimise the impact (Managing Surprises)

Utility should undertake a detailed mapping of the potential surprises envisaged at the start of the project, technical surprises actually encountered along with reasons for its occurrence and the mitigation steps undertaken by the utility. This is important as it would enable the utility to justify to the regulatory commission that the cost incurred was in the best interest of the project and the additional expenditure was beyond the control of the utility.

9.5.2. Ex-Post evaluation of surprises and lessons learnt for future R&M projects (Managing Surprises)

Ex-post evaluation of surprises encountered during execution of R&M works and the actions undertaken is essential to understand the impact/effectiveness of the entire plan. Generating company must undertake ex-post evaluation of the R&M works and should document its experiences. This is important especially in case company is undertaking R&M works on multiple units. The learning/experiences gained from the first unit must be incorporated in the implementation plan of the subsequent units even if it requires modification in the scope of work of other units. CEA may provide a methodology/standard template for ex-post evaluation. Further, the learning from different projects should be disseminated through a common platform such as the CEA official website. The CEA may initiate action in this regard.

The following table provides in detail the areas of potential surprises in various components of plant system along with examples and key strategies to address them.

Table 17: Areas of potential surprises in various components of plant system along with examples and key strategies to address them

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
Boilers and Auxiliaries			
1	Boiler Tubes	Boiler tube failure is quite common in thermal plants; the quantity requirement may change due to the time lag between the assessment and execution of R&M works. This may result into additional requirement of boiler tubes than those listed in the contract.	a) The time gap between identification of scope of replacement and execution should be minimized, so that the degradation of retained components is not considerable from the original assessment. Also the plant should be maintained as per regular O&M till the R&M is taken up. b) The bid document and contract should provide for additional requirement of boiler tubes on the basis of unit price.
2	Wind Box	In case of replacement of the wind box chamber, the size of the new chamber may change. In such cases, problems may be encountered in fitment of new chamber. **For Example:** Guru Nanak Dev Thermal Plant (GNDTP) in Punjab faced a similar issue of space constraint during the installation of new Wind Box.	During the designing/engineering stage and before sourcing / manufacturing of new wind box chamber, availability of space should be considered as an important element by the vendor.
3	Furnace	In the interim period between RLA study and	a) Efforts should be made to reduce the

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		actual R&M execution, bulge in the furnace may occur due to minor explosion resulting in increased vulnerability of furnace to failure. Additionally, problem in buck stay system may be overlooked during the time of technical studies.	time gap between studies and execution of work. b) Proper assessment of buck stay system should be undertaken and the bid document and contract should provide for additional requirement of buck stays on the basis of unit price.
4	Boiler Drum	Leakages in manhole, handhole gaskets and in safety valves may be overlooked during the studies. This impacts the overall boiler efficiency.	Proper assessment of boiler drum, its gaskets and safety valves should be undertaken
5	Super Heater	In R&M, to increase the efficiency and to improve the performance of boiler, the coils of the Super Heater needs to be replaced. Additionally problem and assessment of Superheater safety valves may be overlooked during the time of technical studies. While preparing scope of work exact requirement for replacement of coils for Low Temperature Super Heater (LTSH) and Platen Super Heater may not be clearly specified by the utility. During the designing stage, aspects related to shape, gauge,	a) Specific details with regard to the replacement of coils for Low Temperature Super Heater (LTSH) and Platen Super Heater should be provided by the utility. Further, superheater safety valves should be assessed properly during the Assessment Stage. b) Scope of work should be based on the comprehensive assessment of the unit and all critical requirements should be included in the scope/specifications. Deviation in

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		material and size of the new coil fabrication may be overlooked. **For Example:** a) In case of R&M works of Kanti Bijlee Utpadan Nigam Limited (KBUNL) in Bihar, only 50% coil replacement in Super Heater was provided in the work order. This was done to reduce cost. Further, replacement of LTSH supply tubes was not included in the work order. This led to confusion between the contractor and the utility with regard to supply of these tubes. b) In case of R&M works of Unit 6 and 7 of Barauni TPS in Bihar, proxy assessment was undertaken to prepare scope of work (scope of work of Unit-6 was extended to Unit-7). During R&M execution, Platen Super Heater Outlet Header was not found in good condition for the unit on which studies were not undertaken and complete replacement was suggested by the vendor. This led to deviation from the original scope of work.	preparation of scope to reduce the cost (often witnessed during the tender negotiation stage) in case of critical equipments should not be encouraged as this may lead to increased cost at later stages impacting the entire cost-benefit analysis of the selected R&M option. c) Material technology has improved significantly over the years leading to better efficiency. During the engineering and designing stage, such improvements should be considered. These may be expensive initially, however better efficiencies and lower running cost may ensure better recovery in the long-run (over the plant life). d) Comprehensive assessment should be undertaken for each of the unit planned for R&M works. Proxy assessment should be avoided.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
6	Reheaters	Deterioration of coils and sagging of assembly due to constant high temperature and pressure, developed during the time gap between RLA study and commencement of R&M works. Specific details of coil replacement for reheaters may not be clearly mentioned in the scope of works. In addition, condition assessment of reheater safety valves is normally overlooked.	a) Specific details should be provided in the scope of work. b) Efforts should be made to reduce the time gap between studies and execution of work. c) Also, in case of additional work, contingency fund should be provisioned for and utilized.
7	Economiser	In case of replacement of economizer tubes, size shape and gauge of tubes may differ from those installed initially, resulting in problem of fitment.[14]	During the design and engineering stage this issue should be considered by the vendor and incorporated in the scope itself.
8	Superheater and Reheater Safety Valves	There may be cracks in the seat and spindle of the safety valves which may be overlooked during the studies	Proper assessment of safety valves in Superheater and Reheater should be undertaken
9	Air Pre-heater	Due to high corrosive nature of boiler flue gases, there is corrosion in the Air Pre-heater which leads to loss of effective support of the plates in the basket and bents in tubes. Diagnosis of the actual condition	a) Tubular Air Pre-Heaters should be replaced with rotary regenerative Air Pre-heaters depending on the availability of the space. This should be assessed during engineering and

[14]This problem is non-existent when one to one replacement of the entire economizer is taken up.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		may be overlooked during technical studies.	designing stage by the suppliers. b) Grating on which baskets are placed and the baskets of the Air Pre-heater should be changed. Drive units should be inspected before R&M execution. c) Sealing system of the Air Pre-heater should be completely replaced. Double seal may also be installed to improve the efficiency. d) Support bearing of the air pre-heater must be supplied in the beginning as it is the first item to be erected for the boiler duct portion.
10	Soot Blowers	Diagnosis of condition of the soot blowers is often ignored during the scope assessment and finalization stage. In case of replacement, space constraints may be encountered which may not have been assessed at the time of placing of the order.	a) While deciding on the type and design of the new soot blowers, the effectiveness and performances of the blowers along with its positioning in the boiler system must be assessed. b) In case Smart Soot Blowers are being installed, extra care to be taken for proper installation of sensors to detect slag formation on waterwalls.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
11	Fuel Oil / Oil Firing System	Pipe rerouting for Heavy Furnace Oil (HFO) and Light Diesel Oil (LDO) Pump may be required which may be overlooked during the assessment.	This issue should be addressed during the planning stage by the utility.
12	F.D. Fan	Improper assessment of the foundation and capacity of Forced Draft Fans in case of increase in the size of the boiler furnace. Further, there can be damages in the coupling and impeller assembly and blades of the fans during the interim period between RLA studies and R&M execution.	a) Proper assessment of the capacity and foundation of the F. D. Fan for upgraded boiler furnace in the planning stage is very important. b) Condition Assessment of fan along with lube oil system and cooling water system is necessary to assess the physical condition/ damages/erosion/corrosion, deformation, etc of components (like coupling, control devices/dampers, stator parts, bearing assembly, shaft assembly, impeller assembly, etc) by visual/NDT examination at site for replacement or salvaging. c) Performance Evaluation Test may be done considering maximum achievable capacity (MW) of the boiler before R&M. d) Efforts should be made to reduce the time gap between studies and

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
			execution of work.
13	I.D. Fan	a) Over the years, many leakages develop in the system and the utility instead of analyzing the root cause of the leakages, generally decides to increase the size/capacity of I. D. Fan which may not be the requisite solution. b) Surprises related to shaft cracks due to excessive stress and damages in coupling assembly may be observed if it is not properly diagnosed during the studies. Further, there may be deterioration of ID Fan during the interim time period between the studies and execution of R&M works.	a) Proper assessment of the capacity and foundation of the I. D. Fan for upgraded boiler furnace in the planning stage is very important. b) Condition Assessment of fan along with lube oil system and cooling water system is necessary to assess the physical condition/ damages/erosion/corrosion, deformation, etc of components (like coupling, control devices/dampers, stator parts, bearing assembly, shaft assembly, impeller assembly, etc) by visual/NDT examination at site for replacement or salvaging. c) Performance Evaluation Test may be done considering maximum achievable capacity (MW) of the boiler before R&M. d) The root cause analysis of the leakages should be thoroughly assessed as increasing the size of the same increases the auxiliary consumption. Efforts should be made

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
			to reduce the time gap between studies and execution of work.
14	P.A. Fan	If the utility decides to increase the boiler capacity, the required new rating for the new P.A Fans may not be assessed by the utility. Further, typically the Primary Air Fan faces damages in shaft, coupling assembly and in the impeller which sometimes is overlooked during the plant assessment.	a) Proper assessment of the capacity and foundation of the P. A. Fan for upgraded boiler furnace in the planning stage is very important. b) Condition Assessment of fan along with lube oil system and cooling water system is necessary to assess the physical condition/ damages/erosion/corrosion, deformation, etc of components (like coupling, control devices/dampers, stator parts, bearing assembly, shaft assembly, impeller assembly, etc) by visual/NDT examination at site for replacement or salvaging. c) Performance Evaluation Test may be done considering maximum achievable capacity (MW) of the boiler before R&M. d) Efforts should be made to reduce the time gap between studies and execution of work.
15	Scanner Fan	In case of complete replacement of Scanner	During the design and engineering stage

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		fans compatibility issues may be observed. **For Example:** In case of R&M works in GNDTP in Punjab, the contractor faced difficulty in installing new scanner fans due to its new size and had to reposition it later with few modifications.	this issue should be considered by the vendor.
16	Electrostatic Precipitator	Electrostatic Precipitator is an integral part of coal fired thermal plants to control particulate emissions and with increasingly stringent norms for emission, renovation and modernization of ESP is an important part of the scope of work. Some of the technical surprises observed are: a) Space constraint for installing additional ESP may not be considered at the time of designing of the project, b) Unavailability of spares due to technological obsolescence,	a) Earlier, ESP efficiency used to be around 95% and the environmental norms were relatively less stringent. In the present scenario, the efficiency of ESP is around 99% and the environmental norms have also become stringent. The utility should properly assess the ESP requirements otherwise it may face issues from the Pollution Control Board[15]. This is critical as going forward the norms are likely to witness further tightening.

[15] Central Pollution Control Board (CPCB)Standards for Particulate Matter Emissions for Thermal Power Station are as follows-

- Generation capacity 210 MW or more- 150 milligrams per normal cubic metre
- Generation capacity less than 210 MW- 350 milligrams per normal cubic metre

However, it is advised that the utility should also check the standards of their respective state pollution control boards.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		For Example: a) In case of R&M of KBUNL in Bihar, to curtail cost, complete replacement of internal components of ESP was not included in DPR and work order. But during execution it was found that requirement of ESP internals and Rapping Gear boxes were more than what was ordered in the main package. Earlier ESP control panels were Double Front type which are now obsolete and are being replaced with Single Front panel. In case of R&M works of KBUNL, initially replacement of old Double Front type with Single Front type ESP control panels was envisaged but after its delivery, it was found that it cannot be accommodated due to space constraints. So it was decided to again order Double Front panel. b) In case of R&M works of GNDTP in Punjab increase in number of ESP fields were not envisaged initially. However, during execution it was decided to increase the number of fields for better control of	b) To avoid space constraint while installing new ESP fields, the utility should plan this properly, assessing the space requirement upfront. c) Interaction with the O&M department should be undertaken during the planning stage with regard to the availability of spares in the market and accordingly scope of work should be prepared.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		pollutants. This lead to deviation from original scope of work.	
17	Mill and Burner	a) In case of increase in capacity of the boiler, the revised size required for the mill and burner may be overlooked. b) Due to improper assessment of long term calorific value of coal, the size of mill and burner planned for installation may be inadequate. c) Possible technical surprises can arise due to improper assessment of calorific value of coal which has deteriorated over the years the unit was in operation. d) Improper Condition Assessment /Performance Evaluation Test along with time gap between the studies and actual execution.	a) Proper assessment of the required size of mill and burner should be undertaken during the technical studies, especially when the utility plans to increase the capacity of the boiler. b) The Calorific Value of coal has degraded over the years and hence to meet the rating of the boiler, more coal has to be fed. This will also increase in the capacity of the mill and burner system. Therefore, the utility may clearly mention in the scope of work about the range of variation in quality of coal and long term availability of type/quality of coal to be received so that adequate size of mill and burner may be provided by the vendor. c) Efforts should be made to reduce the time gap between studies and execution of work.
Turbine & Auxiliaries			

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
18	Steam Turbine	In Steam Turbine, potential technical surprises observed are given below: - Cracks in rotors and discs, - Corrosion and fatigue of blades and pitting - Technological obsolescence of spare parts especially in case of turbine valves, - Failure on part of vendor to up-rate turbine efficiency due to improper design and - Lack of timely decision by the utility with regard to finalization of turbine design **For Example:** - In case of R&M works of Obra TPS in Uttar Pradesh, vendor was unable to upgrade Unit 9 to 216 MW from 200 MW. Due to high axial shift, the machine load couldn't be raised beyond 180 MW. One of the reasons for this is the improper design of the turbine. Also, after significant delay in decision, utility decided to retain the original turbine design for other units undergoing	a) During preparation of scope, the utility must undertake the following i. Proper engineering and designing of turbine and its auxiliaries. ii. Specification of detailed requirements for turbine and its auxiliaries including spares. iii. Unit price contract for additional requirement must be undertaken by the utility during the bidding stage to avoid any contractual issue at later stages. iv. Also, in case of additional work, contingency fund may be utilized. v. When multiple units are undertaken for R&M, the learning obtained from one unit must be incorporated in other units even if that requires change in scope.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		R&M. Due to this it is expected that there would be significant delay in overall R&M of other units. - In case of R&M of KBUNL in Bihar, as per the work order all valves were to be refurbished but the total requirement of spares for refurbishment valves was not known. When the valves were opened, it was found that many spares would be required which were not part of scope of work. Most of the valves were obsolete and no longer manufactured by supplier/sub vendors. Therefore, those valves had to be replaced with new ones.	
19	Condenser	a) Further weakening of condenser performance due to deterioration of tubes, leakages and insufficient heat transfer during the large time gap between RLA studies and actual R&M implementation. b) Non-availability of condenser spare parts due to technological obsolescence. c) Non-specification of exact number of coils to be replaced in the scope of work. **For Example:** During R&M works of Obra	a) The utility should specify the exact details of replacement of condenser coils after proper assessment. Deterioration of performance/condition post the assessment should be avoided through minimizing time gap between RLA studies and R&M execution. b) The assessment should also include availability of spares and compatibility of the same with the

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		TPS in Uttar Pradesh, non-availability of Condenser spare parts led to complete replacement of condensers by the main contractor.	units installed.
20	Circulating Water Pump	Circulating Water Pump (CWP) faces damages in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Lack of capacity assessment of CWP in case utility decides to increase the capacity of the plant, may lead to technical surprise at later stages as the old CWP may not be able to circulate the water throughout the system efficiently.	Proper engineering and designing during planning stage and finalization of scope to cover CWP in detail. Also, aim should be to minimize the time gap between RLA studies and R&M execution to avoid unrecorded deterioration.
21	Low Pressure Heaters	There can be space constraint in case of installation of new one and compatibility issues in case of new spares. **For Example:** Ukai TPS in Gujarat experienced mismatch of spares of LP heaters due to which the Unit start-up got delayed.	During the designing and engineering stage this issue should be considered by the vendor.
22	High Pressure Heaters	There can be mismatch of the outlet and inlet flanges and the new HP heater may not fit to the existing heater space later during R&M execution. HP Heater extraction Non	Vendors while taking order for new HP heater should assess the compatibility of new flanges with the existing ones.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		Return Valve (NRV) is also normally ignored by the utility which may create problem later on.	
23	Boiler Feed Pump (BFP)	BFP is the interface with the Feedwater system, the Deaerator, and the steam condensate return system. Improper design of BFP can have cascading effect if the utility decides to go for up-rating of the unit and do not assess the capacity and ability to provide feed water to boiler drum at the required temperature and pressure. Moreover detailed requirements of its spares may not be assessed leading to additional requirement during execution. **For Example:** Issue of mismatched spares for BFP cartridge was observed in case of R&M works at Ukai TPS in Gujarat.	a) Proper engineering and designing of Turbine Island. b) In addition, the exact requirement for spares should be provided.
24	Drip Booster Pump (DBP)	Usually DBP suffers problems in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Moreover proper size, capacity and its compatibility with the existing connected system like valves and piping system may be overlooked. **For Example:** In case of R&M works of	It should be ensured that in case new drip booster pump is ordered it should be compatible with the existing connected systems and space available.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		KBUNL in Bihar, DBP could not be installed in the old foundation as the original pump was smaller in size with 7 stages and RPM 3000 whereas the supplied pump was bigger in size with 9 stages and RPM 1480.	
25	Condensate Extraction Pump (CEP)	CEP suffers problems in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Moreover proper size, capacity and its compatibility with the existing connected system like valves and piping system may be overlooked. **For Example:** In case of R&M works of Ukai TPS in Gujarat mismatch in spares for CEP was observed.	It should be ensured that in case new condensate extraction pump is ordered it should be compatible with the existing connected systems and space available.
Balance Of Plant (BoP)			
26	Coal Handing Plant	Possible technical surprises which the utility might face are: a) Replacement of few hammers may be mentioned in the scope of work but during execution more units may need to be replaced. b) Replacements of few crushers may be mentioned in the scope of work but	Comprehensive condition assessment studies for BoP should be undertaken by the utility and the recommendations of the studies should be incorporated in the scope of work. Further, the bidding document should specify the range of variation in quality of coal received by the utility so that the bidders can

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		during execution entire unit may need to be replaced. c) Weak foundation strength of coal crushers d) Usually the building structure and pressure house is in dilapidated condition and is not part of scope. e) Increase in size of marshalling yard for accommodating additional Wagon Tippler is given in DPR but space constraints may not be considered. f) Inadequate assessment of coal bunkers supporting structure strength g) The scope may be for replacement of few rollers and idlers of conveyer belt however later additional replacements may be required during execution. h) Replacement of metal detectors and magnetic separators are usually not part of RLA studies and may need replacement during R&M execution. i) Further there can be more deterioration during the interim period after RLA studies. **For Example:**	accordingly design coal handling plant to suit the boiler, feeder and milling system.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		a) In case of R&M of GNDTP in Punjab, the ducts and coal pipe lines were not thoroughly checked to avoid air ingress and later during execution refurbishment of the ducts and coal pipe was done though originally it was not part of the scope. b) In case of R&M of Barauni TPS in Bihar, scope of work included i) New supplies for one no. railway crossing near fuel oil pump house to enable railway engine/shunter to change the track during wagon placement for unloading and ii) Repair/Overhauling/Replacement of all other components/ systems/ subsystems which are not being supplied new to ensure sustained and safe operation for uninterrupted supply of coal to running units and also to ensure that the loaded railway wagons are released in time. However, during the execution there were contractual issues as some of the high value equipment/ systems related to the railway crossing did not exist or were beyond repairable.	
27	Compressed Air System	a) Lack of proper assessment of the	Comprehensive condition assessment

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		compressed air system. b) Additional installation of auxiliary pipes may be required. **For Example:** In case of R&M works of GNDTP in Punjab, installation of new auxiliary piping for Service Air and Instrument Air were required during execution although this was not envisaged during scope of works.	studies for BoP should be undertaken by the utility and the recommendations of the studies should be incorporated in the scope of work.
28	Cooling Water System	While planning for installing new higher capacity Cooling Water Pump, compatibility of associated components may not be taken into account due to which pump cannot be operated at rated capacity.	During the designing and engineering stage this issue should be considered by the vendor.
29	Control And Instrumentations System	Significant technological advancement is observed in case of C & I. Most of the utility therefore prefers to undertake complete replacement of C&I system and hence may not face any significant technical surprises. In case entire system is not replaced, there may be reliability and compatibility issues of the new system with the old one.	Adequate care need to be taken for selection of C&I equipment/system in respect of compatibility/quality manpower/field-support facilities, etc., to avoid surprises, during R&M.
30	Ash Handling Plant	Ash Hopper over time develops cracks in supporting columns and in some cases there are bents in balancing bolt which the utility	Comprehensive condition assessment studies for BoP should be undertaken by the utility and the recommendations of

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		may overlook during studies. Further, there may be space constraints for installation of new Ash Hopper which may be overlooked.	the studies should be incorporated in the scope of work. Further, the bidding document should specify the range of variation in quality of coal received by the utility so that the bidders can accordingly design ash handling plant to efficiently evacuate the ash from boiler bottom, economizer , air pre-heater hoppers and from ESP
Civil Work			
31	Civil works	Proper evaluation of the foundations of all major equipments like boiler, turbine, ESPs etc. is sometimes overlooked which may lead to technical surprises during the execution. **For Example:** In case of R&M works of PTPS in Haryana, the scope of works had to be changed at the time of execution when it was found that the turbine foundation had sunk and required additional civil work to repair the foundation.	Utility should maintain civil foundation details and proper assessment of the condition of the foundation of all major equipments should be undertaken during the technical studies.
		Site accessibility and space constraint are important factors for delay of R&M works which are generally not considered before the start of the project. Lack of planning with regard to the movement of crane at the start	Site accessibility and movement of crane must be assessed at the planning stage.

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		leads to the occurrence of technical surprises and delay in execution of work. **For Example:** In case of R&M works at Obra TPS in Uttar Pradesh, due to space constraints crane cannot move between the units and therefore R&M works for Unit 10 & 11 were taken together. ESP of unit 11 had to be dismantled so that the crane could move and work on Unit 10 can be undertaken. This was not envisaged at the assessment stage	
Electrical System			
32	Generator	Technical surprise arises due to lack of design documents and information of the sub-vendor with regard to generator and its auxiliaries. **For Example:** In case of R&M works of KBUNL in Bihar contractor was unable to supply Generator seal oil control panel due to the lack of design documents and name of the sub- vendor.	a) Design drawings should be made available to the contractor to the extent possible. b) Efforts should be made to reduce the time gap between studies and execution of work. c) Also, in case of additional work, contingency fund may be utilized.
33	Stator	Damages in the generator stator may be observed during the execution stage which may get overlooked at the time of studies or may develop during the interim period	

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		between RLA studies and execution. **For Example:** In case of R&M works of Ukai TPS in Gujarat, flashover on Unit-1 overhang stator winding coil was observed and therefore six generator stator bars had to be replaced.	
34	Rotor and Excitation System	There can be cracks in overhang portion of the rotor which might be overlooked during RLA studies or may develop during the interim period between RLA studies and execution.	
35	Transformers (Generator Transformer, Unit Auxiliary Transformer, Station Transformer, HT and LT Transformer)	Insulation strength of paper (Furfural Test) of transformer is normally not conducted in RLA studies and there may be possibilities of flashovers. Another possibility of technical surprise is that connections from bus duct to transformer may be damaged which may be overlooked during assessment.	Comprehensive assessment of the unit should be undertaken including that of the transformers.
36	Motors (HT and LT Motors)	Technical surprise may arise due to improper assessment with regard to compatibility of HT/LT motors with the up-rated system. **For Example:** a) In case of R&M works of Obra TPS in	a) Deviation in preparation of scope to reduce the cost in case of critical equipments should not be encouraged as this may lead to increased cost at later stages or non-realization of envisaged benefits from R&M works. b) In case of additional work, contingency

S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		Uttar Pradesh, some of the motors were replaced whereas the rest were refurbished by re-winding it or by renewing the insulators. However the refurbished motors may not be able to provide rated output and there are chances that it may not be able to perform against the new system. . Obra TPS also increased the capacity of ID fans for the plant to operate at 216 MW but the motor was not changed and only rewinding was undertaken. Due to lack of funds, UPRVUNL didn’t include it in the scope of work although all heavy HT motors and continuous running motors which have no standby should have been changed with new one with higher capacity. b) In case of R&M works of Ukai TPS in Gujarat, additional rewinding and re-caging of four HT motors were undertaken which were not part of scope so that the motors can operate at the new required capacity.	fund may be utilized.
37	Cables (HT and LT Cables)	In most cases the old cables are usually replaced with new ones. Cable tray fowling	Unit price contract for additional requirement must be undertaken by the

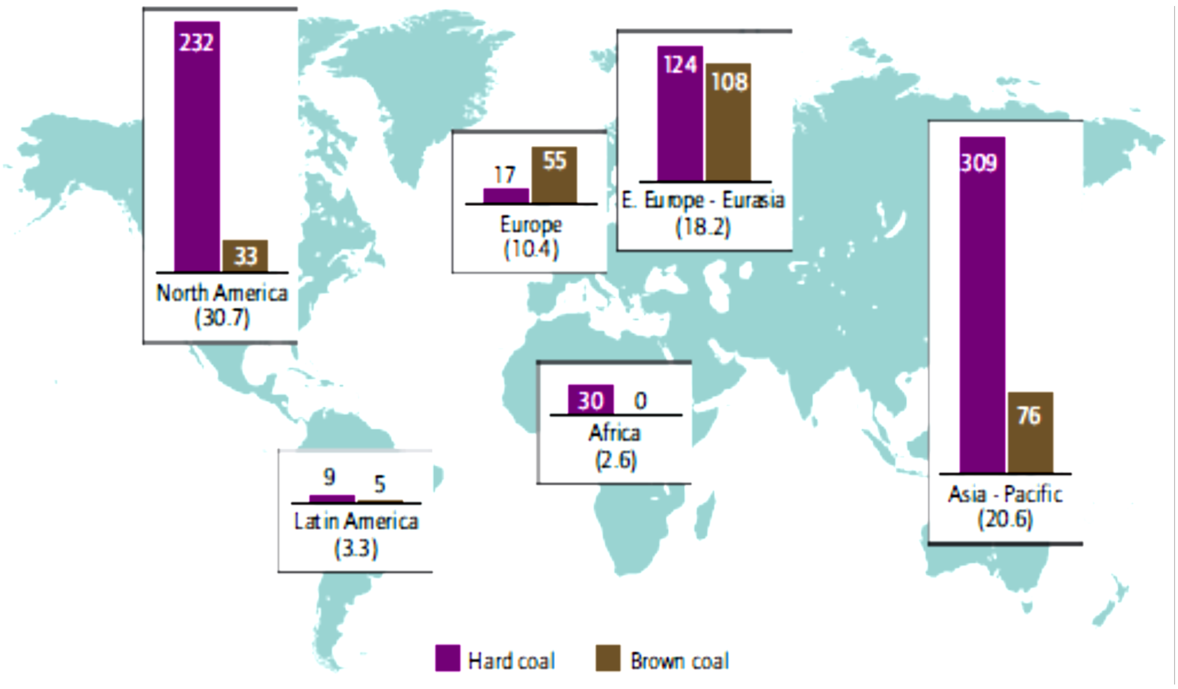
S. No	Plant System	Areas of Potential Surprises	Strategies to handle the Surprises
		with the existing structure may need rerouting during execution. Although the scope may include replacement of paper insulated cable and some PVC cables having multiple joints with XLPE cables but exact requirement (in kms) may not be provided.	utility during the bidding stage to avoid any contractual issue at later stages.
38	UPS, Battery and Battery Charger	Scope of UPS, battery and battery chargers may not be clearly defined. During the plant assessment the condition of battery and battery charger can be found to be operating properly but due to time lag between studies and actual R&M execution, the deterioration may set in.	The utility while preparing the scope of work should take into account the expected time for undertaking entire R&M of the plant and then accordingly should include the scope of UPS, battery and its chargers.
39	Plant illumination	Energy efficiency opportunities in illumination system of the plant (i.e. replacement of bulbs with CFL, LEDs etc) may not be assessed.	Energy Audit of the unit should be undertaken and its recommendation should be implemented while preparing the scope of works.

Chapter - 10
Global R&M Experience: Case Studies from selected countries

10.1. Context of R&M – A World Wide Experience & Perspective

Coal is the most abundantly and dispersedly available fossil fuel in the World, with proven global reserves of nearly 1 trillion tonnes, sufficient for 150 years of generation at current consumption rates (Figure below).

Figure 9: Coal reserves by region and type (end 2009)



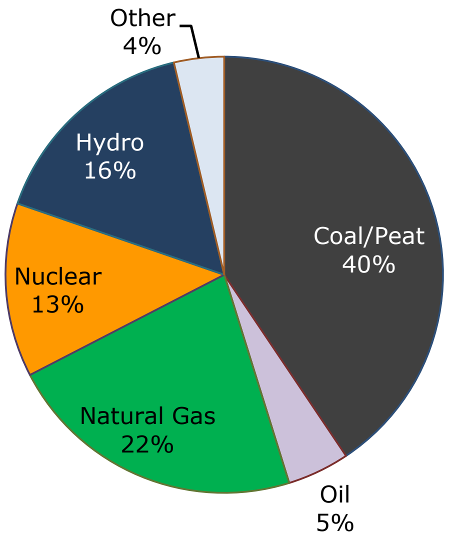
Note: Numbers in parentheses represents the ratio of total coal resources-to-reserves for each region

Coal reserves in gigatonnes (C_t)

Therefore, Coal is World's most widely used fossil fuel for electricity generation. In 2010, coal accounted for more than 40% of total electricity generation in the World, (Refer Figure below) followed by natural gas and hydro. Power generation from fossil fuel accounts for majority of CO_2 emissions. In 2009, generation of electricity and heat contributed to 41% of the World CO_2 emissions from fuel combustion primarily due to its heavy dependence on coal.

Despite increasing environmental concerns, coal is expected to remain one of the major fuels for power generation in the foreseeable future driven by the increasing demand from developing countries to improve electricity access in their respective countries. Given the current and expected dominance of coal in the World energy mix, improvement in the efficiency of coal based generation is of immense importance.

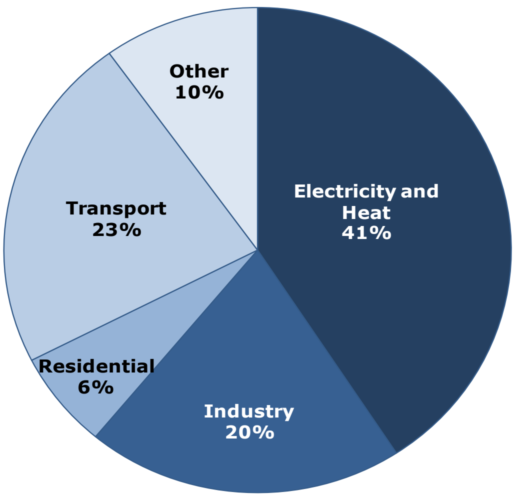
Figure 10: Share of different fuels in total electricity generation worldwide



Notes: Other includes geothermal, solar, wind, bio-fuels and waste, and heat.
Total electricity generated in 2010 is 21 431 TWh. This excludes pumped storage.

Source: IEA 2012 (a)

Figure 11: World CO_2 emissions from fuel combustion by sector in 2009

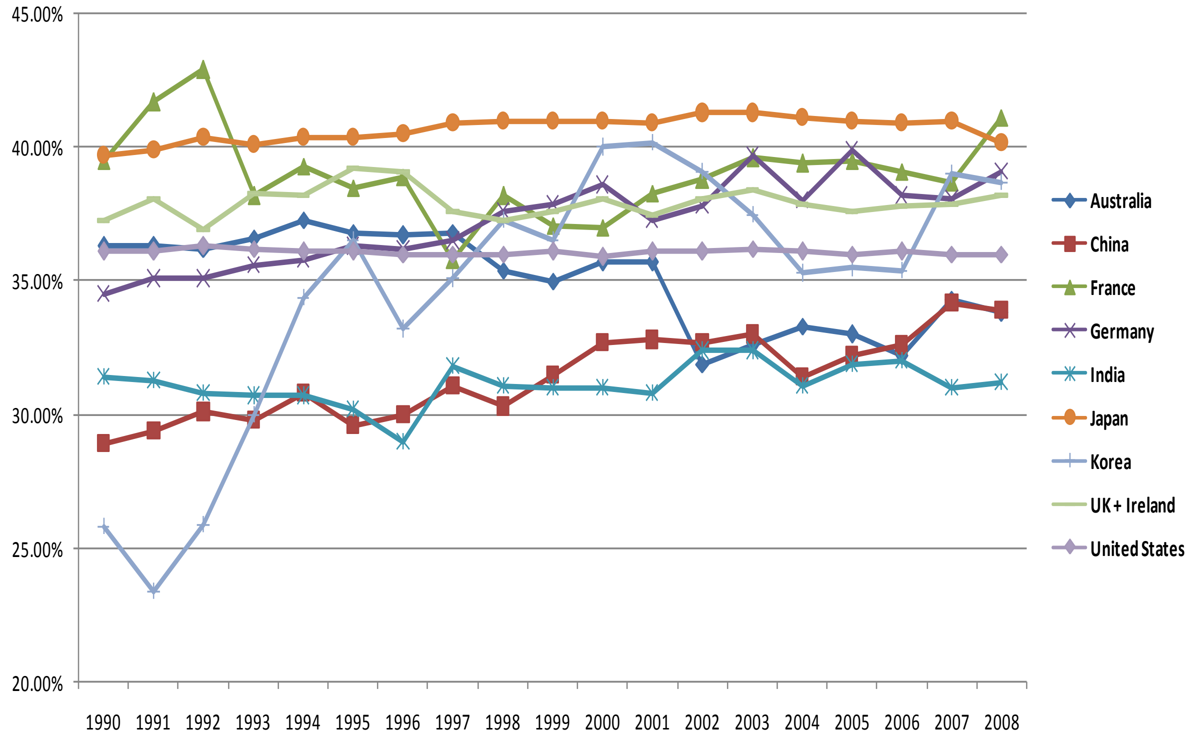


Other includes commercial/public services, agriculture/forestry, fishing, energy industries other than electricity and heat generation and other emissions not specified elsewhere.

Source: IEA 2011

The average efficiency of coal-fired power generation units in the major coal using countries varies enormously. Efficiencies from fossil fuel based power plants for some of the countries are shown below. In 2008, the energy efficiencies for coal-fired power generation ranged from 31% in India to 41% in France.

Figure 12: Efficiency of coal fired power generation in various countries



Source: ECOFYS 2011

Worldwide coal-fired power plant efficiency averaged around 35.1% in 2007 (IEA, and CIAB 2010). These differences arise from diverse factors, including the age of operating plants, technology employed i.e. sub critical, super critical or ultra-supercritical etc., local climatic conditions, coal quality, operating and maintenance skills, and receptiveness to uptake of advanced technologies.

As observed from above, there exists significant scope of improvement in current efficiency of coal based power plants in India either through Renovation and Modernisation (R&M) or by installing new systems based on advanced technologies. Improving the efficiency of coal based generation plants offers several benefits in terms of resource security i.e. reduced consumption of coal; reduction in environmental degradation i.e. reduction in both global CO2 emissions and local pollutants; meeting energy shortages and increased access to electricity.

Although review of literature indicates that R&M is one of the cost effective options to improve the efficiency of thermal power plants, the drivers for undertaking R&M differ across countries. The decision for undergoing R&M depends upon a number of macro and micro level factors such as national level policies, environmental regulations, resource availability, cost effectiveness of competing fuels for power generation, need for increasing the availability and reliability of power plant etc. For e.g., in EU member countries, climate change policy and compliance to environmental standards acts as a major driver for improving efficiency of thermal power plants. In South Africa, power augmentation is a key driver. Similarly, in case of India, power augmentation act as a key driver for refurbishment decisions (although in certain cases environmental considerations also have been the priority).

Given the above background, this chapter presents the international R&M experience of selected thermal power plants in different countries. The case studies have been developed keeping in view the following research questions (consistent with the scope of work and identified risks as part of Task 1 and Task 2 of this assignment):

a) Selection of Unit/Plant for R&M along with objectives of carrying out R&M,
b) Advanced technological options for EE R&M such as turbine up-gradation, efficient and environment friendly furnace-boilers, coal utilization etc.
c) Finalisation of Scope of Work for R&M,
d) Procurement Process for Selection of Consultant/Contractor,
e) Funding of R&M Projects,
f) Cost Benefit Analysis,
g) Implementation of R&M Projects including shut down time,
h) Environmental safeguards,
i) Measures for Guaranteed Performance post R&M.

Based on these experiences, lessons have been drawn for India for the successful implementation of R&M in the country and measures required to mitigate risks and technical surprises faced during the entire R&M process.

10.2. Overview of Power Sector of Different Countries

This chapter presents a brief overview of the power sector of different countries.

Table 18: Overview of Power Sector of different countries

S No.	Country	Brief overview of Power sector of the country
1.	Indonesia	i. Coal dominates the electricity production in the country. As of 2012, the installed capacity of the country was 39193 MW out of which almost 52% of electricity was generated from coal followed by 23% from gas, 15% oil, 6% and 5% from hydro and geothermal resources. ii. Demand has outpaced the supply of electricity leading to power shortages and low electrification rates in the country. In 2011, only around 70 percent of Indonesia's population had access to electricity.

S No.	Country	Brief overview of Power sector of the country
		iii. In 2011, Indonesia became the world's largest exporter of coal by weight. iv. Due to abundant domestic supply of coal, government has been encouraging increased use of coal in the power sector and reducing its dependence on liquid fuels. v. The focus of the government has been to maximize the utilization of low-rank coal (around 4,200 kcal). This policy has some important benefits as low value of the coal enables power generation at a lower cost and leaves higher quality coal for exports leading to maximum usage of coal resources.
2.	Czech Republic	i. In 2011, the installed capacity of the country was 20,250 MW. Electricity is generated largely from domestic coal and nuclear, whereas natural gas is mainly used as complementary fuel in multi fired units and for peaking purposes. Coal accounts for almost 53% of the installed capacity followed by Nuclear at 20%. Hydro including pumped storage and Renewable energy (Wind and Photovoltaic (PV)) each accounts for 11% share while Combined Cycle and gas fired accounts for remaining 6% share. ii. Czech Republic is a net exporter of electricity. Net electricity production in 2011 was 81028 GWh while 17044 GWh was the net export of electricity to other countries accounting for ~21% share. iii. Refurbishment of existing generation capacity through efficiency improvements is an integral aspect of State Energy Policy to attain a self-sufficient and export oriented electricity sector and energy security of the country.
3.	Poland	i. In 2009, total installed capacity was 35.6 GW of which 31.6 GW was coal-fired. The remaining capacity was split between hydropower (2.3 GW), gas (0.9 GW), biomass (0.6 GW), oil (0.5 GW) and wind (0.4 GW). Coal accounts for almost 90% of electricity generation in the country.

S No.	Country	Brief overview of Power sector of the country
		ii. In 2009, Poland was the world's ninth-largest hard coal producer and is the third-largest lignite producer in the EU, after Germany and Greece. iii. Poland has significant experience in rehabilitation of power plants. Power plant rehabilitation and boiler retrofits carried out over the last twenty years have considerably improved the efficiency and environmental performance of the power plants. iv. Two thirds of the installed coal plants are older than 30 years presenting an opportunity for Poland's old power plants to be replaced by newer and significantly more efficient power stations.
4.	Romania	i. Romania has a relatively balanced generation portfolio comprising 36% hydro, 33% coal, 19% Nuclear, and 10% Gas and rest being contributed by renewable energy. ii. In 2010, the gross generation capacity was over 20GW, while the net generation capacity was approximately 17GW (increasing from 16.1GW in 2009), giving Romania the largest generation sector in South- East Europe. iii. In 2010, Romania was a net exporter of electricity.
5.	Turkey	i. In 2009, the installed capacity of the country was ~44782 MW out of which almost 49% of electricity was generated from natural gas followed by 29% from coal, 18% from hydro, 3% from liquid fuels and 1% from wind, geothermal and biogas. ii. Turkey produces both hard coal and lignite. However, it has significant reserves of lignite as compared to hard coal. It produces all the lignite it uses while it imports about 90 per cent of the hard coal it consumes. Further, it is expected that volumes of imported coal may rise in the future with the increase of coal's importance for electricity generation.

S No.	Country	Brief overview of Power sector of the country
		iii. In 2009, Turkey was a net exporter of electricity but on a small scale. Net exports averaged around 1 TWh i.e. ~0.5% of total electricity supply in Turkey. iv. In order to improve the environmental performance of the energy sector Government of Turkey (GOT) identified rehabilitation of existing thermal power plants and retrofitting of FGD units as an important part of its energy strategy.
6.	South Africa	i. Total installed electricity capacity in 2009 was ~43.5 GW. Electricity is mainly generated by thermal sources with coal dominating the installed capacity in the country (~85% of share in the total installed capacity). ii. South Africa has the world's ninth largest recoverable coal reserves and holds 95 percent of Africa's total coal reserves. Additionally, it is the fifth largest coal exporter in the world. iii. South Africa's total electricity consumption has grown by about 20 per cent during 2000-2010 while installed capacity grew at a slower rate of 7 per cent during that same time period leading to significant energy shortages in the country. Country faced severe power crises in 2008 leading to rolling blackouts in the country. iv. In 2009, approximately, 12.5 million people had no access to electricity. Overall electrification stood at 75% with 88% of urban and 55% of rural population having access to electricity in the country. v. In January 2008, the Department of Minerals and Energy and Eskom released a new policy document, “National response to South Africa's electricity shortage” wherein several measures to meet shortages was highlighted including capacity expansion programmes from existing projects.

10.2. Case Study of Suralaya Power Station Unit 1 And 2 (2x400 Mw), Indonesia

1. Plant Details

Suralaya Thermal Power Plant is one of the largest coal fired thermal power station in Indonesia with a total generating capacity of 4025 MW. The plant comprises 8 units of different capacities commissioned between 1983 and 2011. Units 1 to 4 are of 400 MW each, Units 5 to 7 are rated at 600 MW each and Unit 8 is rated at 625 MW.

The plant was constructed in 4 stages with Units 1 and 2 being placed into service in 1983 and 1984. Units 3 and 4 were commissioned in 1989. Units 5 to 7 were placed into service in 1997. The last stage, consisting of Unit 8, was placed into service in 2011.

The Suralaya Plant is owned by Indonesia's government-run utility company, Perusahaan Listrik Negara [PLN].

Unit 1 and 2 have been operated for baseload power since commissioning. Having exceeding their design life, rehabilitation and up gradation works were carried out on the ageing boilers for Unit 1 and 2. The boilers for Units 1 and 2 are 400 MW pulverised coal fired radiant tower types and were originally supplied by Babcock & Wilcox Power Generation Group Inc. and Japan's Marubeni Corporation back in the early 1980s. The first unit outage began in October 2010 and successfully passed all of its performance guarantees in July, 2011. The second unit outage began in July 2011 and successfully completed its performance tests in February 2012.

2. Objectives of R&M (Rehabilitation and Capacity Upgrade Project)

The main objective of this R&M was to upgrade the capacity of these units in order to meet the growing demand for electricity. The specific objectives were as follows:

a) To extend the life of these units
b) To upgrade the capacity of Unit 1 and 2 from 400 MW to 440 MW
c) Reduction in NO_x and CO_2 emissions
d) Restoration of unit efficiency - Use of latest technology including restoration of boiler efficiency i.e. make appropriate and required modifications to allow the boiler to achieve the increased steam output at the increased load condition.
e) Improving operating plant efficiency thereby decreasing the operating and maintenance costs
f) Enable the plant to use wider varieties of Indonesian Coal
g) Improving reliability of other plant equipments
h) Achieve security of supply and increasing electricity demand

3. Project Planning and Assessment

In order to achieve the above objectives RLA (Residual Life Assessment) or Life Cycle Management Process studies were undertaken to assess the condition of the equipments. The life cycle management process comprised of three stages:

a) **Risk Assessment**

Risk assessment on Unit 1 and 2 boilers was undertaken to determine the probability of occurrence of a perilous event. Based on known history, statistical data, judgment by experts, and an evaluation of the consequences and repair or replacement costs of the equipment, PLN/PT Indonesia assessed the potential risks.

b) **Condition assessment**

In order to assess the condition of the boiler and auxiliary equipments following steps were undertaken:

i. Visual inspections and photo summary
ii. Evaluation and testing surveys of various components of the boilers
iii. Mechanical checks, sample collection and laboratory analysis

c) **Life Cycle decisions**

After reviewing the results and the recommendations from the condition assessment step in the life cycle management program and taking into consideration the concerns identified during the risk assessment stage of the process, PLN / PT. Indonesia Power decided that the equipment could be refurbished / rehabilitated more economically than a complete replacement of the boilers and associated equipment. The life cycle of the equipment would also be extended significantly if rehabilitation were performed on Units 1 and 2. Therefore, the utility decided to proceed with the rehabilitation work and capacity upgrade for Suralaya Steam Power Plant Units 1 and 2.

The rehabilitation involved replacement of the existing coal-/oil-fired burners, heat transfer surface of the primary and secondary air heaters, all boiler safety valves with the exception of the cold reheat valves, and the replacement of a significant portion of the convection heating surface.

In addition to the above, evaluation of the original boiler design, original performance data sheets, new turbine heat balances, setting drawings, and the current fuels being used were also undertaken to improve on the conceptual design improvements for the capacity upgrade and rehabilitation of Units 1 and 2.

4. Project Execution

This project was carried out in partnership with Japan's Marubeni Corporation and Babcock & Wilcox Power Generation Group Inc. (B&W) of the US and was funded by the Japan Bank for International Co-operation.

The technological interventions undertaken included the following:

a) **Convection pass pressure part replacement**
Convection heating surface modification was carried out and worn out pressure parts were replaced by modified material to increase operational reliability and to accommodate a capacity increase.

b) **Safety valve replacement**
Safety valves were replaced to accommodate the increased steaming capacity of the boilers.

c) **Air heater refurbishment**
Worn/corroded air heater baskets, seals and some sector plates were replaced. This reduced leakage and lowered the air heater exit gas temperature.

d) **Burner upgrade**
Existing burners were replaced with low NOx burners complete with igniters and flame scanners, which resulted in NOx emissions reduction of 56% for both units combined.

e) **Pulverizer rebuild and upgrade**
Pulverizer rebuild and upgrade was undertaken to increase coal fineness leading to improved combustion, improved overall pulveriser performance and reduced pulveriser power consumption.

Based on the above interventions the comparison of pre and post overall project benefits are provided in Table below:

Table 19: Overall Project References

Parameter	Pre-Retrofit	Post- Retrofit	% Change
Boiler Efficiency	85.51%	86.22%	+0.71%
Fuel Consumption (metric tons/yr)*	27,10,000	26,88,000	-0.81%
Primary, Secondary & ID Fan Power (kW)	30,000	29,000	+3.33%
NO_x Emissions (metric tons/yr)*	15,970	7,080	-56%
CO_2 Emissions(metric tons/yr)*	54,13,000	53,62,000	-0.94%
**NOTE: The values for (metric tons/yr) are for both units combined and are based on a boiler capacity factor of 0.85 and the post-retrofit (increased) boiler output for both the "Pre-Retrofit" and "Post-Retrofit" values.*			

The project was successful and met all the initial overall objectives, which were to extend the life of the units, reducing the emissions and restoring unit efficiency subsequently leading to reduction in fuel consumption.

5. Summary

In summary, the following points need to be highlighted:

a) Life extension/Rehabilitation works of unit 1 and 2 undertaken after the end of the useful life of the plant (approximately 25 years)
b) Detailed studies were undertaken by the utility to assess the condition of the plant.
c) The boiler inspection including RLA/CA studies were done by Original Equipment Manufacturer (OEM) i.e. B&W PGG.
d) Based on the life cycle management process, it was determined that the equipment could be refurbished/rehabilitated more economically as compared to complete replacement of the boilers and associated equipment.
e) Burners, pressure parts, pulverizers, air heater and flame detection system were upgraded in order to handle wider range and variety of coal.
f) Combustion systems were redesigned in order to reduce NO_x emissions.
g) The project was successful and met all the initial overall objectives.

10.3. Case Study of Tusimice II (ETU II) Power Plant (4x200 MW), Czech Republic

1. Tusimice II TPP: Plant Details

The Tusimice II TPP (ETU II) is owned by CEZ, the largest generating company of Czech Republic. Tusimice TPP has 4 units of 200 MW each. The power plant was put into operation unit by unit. The 1st Unit was commissioned in 1974 and the 4th Unit was commissioned in 1975. During 1990's these units were de-sulphurized and modernized due to which the lifetime of these units was extended by another 10-15 years. The power plant is located near the Libouš brown coal mine.

In the period from 2007 to 2012, Tušimice Power Plant II underwent complex restoration works to ensure its future operation in line with the current European standards and planned operation life of the plant after rehabilitation corresponds to the remaining life of the adjacent Libouš mine.

2. Objective of R&M

There were several objectives for undertaking R&M. At the country level, the decision for R&M was driven by energy security, compliance to EU environmental regulations etc.

At the plant level, the decision for renewal of plant was based on the availability of sufficient coal and quality of the available coal. The following two considerations were assessed:

a) **Option 1:** In case of new plant, coal would be required for around 40 years
b) **Option 2:** In case of modernization, life of 25 years can be obtained

Since, the remaining life of Libouš coal mine was only 25 years, Option 2 was selected.

Further, assessment of the mine indicated that the coal available from the mine for future utilization would be of markedly low quality and hence power plant needs to be adapted to the lower fuel efficiency and higher content of sulphur in future.

The main objectives for undertaking R&M were as follows:-

a) Restoring production portfolio for the next 25 to 30 years indexed to the life of the coal mine, the only possible coal source in the vicinity.
b) Improving the environmental performance of the plant and to comply with the emission standards prescribed by the European legislation.

c) Increasing the efficiency of electricity production, reduce consumption of primary fuels.
d) Providing ability to burn low quality coal
e) To remain self-sufficient in energy, to ensure energy security for the country and to maintain as a net exporter of electricity.

3. Project Planning and Assessment

Detailed studies and assessment of the plant condition was undertaken by the utility.

Civil surveys were also undertaken to inspect both the conditions for laying foundation of the new structures and as-built state of the existing structures. These surveys resulted in the decision on preservation or repair of the original structures in order to allow the extension of the operational life of the plant.

On the basis of technical and economic study, a business plan was prepared which provided the targets of the reconstruction of the power plant and main principles of the technical solution.

In addition to the studies, comprehensive assessment of the following parameters was also undertaken by the utility before undertaking R&M:

a) Technical parameters of the existing units such as power, efficiency, steam admission conditions - temperature and pressure etc. and the required parameters of the units after the reconstruction
b) Required emission limits
c) Operating life of the existing power plant and service life required after the reconstruction
d) Fuel, its quality (parameters)and total amount of the extractable fuel (e.g. coal) with respect to the design service life of the power plant
e) Source of water and its capacity
f) Economy of the secondary energy products (waste) – present arrangements and its possible disposal during design service life
g) Generator-to-grid connection and connections to the transmission system
h) Possibility to supply heat if required
i) The existing I&C system
j) Key technical data and information on the main plants and components: coal handling, boiler including the downstream systems, flue-gas desulfurization (FGD) units, turbine island, electrical parts, water chemical treatment plant, water management, cooling circuit
k) Civil structures used and their possible use for the assumed design life
l) Existing infrastructure and its potential additional use and Ties to

the existing infrastructure.

4. Project Execution

The project was executed through EPC contractor Skoda Praha Invest, Group Company of CEZ. The contract for the preparation of the design was signed in May 2005. The geological survey and inspection of the condition of buildings, structures and process equipment at the power plant was carried out in order to determine the possibility of their use for another 25 years.

After the successful completion of this stage, the EPC contract for the Power Plant was signed in April 2006. The work related to the specifications started immediately, along with the supplier selection procedure. The sub vendors for the project were selected by Skoda Praha Invest on tender basis. Packaging was done in a way that it ensures competition among different vendors leading to competitive prices and at the same time the number of vendors to be managed was limited. Around 10 major vendors were selected for the work related to Machine, Turbine, Boiler House, I&C, Chemical Water treatment etc.

Further, for undertaking R&M works, dedicated team of 10 people was formed by the utility. **The funding for the project was garnered from the internal resources of the utility.**

The following tasks were undertaken as part of the execution of the rehabilitation process

4.1. Phased Execution/Implementation of R&M

a) The project implementation was divided into two stages, **with two units being considered for R&M works at a time and remaining two units being operated in parallel.**

b) The first stage of the execution started in June 2007 with the shutdown of Unit 3 and 4. The Unit 3 and 4 were commissioned in February 2009 and April 2009 respectively. The trial run of these units was completed in November 2009 and Protocol of the Provisional Acceptance (PAC) was signed in September 2010.

c) The second stage of the execution started in November 2009 with the shutdown of Unit 1 and 2. The trial run of Unit 2 was completed in October 2011 and PAC protocol was signed in November 2011. The trial run of Unit 1 was completed in April 2012 and PAC protocol was signed in April 2012.

d) It was observed that first phase of R&M was delayed by one year but the second Phase of R&M was delayed by only one month. The experience gained and lessons learnt in undertaking R&M works during the first phase was duly incorporated while executing R&M works of second phase.

4.2. Meticulous planning in separation of operating and non-operating units

One of the key preparatory activities at the time of commencement of R&M **was construction of buildings and separation of operating units from the non-operating ones (that will undergo R&M).** This was completed well in advance and before the commencement of the works. A large number of temporary measures were implemented related to wide variety of process, civil and especially electrical and I&C works during the planned 3-week complete shutdown of the units so that the operation of units 1 and 2 could continue during the reconstruction of units 3 and 4. A separator wall was also created within the turbine house to create this separation and over 200 temporary measures were implemented to effect such separation.

4.3. Handling of Technical Surprises

During implementation of R&M works for units 3 & 4, there was occurrence of technical surprises in construction related work, Process Equipment Disassembly and Assembly and works related to Commissioning and start-up of the new units. These are explained in detail below:

a) **Construction Work**

i. Several underground systems and structures not recorded in the documentation of ETU II were discovered during the construction.
ii. Probes carried out after the dismantling of process equipment showed in some cases (FGD plant) less load carrying capacity of earth than in preliminary surveys.
iii. Some civil structures (e.g. Turbine Hallroof) had to be more significantly overhauled than originally indicated by the preliminary surveys.

b) **Process Equipment Disassembly and Assembly**

Some components intended for minor repairs by preliminary surveys were completely replaced due to the operation life required (some pipelines, LJ flushing tank, some components of the fan mills, etc.).

c) **Commissioning and start-up of the new units**

i. Unusual composition of slag from the boiler caused difficulties in the newly designed semi-dry slag and ash extraction system and consequently in the balance of waste water. It was resolved by adjusting the pumping in waste water tanks.
ii. Cooperation between the existing systems and the new units during the temporary operation (2 units out of service for upgrade and2 units in operation) for example between the FGD plant and the existing gypsum handling system.

iii. Difficulties with restarting the turbine generator in hot condition after the trip – addressed in co-operation with the TG supplier, ŠKODA POWER.

4.4. In order to resolve the technical surprises a joint committee was formed by EPC contractor and CEZ

a) A common committee was formed by the Skoda Praha Invest, the EPC contractor and CEZ to sort out issues/disputes of suppliers and surprises faced during the implementation stage. The objective of this committee was to decide that in case of occurrence of technical surprise or additional scope, whether there exists any title on behalf of the supplier to claim additional financial resources and the quantum for the same. The committee was also consulted during occurrence of disputes/hindrances in the project execution.

b) In order to implement R&M works successfully, it was important that utility, EPC contractor, suppliers etc. should work as a team. Disputes must be resolved in a timely manner through negotiations in an amicable manner. This was followed as a practice between the utility, the EPC contractor, and the sub-contractors.

c) Formation of such committee also proved useful in cases where utility wanted to increase the scope of work beyond that mentioned in the contract. For e.g., earlier only renovation of outer wall panel windows of boiler house was part of the contract but later decision was taken to completely replace the same.

d) Also, in case of sanction of additional work that influence other work elements, the entire timeline and activities were re-aligned according to such new work. This was mutually decided by CEZ and Skoda Praha Invest.

4.5. The advanced technological options considered while undertaking R&M are highlighted for each of the components below:

a) **Boiler**
Boilers were installed by Vitkovice Power Engineering and were designed in a manner that can reach high effectiveness even while burning fuel with a decreased quality in the future, while fulfilling emission requirements.

b) **Flue gas Desulphurization units**
The reconstructed electrostatic precipitators ensure that the concentration of solid pollutants in the output flue gases is below 100 mg/NM3. The dust-free flue gasses are routed into the new

outdoor desulphurization unit (supplied by Andritz Energy & Environment), designed as one unit per boiler pair.

c) **Machine Room**

Modern three-stage turbines, each with a 200 MW power output, were mounted on the slightly adjusted turbine foundations in the original machine room. The turbines installed are of the action blading, condensing type with steam reheating and eight non-regulated steam outlets for heating of the condensate, feeding water, and exchanger station heating water and feed water pump drive. The turbine is being supplied by Skoda and generator is being supplied by Siemens.

d) **Coal handling Plant**

The original equipment was repaired and worn out parts exchanged.

e) **Water handling**

Removal of hydraulic de-slagging and integration of waste water in the power plant process

f) **Electrical part and Instrumentation and Control (I&C)**

The electrical part was modernized and exchanged in the course of the complex renewal of the Tusimice II power plant, including repair and maintenance of some parts. I&C system was also completely changed. The new process control systems contain systems for control, monitoring and evaluation of the technological process of power production, desulphurization and auxiliary parts of the Tusimice II power plant, including the field instrumentation, control valves with actuators, cabling and cable trays. The power plant process is monitored, controlled and secured by distributed control system supplied by Siemens.

g) **Construction**

Some of the major civil parts of the work included repair of the boiler steel structure, exchange of the machine hall roof shell, adjustment of the turbo set foundation, repair of the internal and external surface of the cooling towers etc. Construction of completely new buildings also formed part of the work (such as FGD buildings, water treatment, new piping and cable bridges and slag silos).

h) **Power plant parameters Pre and Post R&M**

The comparison of the original unit technical parameters and emission values before the reconstruction and designed parameters of the reconstructed units is shown in the following overview of the power plant performance.

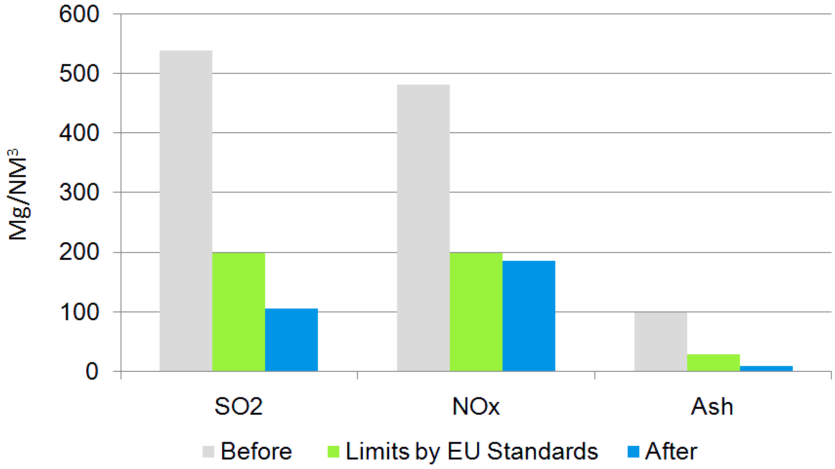
Table 20: Power plant parameters Pre and Post R&M

Power Plant Parameters	Before Renewal	After Renewal
Boiler Effectiveness	86-87.6%	Min. 90%
NO_x Emissions	320-440 mg/Nm^3	Max 200 mg/Nm^3
SO_2 Emissions	450-500 mg/Nm^3	Max 200 mg/Nm^3
Fly ash emissions	60-100 mg/Nm^3	Max 20 mg/Nm^3
Unit efficiency	33-34%	37.82%
Fuel calorific value	10-11 MJ/kg	8.5-11 MJ/kg
Water content in the untreated fuel	32-38%	31-34%
Ash content in the untreated fuel	18-25%	31.74%
Nominal steam output of the boiler	660 t/h	570 t/h
Nominal superheated steam pressure	17.46 MPa	18.1 MPa
Nominal reheated steam pressure	4.06 MPa	3.81 MPa
Nominal superheated steam temperature	540 C	575 C
Nominal reheated steam temperature	540 C	580 C
Feed Water Temperature	253 C	258 C
Unit rating	200 MW	200 MW
Maximal steam output	660 t/h	575 t/h
Superheated steam pressure under maximum power	17.5 MPa	19.1 MPa
Ash content in dry fuel	42.98%	35-46%
Sulphur content in dry fuel	2.87%	Max 3.5%

Post R&M, an efficiency improvement from 33% to 38%. Further, net efficiency enhancement related to CO_2 reduction was also achieved. CO_2 emission factor reduced from 1.1 tCO_2/MWh pre R&M to 1.0 tCO_2/MWh post

R&M. Results of the warranty tests showed that the renewed power plant equipment met all required technological and ecological parameters as highlighted above. The EPC contractor met all the conditions and the requirements stipulated in the contract. Emissions post R&M works were less than the emission limits provided by EU standards.

Figure 13: ETU II Emissions pre and post R&M



Source: AF-Mercados EMI interactions with the utility and the EPC Player

4.6. Post R&M Guarantees

The guarantee period of 24 months for process equipment and 60 months for the civil structures start after the signature of the Protocol of the Provisional Acceptance (PAC).

Learning from the implementation of R&M works of ETU II was incorporated by CEZ in implementation of R&M works of Prunerov II, the subsequent plant taken for R&M by CEZ (discussed in the subsequent sub-section).

5. Summary

In summary, the following points need to be highlighted:

a) Life extension/Rehabilitation works were undertaken again after the end of the useful life of the plant.
b) Availability of adequate coal and inferior quality of coal were important consideration for rehabilitation works.
c) R&M works were driven by both plant level economics and country level objectives of energy security, compliance to EU environmental regulations etc.
d) Detailed studies were undertaken by the utility to assess the condition of the plant. Civil surveys were also undertaken to inspect both the conditions for laying foundation of the new structures and as-built state of the existing structures.
e) Execution of R&M works were undertaken on EPC basis. The sub-vendors for the project were selected on the basis of competitive

bidding.

f) Execution of R&M works on the plant was divided into phases.
g) The funding for the project was garnered from the internal resources of the utility
h) Occurrence of technical surprises was observed during the implementation of R&M works and were resolved through formation of joint committee between EPC contractor and the utility
i) The project was successful and met all the conditions and the requirements stipulated in the contract.

10.4. Case Study of Prunerov II (EPR II) Power Plant (5x210 MW), Czech Republic

1. Plant Details

The Prunerov TPP is owned by CEZ, the largest generating company of Czech Republic. It consists of 5 units of 210 MW each, which was first taken into operation in 1981 – 1982. In 1996, all units were retrofitted with limestone based wet scrubbers to ensure proper SO_2 emission control. In addition to the production of electricity, also district heating is supplied to the neighbouring urban agglomerations. Currently, R&M works are on-going on unit number 3-5.

R&M works are proposed for Unit 3-5 only. Unit number 1 and 2 are in operation and are proposed to be retired after the R&M works for Unit 3-5 are completed. Unit 1 is proposed to be closed in 2016 and Unit 2 in 2018. Time schedule for R&M of Unit 3-5 is Sept 2012-2014.

2. Objective of R&M

The objective for undertaking R&M works include:

a) Extending the useful life of the three units with a period of 25 to 30 years
b) Improving the environmental performance of the plant and to comply with the emission standards prescribed by the European legislation.
c) Increasing the efficiency of electricity production, reduce consumption of primary fuels.
d) Providing ability to burn low quality coal
e) To remain self-sufficient in energy, to ensure energy security for the country and to maintain as a net exporter of electricity
f) Maintain the supply of heat to external customers using only the capacity of the three renewed blocks.

3. Project Planning and Assessment

The reconstruction project comprises the following activities:

a) Upgrading and maintenance to the existing lignite unloading, handling and transport system
b) Upgrading and maintenance to the existing limestone unloading, handling, and transport system
c) Refurbishment of the existing lignite mills with redesigned classifiers, new motors and hydraulic Controls
d) Replacement of the three existing boilers, including combustion chamber and lignite burners by three once-through boilers (Benson boilers) with higher steam parameters
e) Partial replacement of the turbine
f) Installation of new electrostatic precipitators for dust removal

g) Installation of new wet scrubbers for SO2 removal
h) Complete replacement of the automatic control system for the entire facility
i) Partial replacement and modernisation of electrical equipment
j) Introduction of cleaned flue gas in the reconstructed cooling towers

The three refurbished blocks of EPR II will have an increased unit capacity of 250 MW.

4. Project Execution

In order to build upon the experience of R&M works of Tusimice and to handle technical surprises, the learning of the project has been incorporated in the preparatory work of EPR II.

This project is also executed under EPC mode and Skoda Praha Invest is selected as the EPC contractor. In order to utilise the past R&M experience, suppliers of key components are being retained.

Also, same project manager involved in R&M works of Tusimice power plant has been involved for the R&M works of EPR II from the utility side.

The implementation of the project has started and timeline for R&M works has been Sept 2012-2014. In order to effectively manage the project Skoda Praha Invest organises working meetings with the relevant officials on a daily basis. Further one official meeting per 14 days is also organised besides providing the summary of work to the utility every week.

Post R&M it is expected that there would be an efficiency improvement from 32.6% to 39%. Further, CO_2 emission factor is expected to be reduced from 1.2 tCO2/MWh pre R&M to 0.9 tCO_2/MWh post R&M.

5. Summary

In summary, the following points need to be highlighted:

a) Life extension/Rehabilitation works are on-going and are expected to be completed by 2014
b) Three refurbished blocks of EPR II will have an increased unit capacity of 250 MW.
c) In order to build upon the experience of R&M works of Tusimice and to handle technical surprises, the learning of the project has been incorporated in the preparatory work of EPR II.
d) This project is also executed under EPC mode and Skoda Praha Invest is selected as the EPC contractor. In order to utilise the past R&M experience, suppliers of key components are also being retained.
e) The utility has retained the same project manager involved in R&M works of Tusimice power plant.

10.5. Case Study of Belchatow Power Plant (12x370/380 MW), Poland

1. Plant Details

PGE Elektrownia Belchatow, in the Lodz province of Poland, approximately 170 km south west of Warsaw, is the largest power plant in Poland and the largest lignite-fired power station in Europe. It consists of 12 x 370/380 MW (originally 360 MW) lignite fired reheat units commissioned between 1982 and 1988 (initially 4320 MW installed capacity, now 4450 MW, following the various modernisation activities completed to date). The plant accounts for 20% of the electricity produced in Poland. Upon completion of a new 858 MW supercritical unit, currently under construction, and completion of modernisation programmes on ten of the existing units, the installed capacity will be around 5500 MW. The Belchatow power plant was originally developed by the state-owned power utility, but as a result of the privatisation process, it is now owned and operated by PGE (Polska Grupa Energetyczna).

All units are in operation and R&M works are expected to be carried out initially on 10 of its units. It was decided to operate Unit 1 and 2 till the time R&M works are completed on other units and the new unit is being commissioned. Unit 3, 4, 5, 6 are renovated as on date. R&M works on Unit 7 and 8 is expected to be completed in 2013. Based on the R&M experience, generating company has decided to even undertake R&M on Unit 2 as well. Therefore, in total 11 units are subjected to R&M works and are expected to be refurbished by 2016. Although R&M works on Unit 7 and 8 are on-going, contracts for unit 9-12 have been signed and awarded wherein the R&M work will commence after the completion of R&M works on unit 7 and 8. Although R&M works are undertaken on several units, details are provided with regard to Unit 6 as it has one of the most recent experiences.

2. Objective of R&M

The objective of R&M for Unit 6 was to extend the plant's life, increase output and availability of the plant, enhance the environmental performance etc. The key objectives are detailed out below:-

a) Unit life to be extended up to a total of 320 000 operating hours.
b) Thermal optimisation to increase generated output to between 390 and 400 MW, while maximising thermal efficiency.
c) Reliability, availability, and maintainability (RAM) to be improved to achieve levels comparable with the best in the industry. The time between main overhauls also to be extended.
d) Boiler firing system to be upgraded to meet emissions requirements of less than 200 mg/Nm^3 for both CO and NO_x, as well as achieving optimum coal burn parameters within the operating load range to ensure compliance with EU Directive 2001/80/WE (Large Combustion Plant Directive).
e) Automated start-up, shutdown and operation of the unit throughout

the load range, and operating load range extended from 60-100% MCR to 40-100% MCR plus compliance with grid code requirements.

Effective utilisation of the coal mine was also one of the key drivers for R&M works of the power plant as the generating company is also the owner of the mine.

3. Project Planning and Assessment

Separate feasibility studies were carried out during 2002-2003 for the boiler and turbine. Diagnostic studies were undertaken to undertake pre-assessment and this was done through hiring of consultants/suppliers. The source of financing for undertaking R&M works included internal resources and balance sheet financing. Scope of work was prepared based on the diagnostic studies. Also, during the entire period of operation, condition of plant was regularly monitored. Normal overhauling and inspection programs are carried even if the plant is undergoing R&M. This enables effective monitoring of the condition of the plant on a regular basis.

Based on the studies, PGE Elektrownia Belchatow initially aimed for a live steam temperature of 547°C, a reheat steam temperature of 568°C and live steam pressure of 170.2 bar, with the existing feedwater temperature, 255°C, for units 3 and 4.

Unit 3 was the first unit which underwent R&M. It acted as a pilot project wherein the execution process and the results of R&M were tested.

However, based on R&M experience obtained from Unit 3 and 4, regular monitoring of the condition of the plant, R&M works on other units were continued and based on new feasibility study carried in 2008-09, it was decided to increase live steam temperature to 568°C, live steam pressure to 185 bar and feedwater temperature to 275°C for the subsequent modernisations (i.e. Unit 5 onwards).

Based on the feasibility studies, the scope of work/technological interventions for modernization of Unit 6 that were planned included the following:

a) **Turbine island modernization** included HP and IP turbine retrofits, turbine auxiliaries, extraction pipe-work, generator retrofit, new feed-water heat exchangers, electro- hydraulic control system and, I&C equipment.
b) **Boiler modernization** included pressure parts, firing system, flue gas and air ducts, ID and FD fan retrofit and I&C equipment.
c) Air pre-heater refurbishment
d) Electrostatic precipitator refurbishment
e) New Distributed Control System
f) New Flue gas heat exchanger.

4. Project Execution

Indicative cost of R&M works for Unit 3, 4, 5, 6 were in the range of 200-220 Million Euros for each of the unit. However, there was decrease in the cost of R&M works for subsequent units i.e. for Unit 7-12 due to the experience gained from the R&M works on the earlier units. Indicative cost of R&M works for Unit 7-12 are in the range of 180 Million Euros/unit.

Packaging strategy for each of the units differed. Initially, R&M works (in case of Unit 3) were divided into large number of packages but due to coordination issues among different vendors and inability of the utility to manage large suppliers, works were later divided into lesser number of packages as illustrated below:

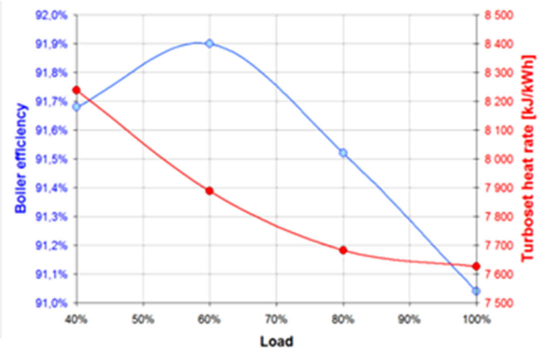
a) Contracts for unit 5 were awarded as separate component packages
b) Contract for unit 6 was awarded as an integrated project executed by Alstom.
c) Similarly, contracts for unit 9-12 were awarded as separate component packages wherein Alstom undertook works related to turbine generator, ESP, certain BoP works etc. and Babcock undertook boiler works.

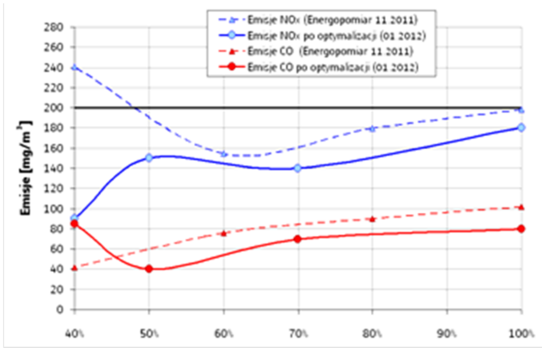
Vendors were selected based on competitive bidding.

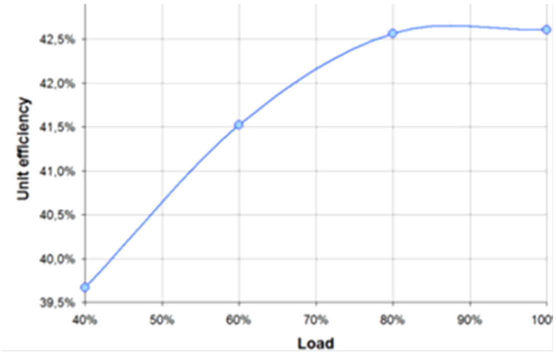
4.1. Post R&M Result

Modernisation of units 3 and 4 has led to a significant improvement in unit efficiency providing a heat rate improvement of 1.35%, while the integrated approach adopted for unit 6 promises a further efficiency improvement of 0.85% on unit heat rate providing a total unit efficiency improvement of 2.2% compared with the original units.

Figure 14: Technical Results achieved during the Trial Run







Load		NOx	CO	Hu	O2	T.SH	T.RH
%	MW	mg/NM³	mg/NM³	MJ/kg	%	°C	°C
100	394	180	90	7800	2.2	570	570
70	275	140	70	7300	2.9	570	>568
50	186	150	40	7300	3.9	>568	540
40	157	90	85	7600	5.1	540	540

Source: Modernisation summary of unit 6 in Belchatow Power Plant, Presentation by Jarek Ciesielski Kołobrzeg, 24-27/04/2012

4.2. Post R&M Guarantees

Warranty period is three years and one warranty engineer is present at the site for any assistance during the warranty period. Efficiency is guaranteed only through performance tests but not beyond that. Through performance tests it is shown that supplier has met the efficiency and this is not included in warranty. In case efficiency is included ageing is considered as efficiency of plant decreases with the increase in the age of the plant.

a) Absolute guarantees

i. NOX content in combustion gases: 200 mg/m^{3}r
ii. CO content in combustion gases: 200 mg/ m^{3}r
iii. Vibrations: the dynamical behaviour (absolute and relative) of structures and delivered equipment

b) Penalized guarantees

i. Rated electric power output of power unit at generator terminals - 394 MW
ii. Gross efficiency of integrated boiler – turbo set system - 41.34%
iii. Live steam temperature with contract coal - 570 degree Celsius
iv. Reheated steam temperature with contract coal- 570 degree

Celsius

v. Water injection to reheated steam - ≤ 20 t/h
vi. Combustible part in volatile ash - ≤ 3%
vii. Availability - 90%-92.5%

5. Summary

In summary, the following points need to be highlighted:

a) Life extension/Rehabilitation works were started towards the end of the useful life of the plant.
b) Phased approach to R&M works were adopted for different units of the plant.
c) Detailed studies were undertaken by the utility to assess the condition of the plant. Based on the experience gained from R&M works of initial units, a detailed feasibility study was again undertaken for rest of the units to tighten the performance parameters.
d) Regular O&M works were carried out by the utility even if the units were scheduled for R&M. Monitoring of plant condition by the utility and increased familiarity of the vendors with regard to the actual condition of the plant led to gradual reduction in the cost of R&M works.
e) The funding for the project was garnered from the internal resources of the utility and also from balance sheet financing.
f) Different packaging models were adopted by the utility for undertaking R&M works on different units.
g) Warranty period of three years included in the contract and one warranty engineer is made available at the site by the vendor for any assistance during the warranty period.

10.6. Case Study of Turceni Thermal Power Plant (7x330 MW), Romania

1. Plant details

Romania has a diversified and balanced energy mix. Hydropower dominates the energy mix with a share of ~36% followed by Coal with 33% and Nuclear with 19% share.

Furthermore, Romania is a net exporter of electricity, with an approximate net export of 2.91 TWh in 2010. The Turceni TPP is the largest in Romania with an installed capacity of 2310 MW (7 X 330 MW) and a current operational capacity of about 1320 MW. These units were commissioned during 1978 and 1987. The main fuel used is lignite with a low heat value of 1400 – 1800 kcal/kg.

Phased approach was undertaken for refurbishment of different units of the Turceni TPP.

The units have been subject to several rehabilitation programs:

a) **A1 Program**
Urgent repairs of units 2 and 6, in cooperation with ABB and Babcock Germany. It was financed via an IBRD loan and own financial resources. It has led to an increased time availability of units and an average output.

b) **A2 Program**
Reconditioning of units 3 and 7, in cooperation with ABB, Babcock, Hannemann, Flender, Taprogge, Hartmann Braun (Germany), Voith (Austria), Alsthom (France) financed by EIB loan and own financial resources. It has led to increased time availability and an increased average output.

c) **A3 Program**
Rehabilitation of units 4 and 5, in cooperation with ABB Kraftwerke and Deutsche Babcock. Unit 4 was commissioned in 2004; Unit 5 was commissioned in 2006. It was financed via a KfW loan and own financial resources. It has led to increased time availability, average output, reduced fuel and internal electricity consumption.

The project named "Program A3 - Rehabilitation of Turceni Thermal Power Plant Units 4 & 5" has been initiated by CONEL (National Power Authority) - Termoelectrica Subsidiary in order to rehabilitate and modernize the power units 4 and 5 rated 330 MW each, running on lignite. The rehabilitation of units 4 and 5 in Turceni TPP has been made by ISPE together with ABB/DBE German Consortium.

2. Objective of R&M

The objectives for undertaking R&M were as follows:

a) To meet the in country increasing demand for electricity and to maintain its current position of being a net exporter of electricity
b) Use of more efficient technologies, which reduces atmospheric pollution
c) A very small number of thermal plants have been built since the last 20 years and the existing thermal units are fairly old and inefficient with old technologies. The average age of thermal power plants in Romania is around 32.7 years.
d) To increase the operational and installed capacity of the existing plants.
e) To increase the availability of Units for generation;
f) To increase the lifetime of the generating units by at least 15 years;
g) To improve the techno-economic parameters of the Units by reducing the specific gross heat consumption among others;
h) To implement a modern automation, adjustment and control systems that shall fulfill the present technical requirements.

3. Project Planning and Assessment

The rehabilitation of units 5 was made by ISPE (Institute for Studies and Power Engineering) together with ABB/DBE German consortium. The rehabilitation technology for Unit 5 is provided by Consortium ABB KW Mannheim – Deutsche Babcock Energie Oberhausen, and represents best available technology for coal-fired power plants in Romania. Inspections and expert appraisal were undertaken on site in order to evaluate the technical status of the equipments and to establish the upgrading measures which were to be taken.

In order to execute this Project, Pre-Feasibility and Feasibility Studies were undertaken by I.S.P.E. As general designer of the plant, ISPE offered the following services related to this project:

a) Inspections and expert appraisal on site in order to evaluate the technical status of the equipments and to establish the up-grading measures which were to be taken;
b) Basic and detail engineering for the two units;
c) On site supervision and commissioning;
d) Configuring of control systems.

4. Project Execution

The following interventions were undertaken for the rehabilitation of Turceni TPP Unit no.5:

a) Boiler – full replacement of pressurized water circuit: a new design of feeding water piping, as well as steam vaporization and overheating sections has been put into place.

b) Turbine – HP casing and rotor along with the bearings were replaced. Some minor modifications were carried out in IP and LP rotor including casing.
c) Generator – the existing auxiliary generator exciting system was replaced with static type system, provided with UNITROL-type ABB voltage regulator.
d) A new technical solution for the lignite firing system has been adopted: coal crunching mills have been integrally replaced, leading to improved coal availability and operation security. Coal firing system has been re-designed.
e) A digital command system has been implemented.
f) Conveyor belts modernization
g) ESP modernization

4.1. Achievements Post R&M

a) Time availability increased from 44% to 94%
b) Own consumption decreased from 15% to 7%
c) Reduction of particulate emissions below 50 mg / Nmc

5. Summary

In summary, the following points need to be highlighted:

a) Life extension/Rehabilitation works were undertaken at the end of the useful life of the plant.
b) Detailed studies were undertaken by the utility to assess the condition of the plant.
c) Execution of R&M works on the plant was divided into phases.
d) The funding for the project was garnered from the internal resources of the utility and through loan from KfW.
e) The project was successful as highlighted by the post R&M achievements.

10.7. Case Study of Afsin-Elbistan A Thermal Power Plant (1355 MW) (3x340 + 1x335) MW, Turkey

1. Plant details

"Afsin Elbistan A", a conventional thermal power plant utilizing low quality lignite, was established by TEK in 1984-1987 and has 1355 MW of capacity. It has four units and is of great importance in Turkey. The plant, owned by EÜAS, the state owned Electricity Company. The plant was designed to burn low quality lignite with high moisture easily without using supplementary fuel. The system developed for such lignite is to first dry the lignite to increase its calorific value. This TPP was designed for an annual electricity production of 8,800 GWh.

However, with the decrease in capacity and reliability of the plant due to wear and tear of equipments and some unscheduled shutdowns. The average efficiency decreased below the design efficiency. The R&M of this project was planned as part of The World Bank's support under the proposed Electricity Generation Rehabilitation and Restructuring Project of Turkey.

2. Objective of R&M

Objectives envisaged for undertaking R&M were:

a) **Technical**

i. Extension of Plant Life for 20 years
ii. Removal of operational problems (wear, tear, cracks, vibration and cavitations)
iii. Reduction of maintenance work
iv. Technological improvements (especially in electrical components)

b) **Economic**

i. Increasing the capacity and efficiency
ii. Increasing the amount of electrical energy produced
iii. Help the generator decrease its losses
iv. Increasing operation period
v. Increasing the Availability and Reliability

c) **Environmental**

i. To reduce SO_2, CO_2 and NO_x emissions as per the Turkish Regulations

3. Project Planning and Assessment

Technical and Economic assessment was undertaken where extensive site inspection, performance tests on boiler, turbo generator, mills, ash precipitators was conducted. The scope of the rehabilitation component was developed based on a comprehensive feasibility study and technical review. The initial pre-feasibility study was done by Chubu Electric from Japan in 2004. This study established the broad scope of the rehabilitation needed based on a technical and economic assessment. **This work clearly established the economic benefits of the rehabilitation.** The Bank's power engineers reviewed the pre-feasibility report and assisted EUAS in defining the terms of reference for the detailed engineering study and finalizing the scope of work. **The detailed engineering study/feasibility study was undertaken by RWE Consulting Engineers, Germany**. Further, it also assisted in the development of tender documents and bid evaluation assistance.

This review provided important inputs to the decisions on what is required and what is optional, and enabled EUAS to finalize the scope and cost estimates for rehabilitation.

The rehabilitation work was expected to improve the plant performance as follows:

a) Plant output of each unit will be increased from about 260 MW net to 300 MW net;
b) Capacity factor will be increased from 40% or below to 75%; and
c) Net plant efficiency will be increased from 27% to 31% (30.6% with the FGD).

The detailed scope for rehabilitation was prepared based on the feasibility study and broadly it included R&M of the boiler and firing system, the electrostatic precipitators (ESPs), the main cooling water and condensate water system (covered under the Balance of Plant Mechanical), control and instrumentation, and ash and coal handling. The scope of rehabilitation work is summarized below:

a) **Boiler**
Detailed inspection and repair work of the boiler waterwall, superheater, reheater and economizer tubes, headers and other pressure parts. Installation of new boiler cleaning system and soot blowing system to improve the boiler efficiency as well as preventing slugging which causes tube failures.

b) **Steam Turbine**
Overhauling of high pressure (HP), intermediate pressure (IP) and low pressure (LP) inner casing and blades and replacement of the same in selected units in order to achieve efficiency improvements and increase in plant output. It also included replacement of turbine governors for better frequency control.

c) **Balance of Plant Mechanical**
This included inspection, overhaul, repair and replacement work for

circulating water system, fire suppression system, the main cooling water system, condensate water system (LP feed water heater replacement), condenser air extraction system, gland steam system, condenser re-tubing, other system pumps.

d) **Balance of Plant Electrical**
This included inspection, overhaul, repair and replacement work for transformers, large motors, general instrument supplies, 6kV switchgear, 380V switch gear, generator protection and control system, automatic voltage regulator, high voltage system, medium and low voltage systems, uninterruptible power supplies, emergency generators and DC systems, power metering and fire protection.

e) **Precipitator**
This included addition of a compartment to the main boiler flue gas and the bruden vapour Electrostatic Precipitators (ESPs) to achieve the required particulate emission level (100 mg/Nm^3). This was necessary to comply with the Turkish environmental regulations for Afsin (150 mg/Nm^3) and the Bank's environmental guidelines for rehabilitated existing plants.

f) **Control and Instrumentation**
Modernization of complete boiler and turbine control system to Distributed Control System (DCS)

g) **Ash and Coal Handling**
This included replacement of the existing system with the dry bottom ash handling system and enhancement of the coal handling system including covering tops of conveyers and lighting systems to improve availability of the plant.

h) **Civil Works**
This included repair/replacement of the reinforced concrete, steel structure for the boiler, turbine and balance of plant. It also included exterior and interior painting, earthquake safety (additional walls) repair of damaged clear covers, and exposed reinforcement, protective coatings and new foundations for concrete structure

Initially two stage bidding process was adopted. Two bidders applied at the first stage with qualified bids, and were initially not found fully responsive. Clarificatory meeting were held with the bidders, on the basis of which the bidders were considered qualified, and were invited to the second stage.

The main concern of the bidders were perceived risks of not being able to achieve the functional guarantees of a large scope rehabilitation works (1,300 MW), and the associated financing challenge.

Based on the discussions, the guarantees were reassessed: EUAS agreed with the bidders to remove the requirement for functional guarantees for the boiler efficiency and availability as these parameters are difficult to measure accurately and depend on a number of factors, such as coal quality, outside the control of the contractor.

Further, one of the bidders stated that they would not be able to qualify for the rehabilitation of all four units of the plant, and thus requested that four units of the plant be rehabilitated in two stages of two units each, EUAS did not agree with this request, but allowed the bidder to strengthen their consortium.

However, despite all these adjustments, neither of the two bidders bid at the second stage of the bidding process for the rehabilitation works.

Thereafter, EUAS proposed to proceed with the project with a revised procurement approach – by separating the single consolidated package covering the entire project into separate supply and installation packages for different works.

However, at the same time, the Government started an unrelated investigation into the procurement actions by EUAS wherein the General Manager of EUAS was requested to be on leave to facilitate the investigation. In the absence of senior management, and environment of the ongoing investigation, the transitional management team of EUAS did not felt empowered to take decisions.

In September 2009 therefore, EUAS requested the Bank to allow cancellation of the bidding process, followed by a cancellation of the Bank loan.

The Government and the Bank agreed that under the environment of the on-going investigation, EUAS may not be in a position to implement such a large and complex project. Therefore, instead of re-starting a third procurement attempt, it would be more prudent to cancel the project.

4. Summary

In summary, the following points need to be highlighted:

a) The R&M of this project was planned as part of the World Bank's support under the proposed Electricity Generation Rehabilitation and Restructuring Project of Turkey.
b) Detailed studies were undertaken by the utility to assess the condition of the plant, preparation of scope of work etc.
c) Higher perceived risks by the vendors led to their limited/non-participation in the bidding process.
d) Vendors were to be selected based on competitive bidding.
e) R&M works on all the four units were envisaged to be implemented at the same time which also acted as one of the reasons for non-participation of vendors due to increase in

perceived risks

f) R&M works were not implemented on the plant due to start of an unrelated investigation by the government related to procurement actions of EUAS.

10.8. Case Study of Arnot Power Station (6x350 MW), South Africa

1. Plant Details

ARNOT thermal power station is a coal fired power station located in Mpumalanga, South Africa, is a coal-fired power plant operated by Eskom, a South African utility. The plant initially comprised of 6 units of 350 MW each and was commissioned between 1971 (unit 1) and 1975 (unit 6). Completion of 30 years of its useful lifetime/design life combined with the increasing demand for electricity in the country, sustained running of the plant required replacement/retrofit of most of the parts. Alstom was selected to retrofit and up-rate the six units of Arnot power station.

2. Objectives

The objective of Rehabilitation works were to retrofit major plant components in the most cost effective manner such that each unit would produce a continuous gross electrical output of 400 MW and there is extension in the life of the plant by another 20 years.

3. Project Planning and Assessment

A comprehensive study was undertaken to investigate the feasibility of an increase in capacity, up to a maximum gross output of 400 MWe per unit, and to estimate the costs. Based on the study, detailed scope of the project was prepared.

Using the results of the initial studies, Eskom initiated a competitive tendering process, as a result of which Alstom was awarded a single contract for the execution of the project.

4. Project Execution

The scope of the project carried out by Alstom included the complete retrofit for the high pressure and intermediate pressure steam turbines, a capacity upgrade of the low pressure steam turbine and the replacement and upgrade of associated turbine side pumps and auxiliaries.

In addition, Alstom carried out major upgrading works to the boiler plant.

4.1. Equipment requiring retrofitting/Scope of Work

a) **Turbine Plant**

The major retrofit required to the turbine plant was the complete replacement of the high pressure (HP) and intermediate pressure (IP) turbine inner cylinders. However, the increased operational demand to achieve the project objectives meant that much of the auxiliary equipment associated with the turbine plant was also affected (as highlighted during the studies) and the scope was therefore extended to include modifications to the existing low pressure (LP) turbines and other plant.

b) **Boiler Plant**

The following description outlines the equipment upgraded or replaced as part of the project to upgrade the boiler plant from a continuous output of 365 MW to 400 MW.

i. **Furnace**

The existing furnace size was adequate for the 400 MW upgrade and the furnace plan and heat release rating were within allowable maximums for the normally supplied coals.

ii. **Milling Plant**

Modifications undertaken with regard to the mill classifier and gearbox

iii. **PA Fans**

New Primary air fans were installed.

iv. **Burner Nozzles**

New burner nozzles were installed.The new nozzles were suitable for additional NOx reduction measures without major modification should NOx reduction legislation be introduced in South Africa.

v. **Economiser**

Two additional rows of extended economizer surface were added to the existing configuration. The economizer profile was similar to that previously installed and the support structure was suitable for the additional surface with only minor modifications.

vi. **Up-gradation of Superheater and Reheater Materials**

The fifth stage Superheater and third stage Reheater were upgraded by enhanced 9% chromium material on the leading and trailing tubes of the elements.

R&M was performed during routine major outages of the six units over a three-year period. In each case, the outage length was 13 weeks, principally the significant amount of work required on the boiler.

For each of Arnot's six steam generating units, the output was upgraded from 350MWe to 400MWe. Results of the performance tests carried out by Eskom on two units had been extremely encouraging. Power output under calibrated steady state test conditions has been measured as 406.2 MWe for Unit 3 (against a target of 400) and 409.0 MWe for Unit 2. Informally, substantially higher outputs have been observed under high load conditions.

The incorporation of modern technology and the consequent increased efficiency of the plant led to significant reduction in NOx emissions.

The first unit was completed by December 2007 and the last unit by December 2010.

4.2. Implementation issues and challenges

a) **Quality control**

Manufacture of the turbine retrofit inner cylinders was undertaken in both Europe (Units 3 and 2) and China (Units 6, 4, 1 and 5). Similarly, virtually all manufacture for the boiler upgrades was devolved to South African facilities, both Alstom factories and local subcontractors. Rigorous and identical quality standards were applied throughout the global network by Alstom. Also, representatives of Eskom were invited to visit all factories in which manufacture was being undertaken to observe for the quality of the work. Eskom also exercised their right to institute a more rigorous regime of third party inspection in certain factories. Technical Field Advisers from Europe were also deployed during each outage to guide the local installation workforce. So far as possible, the same personnel were employed on each occasion to benefit from past experiences and ensure consistency of quality and standards.

b) **Technical surprises**

Alstom was the Original Equipment Manufacturer (OEM) for the major equipment at Arnot Power Station. Copies of the original design documentation still existed and had been used for the initial feasibility study. However, to minimize occurrence of technical surprises, access to records of Eskom were made and interactions were held with the plant level officials with long experience at the plant, which revealed some items previously unknown to either party, particularly from the plant’s construction phase. **Minor surprises still occurred when the equipment was opened up** for retrofit. These surprises or variations were recorded in a formal system so that lessons may be may be applied in future, both on other units on the same project and on similar plant elsewhere.

5. Summary

In summary, the following points need to be highlighted:

a) Life extension/Rehabilitation works were undertaken at the end of the design life of the plant (i.e. 30 years).
b) Detailed studies were undertaken by the utility to assess the condition of the plant. Detailed studies were undertaken by the OEM.
c) Alstom was awarded a single contract for the execution of the project based on the competitive tendering process undertaken by the utility.

d) To understand the operational history of the plant, vendor scrutinised the past records of utility and interacted with the plant level officials with long experience at the plant.
e) In order to ensure quality of works, visits were undertaken by the utility officials to some of the factories of the suppliers and third party inspections were also conducted by the utility.
f) R&M works were executed in major shutdowns of the units of 13 weeks over period of three years.

10.9. Comparative Analysis of R&M Experience in Different Countries

Based on the review undertaken in previous chapters, this section presents the comparative analysis of R&M experience in different countries.

Table 21: Comparative analysis of R&M experience in different countries

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	**Suralaya Power Station (Units 1 & 2) 2x400 MW**	**Tusimice II (4x200 MW)**	**Prunerov II (5x200 MW)**	**Belchatow (12x370/380 MW)**	**Afsin Elbistan A (3x340 MW & 1x335 MW)**	**Arnot (6x350 MW)**	**Turceni (7x330 MW)**
1.	Selection of Unit/Plant for R&M along with objectives of carrying out R&M	**The plant was selected for R&M as it is the largest TPP in Indonesia with a total capacity of 4025 MW and plays a critical role in meeting the electricity demand.** **Objectives:** • Reduction in CO_2 and NO_x emissions • Upgrade the capacity of unit 1 and 2 from 400	**Objectives:** • Restoring production portfolio for the next 25 to 30 years indexed to the life of the mine. • Improving the environmental performance of the plant • To comply with the emission standards prescribed by the European legislation.	**Objectives:** • Extend the useful life of the units • Improving the environmental performance of the plant and to comply with the European emission standards. • Efficiency Improvement and reduce consumption of primary	**The plant was selected on the basis:** • The plant had exceeded its useful lifetime and contributes around 20%of the total electricity produced in Poland **Objectives:** • Extension of Unit life • Thermal optimisation to increase	**Objectives:** • Extension of plant life • Removal of operational problems • Reduction of maintenance work • Technological improvements (especially in electrical components	**The plant was selected on the basis that it had completed its useful lifetime/design life of 30 years** **Objectives:** • To increase the unit capacity • Extension of plant life	**The plant was selected for R&M as it is the largest TPP in Romania with a total capacity of 2310 MW.** **Objectives:** • To maintain its current position of being a net exporter of electricity • Reduction of CO_2 and SO_2 emissions in order to follow the environmental regulations. • To increase the operational and

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	Suralaya Power Station (Units 1 & 2) 2x400 MW	Tusimice II (4x200 MW)	Prunerov II (5x200 MW)	Belchatow (12x370/380 MW)	Afsin Elbistan A (3x340 MW & 1x335 MW)	Arnot (6x350 MW)	Turceni (7x330 MW)
		MW to 440 MW • To extend the life of the units • Enable the plant to use wider variety of Indonesian coal	• Increasing the efficiency of electricity production, reduce consumption of primary fuels. • To ensure energy security • Maintain its status as a net exporter of electricity.	fuels. • Ability to burn low quality coal • To ensure energy security for the country and to maintain its status as a net exporter of electricity	generated output, while maximising thermal efficiency. • Reliability, availability, and maintainability (RAM) to be improved • Boiler firing system to be upgraded to meet emissions requirements • Automated start-up, shutdown and operation of the unit throughout the load range, and operating load range	) • Increasing the capacity and efficiency • To reduce SO_2, CO_2 and NOx emissions as per the Turkish Regulations		installed capacity of the existing plants. • To increase the availability of Units for generation; • To increase the lifetime of the generating units by at least 15 years; • To implement a modern automation, adjustment and control systems.
2.	Advanced technologic	• Convection pass pressure part	• Boilers used were designed in	• Partial replacement	• Turbine island modernisation	• R&M of the boiler and	• Turbine Plant: The major	• Boiler – full replacement of

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	**Suralaya Power Station (Units 1 & 2) 2x400 MW**	**Tusimice II (4x200 MW)**	**Prunerov II (5x200 MW)**	**Belchatow (12x370/380 MW)**	**Afsin Elbistan A (3x340 MW & 1x335 MW)**	**Arnot (6x350 MW)**	**Turceni (7x330 MW)**
	al options for EE R&M such as turbine up-gradation, efficient and environment friendly furnace-boilers, coal utilization etc	replacement • Safety valve replacement • Air heater refurbishment • Burner upgrade • Pulverizer rebuild and upgrade	a manner that could reach high effectiveness even while burning low quality fuel in the future, while fulfilling emission requirements. • Reconstruction of Flue gas Desulphurization units • Machine Room: Modern three-stage turbines, each with a 200 MW power output, were mounted in the original machine room. • In case of Coal handling the original equipment was	of the turbine • Installation of new electrostatic precipitators for dust removal • Installation of new wet scrubbers for SO_2 removal • Complete replacement of the automatic control system for the entire facility • Partial replacement and modernisation of electrical equipment • Introduction	include HP and IP turbine retrofits, turbine auxiliaries, extraction pipe work, generator retrofit, new feed-water heat exchangers, electro-hydraulic control system and, I&C equipment. • Boiler modernisation includes pressure parts, firing system, flue gas and air ducts, ID and FD fan retrofit and I&C equipment. • Air pre-heater	firing system, the electrostatic precipitators (ESPs), the main cooling water and condensate water system (covered under the Balance of Plant Mechanical), control and instrumentation, and ash and coal handling.	retrofit required to the turbine plant was the complete replacement of the high pressure (HP) and intermediate pressure (IP) turbine inner cylinders. • Milling Plant: modifications undertaken with regard to the mill classifier and gearbox. • PA Fans: New Primary air fans were installed. • Burner Nozzles: New	pressurized water circuit. • Turbine – HP case and rotor replacement • Generator –system modernisation • Coal firing system has been re-designed, • A digital command system has been implemented • Conveyor belts modernisation • ESP modernisation 0.6.

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	**Suralaya Power Station (Units 1 & 2) 2x400 MW**	**Tusimice II (4x200 MW)**	**Prunerov II (5x200 MW)**	**Belchatow (12x370/380 MW)**	**Afsin Elbistan A (3x340 MW & 1x335 MW)**	**Arnot (6x350 MW)**	**Turceni (7x330 MW)**
			repaired and wear parts exchanged. • Improved Water handling process • Modernization of Electrical part and Instrumentation and control (I&C)	of cleaned flue gas in the reconstructed cooling towers	refurbishment • Electrostatic precipitator refurbishment • New Distributed Control System, • New Flue gas heat exchanger.		burner nozzles were installed. • Up-gradation of Superheater and Reheater Materials	
3.	Finalisation of Scope of Work for R&M	The scope of work was finalized after Life Cycle Management Process/ Residual Life Assessment studies were undertaken.	Detailed studies and assessment of the plant condition was undertaken by the utility. On the basis of technical and economic study, a business plan was prepared which provided the targets of the reconstruction of	The scope of work was finalized based on detailed studies undertaken. Also, the learning of the Tusimice project were also incorporated in the preparatory work.	Feasibility & Diagnostic studies were undertaken to do a pre-assessment and this was done through hiring of consultants/suppliers	The scope of the rehabilitation component had been developed based on a comprehensive feasibility study and technical review. Technical and	Scope of Work was decided based on the detailed studies.	Pre-Feasibility and Feasibility Studies were undertaken. Further, inspections and expert appraisal were undertaken on site in order to evaluate the technical status of the equipments and to establish the upgrading measures which were to be taken.

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	**Suralaya Power Station (Units 1 & 2) 2x400 MW**	**Tusimice II (4x200 MW)**	**Prunerov II (5x200 MW)**	**Belchatow (12x370/380 MW)**	**Afsin Elbistan A (3x340 MW & 1x335 MW)**	**Arnot (6x350 MW)**	**Turceni (7x330 MW)**
			the power plant and main principles of the technical solution			Economic assessment was undertaken where extensive site inspection, performance tests on boiler, turbo generator, mills, ash precipitators was conducted.		
4.	Packaging Strategy	Not available	Packaging was done in a way that it ensured competition among different vendors leading to competitive prices and at the same time the numbers of	This project is also executed under EPC mode and Skoda Praha Invest is selected as the EPC contractor. In order to utilise the past	Packaging strategy for each of the units differed. Initially, R&M works (in case of Unit 3) were divided into large number of packages but due to coordination	Initially, approach of single consolidated packaging strategy was adopted but later on this strategy was revised. The	Entire works was awarded to single player by the utility.	Not Available

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	Suralaya Power Station (Units 1 & 2) 2x400 MW	Tusimice II (4x200 MW)	Prunerov II (5x200 MW)	Belchatow (12x370/380 MW)	Afsin Elbistan A (3x340 MW & 1x335 MW)	Arnot (6x350 MW)	Turceni (7x330 MW)
			vendors to be managed were limited.	R&M experience, suppliers of key components are being retained.	issues among different vendors and inability of the utility to manage large suppliers, works were later divided into less number of packages. Contracts for unit 5 were awarded as separate component packages while contract for unit 6, was awarded as an integrated project executed by Alstom. Similarly, contracts for unit 9-12 were awarded as separate component packages wherein Alstom undertook	single package was divided into separate supply and installation packages.		

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	**Suralaya Power Station (Units 1 & 2) 2x400 MW**	**Tusimice II (4x200 MW)**	**Prunerov II (5x200 MW)**	**Belchatow (12x370/380 MW)**	**Afsin Elbistan A (3x340 MW & 1x335 MW)**	**Arnot (6x350 MW)**	**Turceni (7x330 MW)**
					works related to turbine generator, ESP, certain BOP works etc. and Babcock would be undertook Boiler works.			
5.	Procurement Process for Selection of Consultant/ Contractor	Not Available	The EPC contractor Skoda Praha was selected on nomination basis as it is a group company. While the Sub vendors were selected through a competitive bidding process by Skoda Praha.	The EPC contractor Skoda Praha was selected on nomination basis as it is a group company. While the Sub vendors were selected through a competitive bidding process. However, some of the key vendors	Suppliers for different units were selected based on competitive bidding process.	International Competitive bidding Process was used to select vendors. However, the bidding process was cancelled and R&M works were not undertaken.	Competitive bidding Process was adopted to select the vendor	Not Available

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	**Suralaya Power Station (Units 1 & 2) 2x400 MW**	**Tusimice II (4x200 MW)**	**Prunerov II (5x200 MW)**	**Belchatow (12x370/380 MW)**	**Afsin Elbistan A (3x340 MW & 1x335 MW)**	**Arnot (6x350 MW)**	**Turceni (7x330 MW)**
				involved in R&M works of Tusimice project were retained.				
6.	Funding of R&M Projects	IFI Funding (funded by Japan Bank for International Cooperation)	Funding was through the internal sources of the utility	The source of financing for undertaking R&M works included internal resources and balance sheet financing	The source of financing for undertaking R&M works included internal resources and balance sheet financing	IFI funding (funded by The World Bank)	Not Available	Financed via a KfW loan and own financial resources
7.	Cost Benefit Analysis	Cost benefit analysis was undertaken to calculate the payback period of the capital expenditure incurred for the Rehabilitation process.	Detailed technical and economic studies were undertaken and on the basis of these studies a business plan was prepared. The decision for renewal of plant was based on the availability of	Cost benefit analysis was undertaken by the utility before executing R&M works. Cost benefit analysis linked to the life of the mine and based on the	Feasibility studies were carried out before undertaking R&M of the project.	Cost benefit analysis undertaken before bidding of the project through initially pre-feasibility study was carried out	A comprehensive study was undertaken to investigate the feasibility of an increase in capacity, up to a maximum gross output of 400 MWe per	In order to execute this Project, Pre-Feasibility and Feasibility Studies were undertaken by the utility.

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	**Suralaya Power Station (Units 1 & 2) 2x400 MW**	**Tusimice II (4x200 MW)**	**Prunerov II (5x200 MW)**	**Belchatow (12x370/380 MW)**	**Afsin Elbistan A (3x340 MW & 1x335 MW)**	**Arnot (6x350 MW)**	**Turceni (7x330 MW)**
			sufficient coal and quality of the available coal. The following two considerations were assessed: Option 1: In case of new plant, coal would be required for around 40 years Option 2: In case of modernization life of 25 years can be obtained Since, the remaining life of Libouš coal mine was only 25 years, Option 2 was selected.	availability of sufficient coal, R&M works proposed for three units only.		which established economic benefits of the project. Thereafter, a detailed feasibility study was also undertaken.	unit, and to estimate the costs. Based on the study, detailed scope of the project was prepared and decision to undertake R&M works was undertaken.	
8.	Implementation of R&M Projects	R&M was implemented in a phased manner. Phased outages for	The project implementation was divided into two stages. The	R&M works are ongoing. Time schedule for R&M of Unit 3-	In total 11 units are subjected to R&M works.	R&M works were not implemented	R&M was performed during routine major outages	Phased approach was undertaken for refurbishment of different units of the

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	**Suralaya Power Station (Units 1 & 2) 2x400 MW**	**Tusimice II (4x200 MW)**	**Prunerov II (5x200 MW)**	**Belchatow (12x370/380 MW)**	**Afsin Elbistan A (3x340 MW & 1x335 MW)**	**Arnot (6x350 MW)**	**Turceni (7x330 MW)**
	including shut down time	unit 1 and unit 2. The first unit outage began in October 2010 and successfully passed all of its performance guarantees in July, 2011. The second unit outage began in July 2011 and successfully completed its performance tests in February 2012.	first stage of the execution started in June 2007 with the shutdown of Unit 3 and 4. The Unit 3 and 4 were commissioned in February 2009 and April 2009 respectively. The trial run of these units was completed in November 2009. The second stage of the execution started in November 2009 with the shutdown of Unit 1 and 2. The trial run of Unit 2 was completed in October 2011. The trial run of Unit 1 was completed in April	5 is Sept 2012-2014.	The current modernisation programme underway at the Belchatow plant was started during 2007 and is expected to be refurbished by 2016.	.	of the six units over a three-year period. In each case, the outage length was 13 weeks. The first unit was completed by December 2007 and the last unit by December 2010.	Turceni TPP. Unit 4 was commissioned in 2004; Unit 5 was commissioned in 2006.

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	Suralaya Power Station (Units 1 & 2) 2x400 MW	Tusimice II (4x200 MW)	Prunerov II (5x200 MW)	Belchatow (12x370/380 MW)	Afsin Elbistan A (3x340 MW & 1x335 MW)	Arnot (6x350 MW)	Turceni (7x330 MW)
			2012.					
9.	Environmental safeguards	One of the objectives of undertaking R&M works was to improve the environmental performance. The project was successful and met all the initial overall objectives including reduction in NO_x emissions.	One of the objectives of undertaking R&M works was improving the environmental performance of the plant and to comply with the emission standards prescribed by the European legislation. R&M works included reconstruction of electrostatic precipitators to ensure that the concentration of solid pollutants in the output flue gases is below 100 mg/NM^3. Emissions post R&M works were	One of the objectives of undertaking R&M works was improving the environmental performance of the plant and to comply with the emission standards prescribed by the European legislation. The scope of R&M works includes installation of new electrostatic precipitators for dust removal and installation of new wet scrubbers for SO2 removal.	One of the objectives included up-gradation of boiler firing system to meet emissions requirements of less than 200 mg/Nm^3 for both CO and NO_x, as well as achieving optimum coal burn parameters within the operating load range to ensure compliance with EU Directive 2001/80/WE (Large Combustion Plant Directive).	To comply with the emission standards prescribed by the European and the Turkish Environmental legislation.	The incorporation of modern technology and the consequent increased efficiency of the plant led to significant reduction in NOx emissions. New burner nozzles were installed. The new nozzles were suitable for additional NOx reduction measures without major modification should NO_x reduction	One of the objectives of the R&M works was use of more efficient technologies, which reduces atmospheric pollution. R&M works included ESP modernization. Post R&M, particulate emissions below 50 Mg / Nm^3 were reduced.

S. No.	Parameters	Indonesia	Czech Republic		Poland	Turkey	South Africa	Romania
	Plant Name	Suralaya Power Station (Units 1 & 2) 2x400 MW	Tusimice II (4x200 MW)	Prunerov II (5x200 MW)	Belchatow (12x370/380 MW)	Afsin Elbistan A (3x340 MW & 1x335 MW)	Arnot (6x350 MW)	Turceni (7x330 MW)
			less than the emission limits provided by EU standards.				legislation be introduced in South Africa.	
10.	Measures for Guaranteed Performance post R&M	R&M was successful as it met all the pre-determined objectives	R&M was successful as it met all the pre-determined objectives. The guarantee period of 24 months for process equipment and 60 months for the civil structures start after the signature of the Protocol of the Provisional Acceptance (PAC).	In line with that of Tusimice II project.	Warranty period is three years and one warranty engineer is present at the site for any assistance during the warranty period. Stipulation of Absolute and penalised guarantees in the contract.	R&M works not implemented. One of the main concerns of the bidders were perceived risks of not being able to achieve the functional guarantees of a large scope rehabilitation works.	R&M was successful as it met all the pre-determined objectives. Suitable equipment warranties were negotiated for the scope of hardware and services being provided by Alstom together with adequate non-conformance resolution and remedy.	R&M was successful as it met all the pre-determined objectives.

Chapter - 11
Lessons for India based on review of International Best Practices in R&M

Based on the review of international best practices in R&M, this chapter presents the lessons that can be learned for India. This chapter is divided into three sections, the first presents the cost effective options for R&M based on certain parameters and ways and means through which these International practices can be adopted by the generating companies in India.

Second part presents the measures that can be used to mitigate the risks and handle technical surprises in the thermal power stations in India. Third part presents the standard menu of options/ advance technological options for energy efficiency focused rehabilitation and life extension of 210 MW and above units in thermal power stations in India.

11.1. Lessons from the International practices that can be adopted by the generating companies in India

The lessons from the international practises are presented below:

a) **Formation of Dedicated R&M cell for the project**
Strong project management team was observed to be key in successful implementation of R&M projects undertaken internationally. Based on the interactions held in Czech Republic and Poland it was observed that dedicated utility staff has been involved for the project. To ensure successful implementation of R&M on subsequent units, team or at least the project manager (and key personnel) involved in undertaking R&M projects of previous units were involved right from the beginning. The benefit of such approach is that the learning from the past experience, issues encountered etc. can be incorporated or handled in a more effective manner. Based on the above learning, it is suggested that Indian utilities while undertaking R&M works should form a dedicated R&M cell responsible for such works and frequent transfers of employees from this department should be avoided to ensure institutional capacity and memory.

b) **Creation of Dispute Resolution Mechanism**
While undertaking R&M works technical surprises do occur. The important aspect of this event is the timely resolution and action on the same. In order to handle such surprises it is important to form a joint committee (as done in case of Czech Republic) with representation from both suppliers and utility officials. In case of India, Formation of this committee is important as to arrive at an amicable and mutually acceptable solution/decision in the interest

of the completion of R&M works.

c) **Effective Quality control mechanisms by hiring quality control consultants**

In the case of South Africa it was observed that the utility undertook visits and conducted third party inspections in some of the factories of the suppliers to ensure quality of works. Ensuring quality of the works implemented is essential for the long term sustainability of the project. Stringent quality checks are generally observed to be missing in the Indian context. Therefore, it is required that while undertaking R&M works utility should engage Quality Control and Quality Assurance Consultants to ensure quality of works.

d) **Ex-post evaluation and feedback loop**

Ex-post evaluation or learning from the past experience is the most important part of the R&M project. Study of best practices reveals that the successful implementation of R&M projects depends upon the incorporation of learning from previous experiences in the subsequent projects. In the Indian context given large number of capacity due for R&M, this assumes significant importance as sharing of experience and incorporation of same can provide insights into the issues that arise during implementing R&M and thus can be tackled in a more effective and informed manner in future projects.

e) **Phased approach to R&M works**

From the international review it is observed that while undertaking R&M for multiple units, a phased approach is adopted wherein R&M is undertaken on certain units and rest of the units are in operation. This approach requires meticulous planning at the start of the project as it involves continued use of common facilities in some parts of the plants, and segregation of other parts where R&M is being performed. Adoption of phased approach has the twin benefits i.e. feedback and learning from the initial units can be incorporated in the subsequent ones and secondly, electricity generation from the remaining units continues.

f) **Augmentation of project capacity**

International experience with regard to R&M reveals that augmentation of plant capacity through up rating of power plants is considered as an effective option to augment project capacity. However, the decision to up rate depends upon many factors such as resource security i.e. life of the coal mine, technical and economic feasibility i.e. to what extent the plant can be up rated and at what cost. The decision to augment project capacity is plant specific in nature and therefore it is suggested that before undertaking such decision detailed plant specific studies are required.

g) **Technical feasibility**

Before taking up R&M works undertaking technical feasibility studies are pre-requisites. From the international experience it is observed that such studies are being carried out before undertaking R&M works based on which a detailed scope of work is prepared. In the Indian context, it is observed that at times utility does not undertake comprehensive studies or undertake proxy assessments leading to weak or unrepresentative scope of work and sub-optimal outputs. Therefore, it is suggested that technical feasibility of different R&M options must be undertaken by the utilities before undertaking such works.

h) **Efficiency Improvement**

Efficiency improvement is a key objective and outcome for implementation of R&M works. To effectively implement R&M projects it is important to mitigate different risks and technical surprises that may occur during the implementation of R&M projects. Various measures that are required to be undertaken to address such risks is explained in detail in next section.

i) **Environmental safeguards**

Meeting environmental standards has been one of the key objectives for undertaking R&M works in the international scenario. R&M works are carried out keeping in view not only the existing standards but compliance to possible future stringent standards that may come into effect in future. Some of the interventions undertaken in this regard included installation of new electrostatic precipitators for dust removal, installation of new wet scrubbers for removal of SO_2, Redesigning of combustion system to reduce NO_x emissions etc. Therefore, it is important for successful implementation of R&M works and operation of plant thereafter environmental considerations/safeguards or interventions need to be built in while planning R&M works.

j) **Engagement of specialized agency for O&M post R&M**

Generating company can also include O&M supervision in the contract of executing agency. 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. Similar practice is also observed in the international scenario. In the case of Poland it was observed that a warranty engineer is present at the site for any assistance during the warranty period.

11.2. Measures to mitigate the risks and handle technical surprises in the thermal power stations in India

Certain risks and technical surprises were identified as part of the earlier reports of this assignment. This section presents the measures to manage each of the risk and technical surprises based on the international review. It must be noted that occurrence of technical surprises is also identified as one of the technical risks and therefore the strategy to manage technical surprises is addressed as part of the technical risk. (Refer point 16 in the Table below for measures to mitigate occurrence of technical surprises).

It is worthwhile to mention there that the lesson emanating from the review of international experience have also been incorporated in the "Guidelines for Risk Identification and Mitigation in R&M Projects in Thermal Power Stations in India" and also in the "Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them".

Table 22: Measures to manage risk and technical surprises based on international review

S. No.	Risk	Category of Risk	Measures to Manage the Risk based on International review
1	Reactive approach to identification of plant for R&M	Management Risk	It is observed that a proactive approach is being adopted for identification/selection of plant for R&M in case of international generating companies
2	Lack of long term plan (Optimal Generation Plan) and awareness of available market options	Management Risk	Based on the international review it is observed the selection criteria is driven by a mix of macro level objectives such as energy security, resource efficiency and micro level objectives such as improvement in technical parameters such as improvement in life of the plant, decrease in operational problems; economic parameter such as improvement in availability, efficiency and reliability of plant, and current/future environmental considerations such as compliance to SOx, NOx norms or decrease in carbon intensity.
3	Lack of confidence and uncertainty with regard to success of R&M projects	Market Risk	In order to ensure success and eliminate uncertainty in implementing R&M projects it is important that a phased approach to R&M be undertaken wherein the lessons and experience gained from the implementation of previous projects are incorporated in the subsequent projects. It was observed in case of Belchatow TPS,

S. No.	Risk	Category of Risk	Measures to Manage the Risk based on International review
			Poland that incorporation of learning from implementation of earlier units lead to further improvement and achievement in efficiency parameters for subsequent units compared to earlier unit efficiency targets. As R&M implementation happens in India, it is suggested that lessons learnt by various utilities / plants / suppliers should be shared, and considered in designing subsequent R&M interventions.
4	Delay in obtaining unit shut down for undertaking technical studies	Institutional Risk	Comprehensive studies are being undertaken by the generating companies before undertaking R&M projects. Such studies are conducted during annual maintenance/capital overhaul period of the plant.
5	Inadequate technical assessment/studies	Technical Risk	From the international experience it is observed that comprehensive studies are being undertaken for plants undergoing R&M. Establishment of baseline through comprehensive studies is the key for the success of R&M projects.
6	Weak analytical framework for selection of R&M options	Management Risk	From the international experience it is observed that the objectives for undertaking R&M are very clearly defined and adequate evaluation is being undertaken while selecting R&M as an option. A holistic approach is adopted, wherein decision for R&M or new plant is even being linked with the life of the resource or coal mine, besides environmental and economic conditions.
7	Appropriate Commission not apprised of the R&M project plan	Regulatory Risk	This risk was not observed in the selected international case studies undertaken as part of the study.
8	Limited capacity of utilities in undertaking R&M works	Operational Risk	From the experience of Czech Republic in implementing R&M projects, it is observed that the project manager involved in the R&M of certain units is continued to be involved for R&M of other units to ensure that lessons from previous R&M projects are incorporated into the new ones also.
9	Weakly defined	Contractual	Based on international review it is

S. No.	Risk	Category of Risk	Measures to Manage the Risk based on International review
	scope of work	Risk	observed that scope of work is prepared based on the detailed studies undertaken before the implementation of R&M works and also on past experiences and learning, thus is more clear and precise.
10	Utility unable to mobilise funds	Funding Risk	This risk was not observed in the selected international case studies undertaken as part of the study.
11	Low level of participation by the vendors in the bidding process	Market Risk	From the case studies undertaken it is observed that low level of participation is linked with the perceived risks of suppliers with regard to the R&M project. In case of Afsin Elbistan A TPS in Turkey, it was observed that level of participation of suppliers was low due to functional guarantees involved and confidence with regard to the implementation of project of such magnitude. In order to encourage participation it is important that adequate studies are undertaken to assess the condition of the plant and same is communicated/shared with the supplier. Further, a phased approach to R&M is important as it increases familiarity of the utility and supplier with regard to plant conditions and helps in building confidence.
12	Higher than expected price discovery	Market Risk	From the case studies undertaken it is observed that prices are linked with the perceived risks of suppliers with regard to the R&M project. With the increase in the familiarity of the plant condition by the suppliers, price of the R&M project tend to decrease.
13	Rebidding/Reward/Delay in award of R&M packages/contract	Market and Operational Risk	In order to timely execute R&M projects, timely award of contract is a pre-requisite. Efforts must be made to minimise time in award of contract. Further, efforts must be taken to provide all possible clarifications or address all concerns of the bidders at the bid clarification stage.
14	Implementation contract awarded to vendor involved	Management Risk	From the international review, it was observed that both scenarios existed wherein a) Studies and implementation were

S. No.	Risk	Category of Risk	Measures to Manage the Risk based on International review
	in carrying out technical studies		awarded to same vendor and b) Studies and implementation were awarded to different vendors. However, in case of India option (a) may not be appropriate due to large R&M potential in the country and it is important to develop market for both technical consultants and suppliers.
15	Weak decision-making framework	Management Risk	From the international experience it is observed that dedicated R&M cell is created to facilitate decision making. Also, to enable smooth implementation regular meetings with the suppliers are conducted. Further, to resolve any issues or concerns a dispute resolution committee is formed at the start of the project.
16	Occurrence of technical surprises	Technical Risk	It was observed that technical surprises do occur even in the international scenario. In order to minimise technical surprises it is important to carry out detailed studies at the start of the project. Further, interactions should be carried out with the plant level officials associated with the plant from long to understand the condition of the plant. In order to handle technical surprises it is important to take timely decision for the resolution of the same. Efforts should be made towards amicable resolution of disputes through formation of joint committee having representation from both suppliers and utility. Also, in case of occurrence of surprises, such variations must be recorded for future reference so that lessons may be applied in future, both on other units on the same project and on similar plant elsewhere. Further, experiences from past implementation should be built in the project preparation work of the subsequent units to minimise or address such occurrences.
17	Weak dispute	Contractual	It is important to take timely decision for

S. No.	Risk	Category of Risk	Measures to Manage the Risk based on International review
	resolution mechanism constraining the execution of work	Risk	the resolution of the same. Efforts should be made towards amicable resolution of disputes through formation of joint committee having representation from both suppliers and utility. Any variations must be recorded for future reference so that lessons may be applied in future, both on other units on the same project and on similar plant elsewhere. Further, experiences from past implementation should be built in the project preparation work of the subsequent units to minimise or address such occurrences.
18	Mismatch (or delay) in supply of critical equipment and the shutdown period	Market Risk	This risk was not observed in the selected international case studies undertaken as part of the study.
19	Weak Supervision, Quality Control And Assurance	Operational Risk	In the case of South Africa it was observed that the utility undertook visits and conducted third party inspections in some of the factories of the suppliers to ensure quality of works. Ensuring quality of the works implemented is essential for the long term sustainability of the project. Stringent quality checks are generally observed to be missing in the Indian context. Therefore, it is required that while undertaking R&M works utility should engage Quality Control and Quality Assurance Consultants to ensure quality of works.
20	Failure to comply with environmental standards and perceived negative externalities	Socio-Environmental Risk	Meeting environmental standards has been one of the key objectives for undertaking R&M works in the international scenario. R&M works are carried out keeping in view not only the existing standards but compliance to possible future stringent standards that may come into effect in future.
21	Delay in provisioning of obtaining unit shut down for	Institutional Risk	Obtaining shutdown has not been observed as a concern in the international scenario.

S. No.	Risk	Category of Risk	Measures to Manage the Risk based on International review
	executing R&M works		
22	Sustainability of R&M gains affected by weak O&M practices	Operational Risk	This risk was not observed in the selected international case studies undertaken as part of the study.
23	Post R&M guarantees not achieved	Technical Risk	Guarantees have been an important part of R&M works and are observed to be part of every contract. There are both absolute and penalised guarantees being built into the contract that are required to be met by the suppliers. Generating company can also include O&M supervision in the contract of executing agency. However, a right mix of balance needs to be ensured between performance and guarantees. In the case of Poland it was observed that a warranty engineer is present at the site for any assistance during the warranty period.
24	Non-approval of costs incurred during R&M	Regulatory Risk	This risk was not observed in the selected international case studies undertaken as part of the study.
25	Absence of ex-post evaluation and feedback loop	Operational Risk	Ex-post evaluation or learning from the past experience is the most important part of the R&M project. Study of best practises reveals that the successful implementation of R&M projects depends upon the incorporation of learning from previous experiences in the subsequent projects. In the Indian context given large number of capacity due for R&M, this assumes significant importance as sharing of experience and incorporation of same can provide insights into the issues that arise during implementing R&M and thus can be tackled in a more effective and informed manner in future projects.

11.3. Standard menu of options for energy efficiency focused rehabilitation and life extension of 210 MW and above units in thermal power stations in India

This section presents various technological options available while undertaking refurbishment/R&M of a power plant. A range of applications/options exist for different components of the power plant that can be implemented to improve the overall efficiency of the plant. Based on the review of international experiences, this section brings out the possible/indicative/achievable improvement in the efficiency or station heat rate of the unit in post R&M scenario.

Based on the review of international experience of both developed and developing countries possible interventions that can be undertaken for different components of the plant system are highlighted below:

Boiler Island

- Pulverizers and Feeder Upgrade
- Installation of Coal Drying
- Installation of dry ash extraction system
- Improved Combustion system control/optimize
- Soot blower optimization/Installation of new/intelligent soot blowers
- Low Excess Air Operation
- Replacement/Upgrade Air Pre-heater
- Replacement/Upgrade Economizer
- Improvement in FD Fan efficiency
- Improvement in ID Fan efficiency

Turbine Island

- Refurbishment/Overhaul of Turbine
- Replacement of turbine blades
- Reduction of steam leakages
- Optimization or Repair of Condensers
- Refurbishment of Boiler Feed Pump
- Refurbishment of Feed Water Heaters

Others

- Installation of new integrated Neural Network with Distributed Control System
- Installation of Variable Frequency Drives

Various studies have been undertaken in the past by different organizations to estimate the potential efficiencies that can be achieved by implementing the above mentioned measures. These studies have been undertaken for different regions of the World (including both developed and developing countries) and are based on the condition or situation of the coal based power plants in their respective regions/country. Some of the studies in this regard include:-

a) Study on "Reducing CO_2 Emissions by Improving the Efficiency of the Existing Coal-fired Power Plant Fleet",

National Energy Technology Laboratory (NETL), April 2010
NETL conducted a literature survey of over 110 of published articles and technical papers that identified potential coal-fired power plant efficiency improvement methods. Based on the literature survey the report presents range of efficiency improvement for a variety of power plant components/systems. The summary of this is presented below:

Table 23: Summary of the technological options along with efficiency potential identified by NETL for different power plant components

Power Plant Improvements	Efficiency Increase (percentage points)
Air Preheaters (optimize)	0.16 to 1.5
Ash Removal System (replace)	0.1
Boiler (increase air heater surface)	2.1
Combustion System (optimize)	0.15 to 0.84
Condenser (optimize)	0.7 to 2.4
Cooling System Performance (upgrade)	0.2 to 1
Feedwater Heaters (optimize)	0.2 to 2
Flue Gas Moisture Recovery	0.3 to 0.65
Flue Gas Heat Recovery	0.3 to 1.5
Coal Drying (Installation)	0.1 to 1.7
Process Controls (installation/improvement)	0.2 to 2
Reduction of Slag and Furnace Fouling (magnesium hydroxide injection)	0.4
Sootblower Optimization	0.1 to 0.65
Steam Leaks (reduce)	1.1
Steam Turbine (refurbish)	0.84 to 2.6

It is important to mention that the efficiency improvement indicated for various components are not additive in nature. The actual efficiency improvement affected depends on combination of interventions considered for implementation in the plant. The report also presents the average potential of around 5% for US power plants based on the operating average efficiencies of coal fired power plants in 2007 (32%) vis-à-vis the efficiency of the top 10% performing power plants in US (37%).

b) Study on "Costs And Effectiveness Of Upgrading And Refurbishing Older Coal-Fired Power Plants In Developing APEC Economies", APEC Energy Working Group, Expert Group on Clean Fossil Energy (APEC study), June 2005
Sinclair Knight Merz (SKM), Integrating Consultancy carried out a study for the Australian Greenhouse Office (AGO) in relation to the

Efficiency Standards for Power Generation measures. This report presented the efficiency improvement potential of various technological options for coal based power plants. The analysis is based on the data from the surveys of generators and plant specific data.

Table 24: Summary of the technological options along with efficiency potential identified in SKM report for different power plant components

Action	Efficiency Improvement (%)
Restore the plant to design conditions:	
Minimise boiler tramp air	0.42
Reinstate any feedheaters out of service (Plant X)	0.46
Reinstate any feedheaters out of service (Plant Y)	1.97
Refurbish feedheaters	0.84
Reduce steam leaks	1.1
Reduce turbine gland leakage	0.84
Changes to operational settings:	
Low excess air operation	1.22
Improved combustion control	0.84
Retrofit improvements:	
Coal drying with heat recovery	4.5
Extra air-heater surface in the boiler	2.1
Install new high efficiency turbine blades	0.98
Change to steam driven feed pumps	
Install variable speed drives	1.97
Install on-line condenser cleaning system	0.84
Install new cooling tower film pack	1.97
Install intermittent energisation to ESP’s	0.32

c) Study on “Coal-Fired Power Plant Heat Rate Reductions”, Sargent & Lundy LLC (S&L study), January 2009

Study by Sargent & Lundy, L.L.C. (S&L) presented various methods or options to reduce the heat rate of existing US coal fired power plants for different range of capacity sizes. The study is based on the literature review, interactions with the technology provider and the in-house expertise of S&L.

The summary of the options along with their efficiency improvement potential for 200 MW and 500 MW plants is presented in table below. The study indicated the efficiency improvement potential in BTU/kWh. For the purpose of this report these has been converted to overall efficiency potential.

Table 25: Summary of the technological options along with the efficiency potential identified in S&L report for different power plant components

Technological Options	% Improvement	
Boiler Island	**200 MW**	**500 MW**
Economizer Replacements	0.16 - 0.32	0.16 - 0.32
Implement Neural Network technology	0.16 - 0.48	0.09- 0.32
Installation of Intelligent Soot Blowers	0.09 - 0.48	0.09 - 0.29
Air Heater and Duct Leakage Control	0.03 - 0.13	0.03 - 0.13
Acid Dew Point Control	0.16 - 0.38	0.16 - 0.38
Turbine Island		
Turbine Overhaul	0.32 - 0.97	0.32 - 0.97
Optimization or Repair of Condensers	0.09 - 0.22	0.09 - 0.22
Upgrade/Rebuild Boiler Feed Pump	0.08 - 0.16	0.08 - 0.16
Flue Gas System		
Replacement of centrifugal ID fans with axial fans	0.03 - 0.16%	0.03 - 0.16
Installation of VFDs	0.06 - 0.32%	0.06 - 0.32
Installation of Combined VFD and Fan	0.03 - 0.48%	0.03 - 0.48
Modification FGD System	0 - 0.16%	0 - 0.16
Modification ESP	0 - 0.02%	0 - 0.02
Combined Environmental Controls Technology	0 - 0.21%	0 - 0.21
Cooling Tower Advanced Packing Upgrade	0 - 0.22%	0 - 0.22

d) Study on "Efficiency Standards for Power Generation", SKM – Sinclair Knight Merz Pty. Ltd, Integrating Consultancy, January 2000

The study identified technical options available to reduce CO_2 emissions from existing and planned power plants for the APEC region. The results of the study are based on the survey undertaken in the APEC economies, literature review and use of priced data base such as the World Electric Power Plants Database compiled by UDI/McGraw-Hill Energy.

The summary of the potential efficiency improvement indicated by this study is provided in table below.

Table 26: Summary of the technological options along with efficiency potential identified in APEC report for different power plant components

	Improvement	Net Efficiency Gain (% points)
Combustion System	Pulverizer and feeder upgrades	0.3
	Air preheater repair or upgrade	0.25
	Sootblower improvements	0.35
	Excess air I&C	0.2
Steam Cycle	Feedwater heater repairs	0.4
	Heat transfer tube upgrades	0.6
	Steam turbine blades	0.5
	Cycle isolation	0.5
	Condenser repairs	0.4
O&M	O&M training	
	Computerized maintenance and management systems and Reliability centered maintenance	Included in combustion and steam cycle gains. Efficient operation realized over the long term.
	Distributed control systems	
Combined Total		3.5

The estimated efficiency potential for different technological options by each of the studies is provided below.

It is important to mention that the efficiency improvement indicated for various components are not additive in nature. The actual efficiency improvement affected depends on combination of interventions considered for implementation in the plant. Also, the indicated efficiency should not be considered as achievable benchmark for any plant as actual efficiency improvement will depend on variety of factors such as current plant condition, O&M practices, interventions planned, coal quality, plant technology etc.

Based on the above standard menu of options for energy efficiency focused rehabilitation and life extension for different power plant components is presented in brief below:

Table 27: Standard menu of options for energy efficiency focused rehabilitation and life extension for different power plant components based on international review

	Technological Options		Description	Potential Efficiency Improvement (%)	Reference
Boiler Island					
Coal Handling Plant	Pulverizers and Feeder Upgrade	**Pulverizer:** *Low Speed:* - Ball and Tube Mil *Medium Speed:* - Ring and Ball Mill - Vertical Spindle Roller Mill - Bowl Mill *High Speed:* - Hammer Mill - Attrition Mill - Beater Wheel Mill **Feeder:** Volumetric Feeders Gravimetric Feeders	Improvements in pulverisers and feeder design allows better grinding of coal which leads to: • Improvement in combustion due to better fineness of coal • Reduces the amount of coal required to be burnt in boiler as carbon content in the bottom ash and in fly ash reduces.	Up to 0.3	APEC
	Upgrade Coal Drying Process	**Coal Dryers** - Rotary Dryers - Pneumatic Dryers - Fluid-bed dryers with spouted bed - Vibratory fluid-bed dryers - Shaft Dryers - Mill type Dryers	Coal Drying process reduces the moisture content in coal and improves combustion efficiency of the boiler	0.1 to 1.7	NETL

	Technological Options		Description	Potential Efficiency Improvement (%)	Reference
Ash Handling Plant	Installation of dry ash extraction system	**Bottom Ash Handling** - Water impounded Bottom Ash hopper with hydro jet pump or ash slurry pumps - Dry type Bottom Ash hopper with submerged scraper conveyor - De-watering Bin System - Pressure Pneumatic Conveying System - Dense Phase Pneumatic Conveying system **Fly Ash Handling** - Vacuum Pneumatic conveying system - Vacuum cum Pressure Pneumatic Conveying System - Dense Phase Pneumatic Conveying System	Dry Ash Handling System doesn't require water in the bottom ash removal process. It provides several benefits such as improvement in boiler efficiency, reduced thermal energy losses as the air is heated by the heat of bottom ash. Further, as the land availability is very difficult it is going to be the latest environmental norms.	Upto 0.1	NETL

	Technological Options		Description	Potential Efficiency Improvement (%)	Reference
		- Fly ash Storage Silos - Feeder ejector system - Dry mechanical conveyors			
Boiler	Improved Combustion system control/optimise	**Advanced Low NO_x Combustion System** - Low NOx Burners - Overfire Air (OFA) System **Combustion Optimisation DCS and Software** for - Fireball Centering - O2 distribution balancing - Combustion balancing	Improvement in combustion control enables proper air and coal flow leading to better heat transfer and improvement in boiler efficiency	0.15 to 0.84	NETL – SKM
	Soot blower optimisation/Installation of new/intelligent soot blowers	**Soot Blowers** - Long Retractable Soot Blowers - Wall Blowers **Intelligent Soot Blowers** **Sonic Soot Blowers**	Installation of additional/intelligent soot blowers (ISB) helps in keeping the boiler pressure parts surface clean improves furnace performance by better heat transfer and increases the longevity of tubes.	0.09 to 0.65	S&L – NETL

	Technological Options		Description	Potential Efficiency Improvement (%)	Reference
	Low Excess Air Operation		Excess of air in flue gas means that there is more air than required for combustion. If controlled and tuned, low excess air reduces heat loss from flue gas exiting the boiler and improves the efficiency.	0.2 to 1.22	APEC – SKM

Air Pre-heater	Replacement/Upgrade Air Pre-heater	**Recuperative Type**
		- Cast Iron Air Preheater
		- Plate Air Preheaters
		- Tubular Air Preheater
		
		Regenerative Type
		- Ljunstorm
		    - Bi-sector
		    - Tri-sector
		- Rothemuhle
			Replacement or up-gradation improves the efficiency due to better heat transfer from the flue gas.
			
			Extra heat surface also allows more heat to be extracted leading to maintain/lower flue gas temperature
			
			Provides better heat pickup area and increases the boiler efficiency.
				0.03 to 1.5	S&L – NETL

Economiser	Replacement/Upgrade Economiser	**Boiler Tubes** **Extended Surface** - Stud Fins - Longitudinal Fins - Helical Fins - Rectangular Fins - Baffles		0.16 to 0.32	S&L
FD Fan	Improvement in FD Fan efficiency	**Axial Fan**	Replacement of centrifugal fans with axial fans and replacement of	0.03 to 0.16 (without VFD)	S&L

<table>
<tr><th></th><th colspan="2">Technological Options</th><th>Description</th><th>Potential Efficiency Improvement (%)</th><th>Reference</th></tr>
<tr><td>ID Fan</td><td>Improvement in ID Fan efficiency</td><td>Centrifugal Fan
- Airfoil
- Backward Inclined
- Curved Backward Inclined
- Flat Backward Inclined
- Radial Tip
- Forward Curved Blades</td><td>dampers with Variable Frequency Drives (VFD) maximises efficiency and minimises operating costs by lowering the Auxiliary power consumption.</td><td>0.03 to 0.48 (with VFD)</td><td></td></tr>
<tr><td colspan="2">Turbine Island</td><td></td><td colspan="3"></td></tr>
<tr><td rowspan="3">Turbine</td><td>Refurbishment/Overhaul of Turbine</td><td rowspan="2">Reaction Type Turbine

Impulse Type Turbine</td><td rowspan="2">Technological advancement in computation in fluid dynamics has allowed the manufacturers design higher efficient turbines. In any case, whether the utilities decide to replace the entire turbine or refurbish turbine with better blades, the utility stands benefited from the enhanced performance.</td><td>0.32 to 2.6</td><td>S&L – NETL</td></tr>
<tr><td>Replacement of turbine blades</td><td>0.5 to 0.98</td><td>APEC – NETL</td></tr>
<tr><td colspan="2">Reduction of steam leakages</td><td>Steam leakages in turbine means that the steam gets wasted without doing any useful work in the turbine. Reduction in leakages like in main gland can greatly enhance the performance of the turbine output.</td><td>0.84 to 1.1</td><td>Aus – NETL</td></tr>
<tr><td>Condenser</td><td>Optimisation or Repair of Condensers</td><td>Offline/Online Condenser Cleaning</td><td>From thermodynamics point of view, the steam condensed in condenser</td><td>0.09 to 2.4</td><td>S&L – NETL</td></tr>
</table>

	Technological Options		Description	Potential Efficiency Improvement (%)	Reference
		System	should occur at lowest feasible vacuum temperature. However with time, due to degradation and fouling of condenser, installation of either offline or online condenser cleaning can greatly reduce the back pressure which results in significant reduction in heat rate.		
Boiler Feed Pump (BFP)	Refurbishment of Boiler Feed Pump		BFP consumes significant amount of auxiliary power and thus refurbishment of Boiler Feed Pump can significantly increase the reliability and availability of the unit. In addition to this turbine driven BFP's are also being used.	0.08 to 0.16	S&L
Feed Water Heaters	Refurbishment of Feed Water Heaters		Feed water heaters primarily preheat the boiler feed water and improves steam cycle efficiency by using heat from low / high pressure steam from the turbine. Refurbishment or addition of feed water heaters can significantly increase the feed water temperature	0.2 to 1.97	NETL – SKM
Others					
Control System	Installation of new integrated Neural Network with Distributed Control System (DCS)		Computer simulation model with real time measurement of plant performance from data input from DCS can help in optimising boiler performances by predicting and	0.16 to 2	S&L - NETL

	Technological Options	Description	Potential Efficiency Improvement (%)	Reference
		adapting to the different load requirement at different time of the day. The optimisation Neural Network model can be also be extended to efficient use of FGD, superheat and reheat temperature.		
Variable Frequency Drives (VFD)	Installation of Variable Frequency Drives	Variable Frequency Drives provide many advantages over varying pressure/temperature with fixed speed drives: • Increase in life of motors due to soft start • Increases the life of pumps and fans by reducing the stress and wear • Ensures high degree of accuracy due to accurate speed control and quick response • Increases reliability and availability of drives as it eliminates any sudden voltage dip and ensures smooth control over motors, pumps and fans.	0.06 to 1.97	S&L - SKM

Chapter - 12
Estimation of the Potential Reduction in GHG Emissions on account of Implementation of Energy Efficient R&M

12.1. What is Greenhouse Gas (GHG) Emission?

The weather and climate of the earth is driven by the energy from the sun where the earth absorbs some of the energy it receives and radiates back the rest to the atmosphere/space. However certain gases like carbon-dioxide, methane, nitrous and sulphur oxide, also known as greenhouse gases absorb some of the energy radiated from the earth and trap it in the atmosphere. These gases act as a blanket and warms up the Earth's surface substantially which affects adversely the biodiversity and ecosystem of the earth. Over the years, the emission of the greenhouse gases has been increasing at an alarming rate, mainly due to human activities. Many of the major greenhouse gases can remain in the atmosphere for tens to hundreds of years after being released and they mix in the lower atmosphere, reflecting emission effects globally. The major greenhouse gases associated with human activities are summarized in the table below:

Table 28: Source of Production for different types of Greenhouse Gases (GHG)

Greenhouse Gas	Source of production
Carbon-dioxide	Primarily the emission is through burning of fossil fuels (oil, natural gas, and coal), solid waste, and trees and wood products. Further, deforestation and soil degradation leads to increase in carbon-dioxide, whereas forestation reduces it.
Methane	Methane is emitted during the production and transport of coal, natural gas, and oil. The emission also occurs due to livestock breeding, agricultural practices and from the anaerobic decay of organic waste in municipal solid waste landfills.
Nitrous and Sulphur oxide	Main emissions are from combustion of fossil fuels and solid waste and also from agricultural and industrial activities.

Source: http://www.epa.gov/climatechange/ghgemissions/gases.html

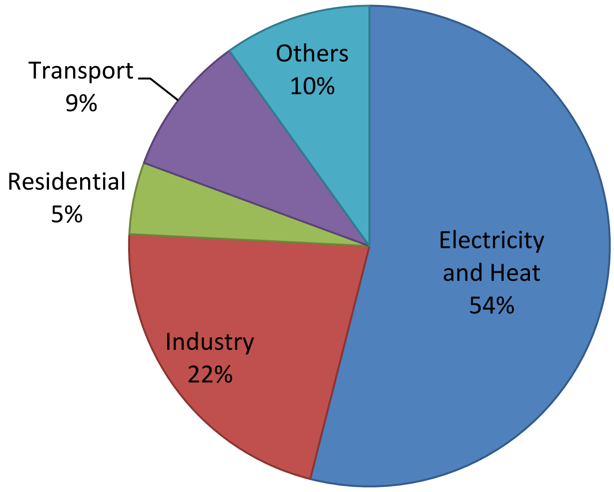
The Fourth Assessment Report of the Inter-Governmental Panel on Climate Change (IPCC) has established that it is unequivocal that Earth's climate is warming and is anthropogenic in nature. Climate change poses serious challenges to social and economic well-being of countries and it is important to reduce World's carbon footprint.

12.2. GHG Emission in the Electricity Sector

Coal dominates electricity generation in the country and is expected to continue its dominance in the short to medium term period with India planning to add 62,695 MW of coal based generation during the 12th Plan[16].

In 2009, generation of electricity accounted for more than 50% of the total CO_2 emissions from fuel combustion in India primarily due to its heavy dependence on coal.

Figure 15: India's CO_2 emissions from fuel combustion by sector in 2009



Other includes commercial/public services, agriculture/forestry, fishing, energy industries other than electricity and heat generation and other emissions not specified elsewhere.
Source: IEA 2011

Further, average efficiency of coal fired power plants in India is lower than the world average. Worldwide coal-fired power plant efficiency averaged around 35.1% in 2007 (IEA, and CIAB 2010).

The variation in efficiency is on account of variety of factors covering:

a) Technology employed i.e. sub critical, super critical or ultra-supercritical etc.
b) Vintage of the power plant
c) Low capacity plants
d) Type and quality of coal used
e) O&M practices etc.

Each of the above are explained below:

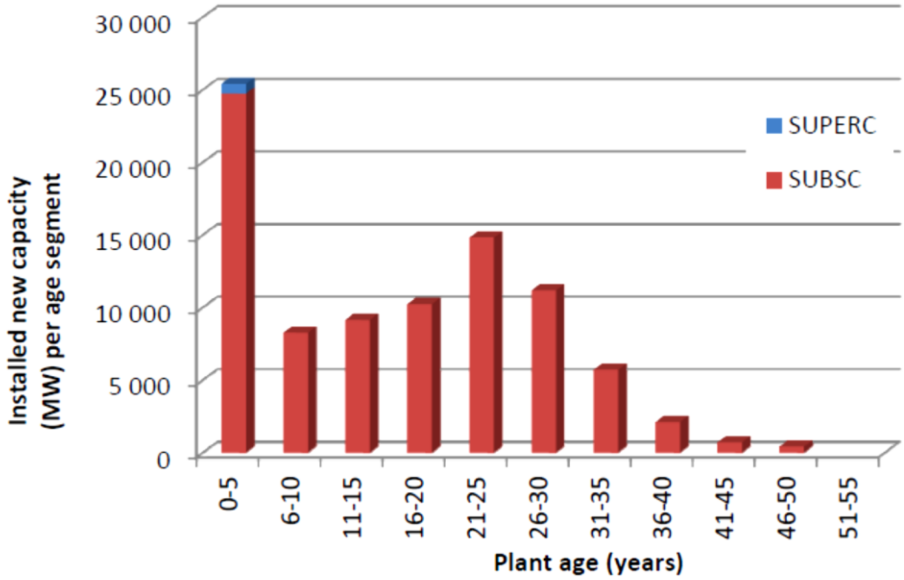
a) Technology

Efficiency to a great extent is dependent upon the technology adopted for power generation. In India most of the past installed capacity is sub critical technology

[16] Report of The Working Group on Power for Twelfth Plan (2012-17), Ministry of Power, Government of India, January 2012

with few recently commissioned super critical power plants.

Figure 16: Profile of operating fleet of coal fired power plants in India



Source: IEA 2012 (b)

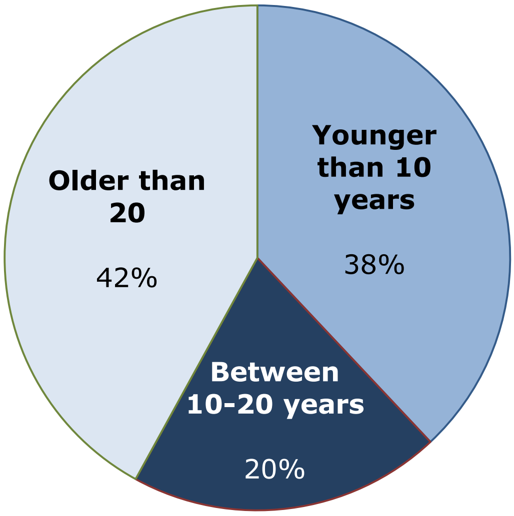
Recent advancement in super critical and ultra supercritical technology has led to higher performance levels by the coal fired power plants. Although, as of now the majority of the new power plants are sub critical, there has been increasing emphasis on the super critical technology and large numbers of recent units (under construction) are super critical units. In addition, according to the 12^{th}Plan Working Group Report on Power, 38% of the overall 12^{th}Plan capacity addition target is based on supercritical technology. Further, it is expected that 13^{th}Plan may stipulate all new coal fired plants constructed to be at least on supercritical technology.

b) Vintage

Lower levels of performance can be expected from plants of older design, although upgrades can improve even the oldest plants. For example, in case of turbine, efficiency decreases with the increase in the years of operation and in the initial years of operation this deterioration in efficiency may be relatively faster. Deterioration may be equivalent of 0.25% of heat rate per year of operation between overhauls and up to 2% in the first two years alone. However, with routine maintenance some of the deterioration can be restored. Plant performance can also be restored during major overhauls (IEA, 2010).

In India, more than 40% of the total operating coal fired power plant fleet is older than 20 years.

Figure 17: Vintage of the operating fleet of coal fired power plants in India

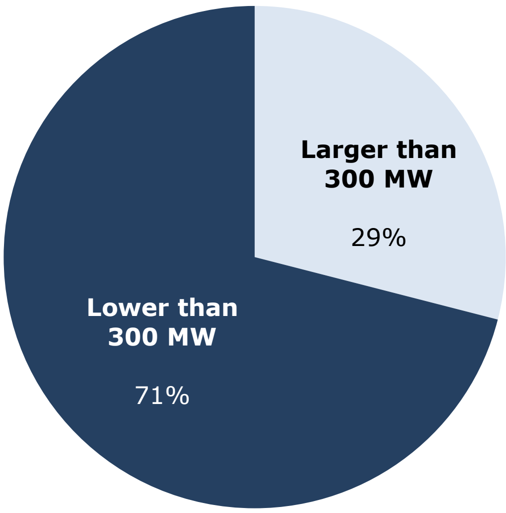


Source: IEA 2012 (b)

c) Low Capacity Plants

In India majority (more than 70%) of the total operating coal fired power plant fleet has a generation capacity below 300 MW implying lower efficiency.

Figure 18: Share of coal fired generation units in terms of capacity in India



Source: IEA 2012 (b)

d) Coal Quality

Indian coal is predominantly from the open cast mines and has high ash and high moisture content, which results in the lower plant efficiency. The typical ash content in Indian domestic coal is in the range of 30% to 45% as compared to 15-20% in most of the developed countries.

Over the years, the coal quality is degrading due to increasing ash content and due to high moisture content. The new coal mines identified are also producing inferior quality coal. Over the years, the calorific value of Indian coal has reduced from 5900 kcal/kg in 1960's to 3500 kcal/kg in the present scenario. This is one of the major reasons for low operating efficiency of coal fired power plants in the country. Poor quality of coal also leads to higher wear and tear in combustion chambers/mills etc. and leads to lower plant efficiency. In FY 2011, the generation loss due to poor coal quality was estimated to be around 5.9 Billion Units[17].

e) Plant Maintenance and Overhauls

Plant operation and maintenance is also one of the key factors in the overall efficiency of the power plant. Better O&M practices may lead to the plant operational efficiency near to the design efficiency levels.

According to the report of ESMAP titled "Strengthening Operations and Maintenance Practices in State-Sector Coal-Fired Power Generation Plants in India":

> *Operational practices among state-sector power generation utilities in India display a wide spectrum, with some of the better managed utilities exhibiting superior systems and procedures, while most of the remaining have critical gaps in several key operational areas, leading to reduced plant performance in terms of availability, generation and energy efficiency. Further, absence of adequate condition monitoring systems leads to reactive maintenance practices rather than pro-active maintenance practices.*

It can be observed from above that the current efficiency of coal based power plants in India is well below the state of art and it is important to improve the overall efficiency of power plants by improving existing plants through Renovation and Modernisation (R&M) or by installing new systems based on advanced technologies. Improving the efficiency of coal based generation plants offers several benefits in terms of reduced consumption of coal, meeting energy shortages, increased access of electricity and savings in balance of payment through reduction in importation of coal. Further, as electricity accounts for majority of emissions, improvement in the efficiency of the coal based generation becomes the key policy target for reducing the GHG emissions of the country.

With the above background, the next section presents GHG emission reduction potential of EE R&M of thermal power stations in India under various scenarios.

12.3. Overall GHG Reduction Potential of R&M/LE

AF-Mercados EMI in its report titled "*Developing Markets for Implementation of R&M Schemes in Thermal Power Stations in India*" has assessed the overall market potential for R&M during the 12th and 13th Five Year Plan[18]. The table

[17] Central Electricity Authority, Operation Performance of Generating Stations in the Country During the Year 2011-12, April, 2012

[18] The report is available in the CEA website.

presented below provides the sector-wise breakup of the R&M/LE potential in the 12th and 13th plan as assessed in the report.

Table 29: R&M/LE Potential in 12th and 13th Plan

Sector	R&M/LE Potential	
	Capacity (MW)	Units
12th Five Year Plan[19]		
State Sector Central Sector	18,360 16,350	89 55
Sub-total 12th Plan	**34,710**	**144**
13th Five Year Plan		
State Sector	8,890	39
Central Sector	5,680	20
Sub-total 13th Plan	**14,570**	**59**

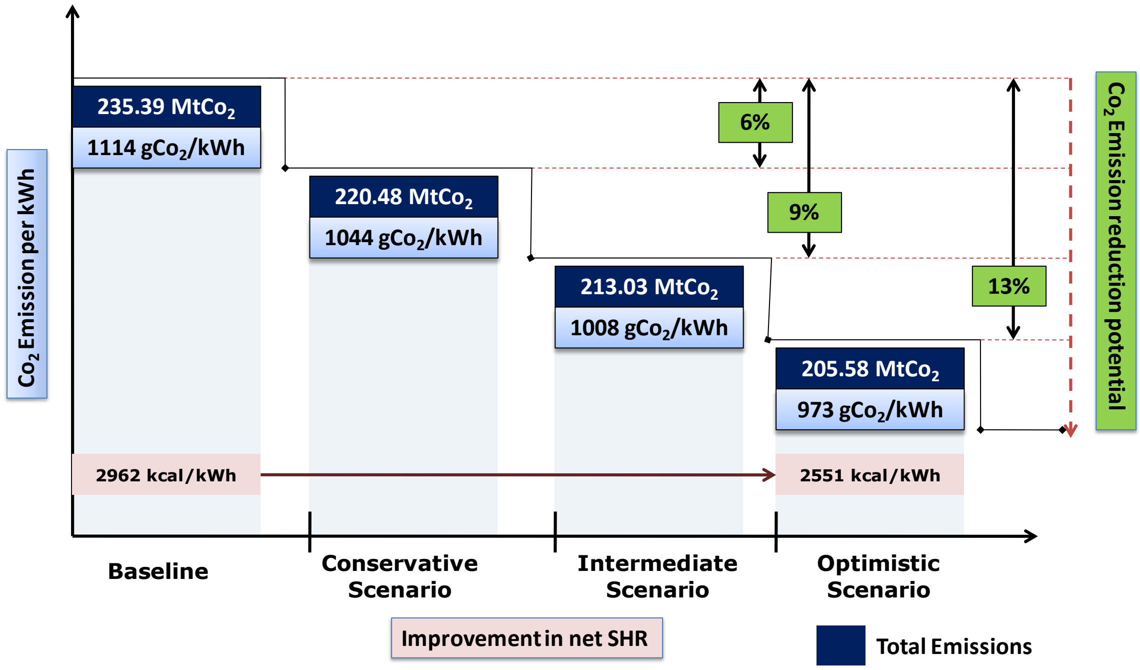
The current operating average net SHR of coal based thermal power plants assessed for R&M/LE in the 12th Plan is around 2962 kcal/kWh which translates into an efficiency of around 29.03%. If all the plants post R&M operate on their design efficiencies, the average net SHR can be improved to 2,551 kcal/kWh i.e. around 33.7%. The CO_2 emission reduction potential ranges from 6%-13% depending upon the level of average efficiency achieved post R&M/LE in the 12th Plan. In absolute terms CO_2 emission reduction potential ranges from 14.91 Mt CO_2 to 29.81 Mt CO_2 across different scenarios with respect to the Baseline.

Similarly, the operating average net SHR of around 2,926 kcal/kWh or efficiency of 29.39% in the 13th Plan which if the plants post R&M operate at designed efficiency can be improved to 2560 kcal/kWh which translates to efficiency of 33.59%.

The results of different scenarios are summarized in the figure below:

[19] This also includes slipped units (Both State and Central) from 11th Plan. Units which have completed R&M/LE during the FY- 2012-13 have not been considered while estimating GHG reduction potential.

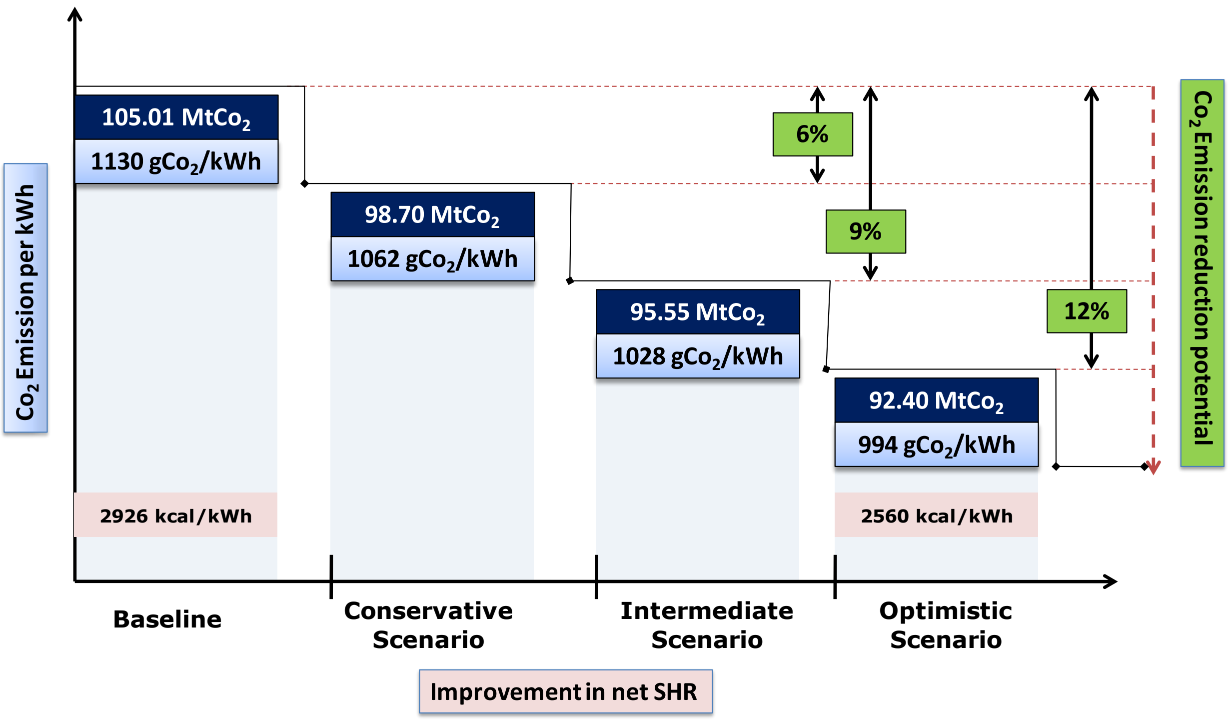
Figure 19: CO_2 emission reduction potential of coal based power plants targeted for R&M/LE in India in the 12th Plan



Source: AF-Mercados EMI analysis

Similarly, CO_2 emission reduction potential ranges from 6%-12% in the 13th Plan with absolute terms CO_2 emission reduction potential ranging from 6.31 Mt CO_2 to 12.61 Mt CO_2 across different scenarios with respect to the Baseline. The result is summarized in the figure below:

Figure 20: CO_2 emission reduction potential of coal based power plants targeted for R&M/LE in India in the 13th Plan



Source: AF-Mercados EMI analysis

12.4. GHG reduction potential of R&M/LE by state and central sector

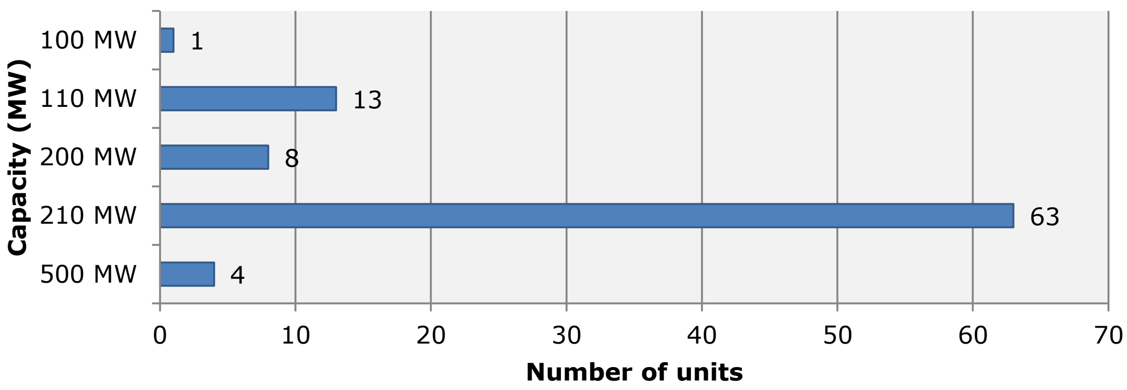
State Sector Results

a) 12th Five Year Plan

The current operating average net SHR of coal based thermal power plants targeted for R&M/LE in the 12th Plan is around 3066 kcal/kWh which translates into an efficiency of around 28.1%. If all the plants post R&M operate on their design efficiencies, the average net SHR can be improved to 2565 kcal/kWh i.e. efficiency of around 33.5%.

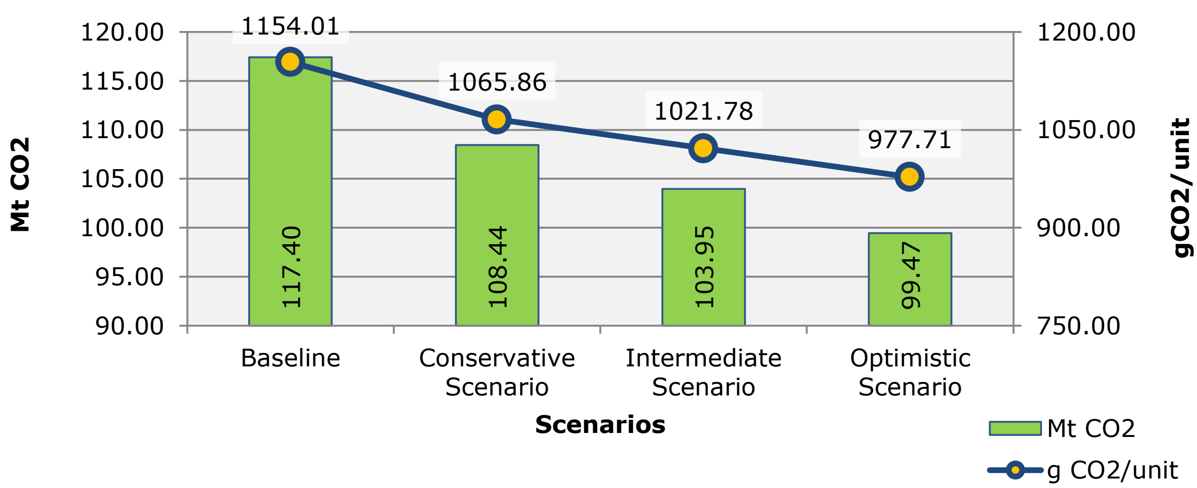
The CO_2 emission reduction potential ranges from 8%-15% depending upon the level of average efficiency achieved post R&M/LE in the 12th Plan. In absolute terms CO_2 emission reduction potential ranges from 8.96 Mt CO_2 to 17.93 Mt CO_2 across different scenarios with respect to the Baseline.

Figure 21: Capacity wise break up for state sector coal based units identified for R&M/LE during the 12th Plan



Source: AF-Mercados EMI analysis

Figure 22: CO_2 emission reduction potential through R&M/LE of coal based power plants in the state sector of India during the 12th Plan



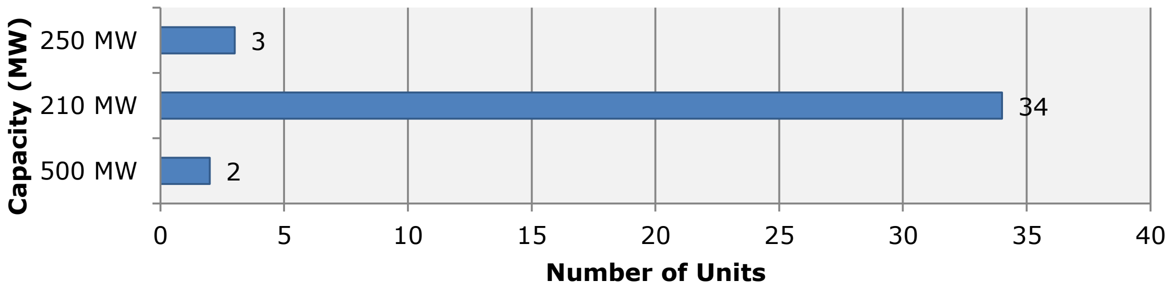
Source: AF-Mercados EMI analysis

b) 13th Five Year Plan

Similarly, for 13th Plan, the current operating average net SHR of coal based thermal power plants identified for R&M/LE is around 2915 kcal/kWh translating into an efficiency of around 29%. If all the plants post R&M operate on their design efficiencies, the average net SHR can be improved to 2546 kcal/kWh i.e. efficiency of around 34%.

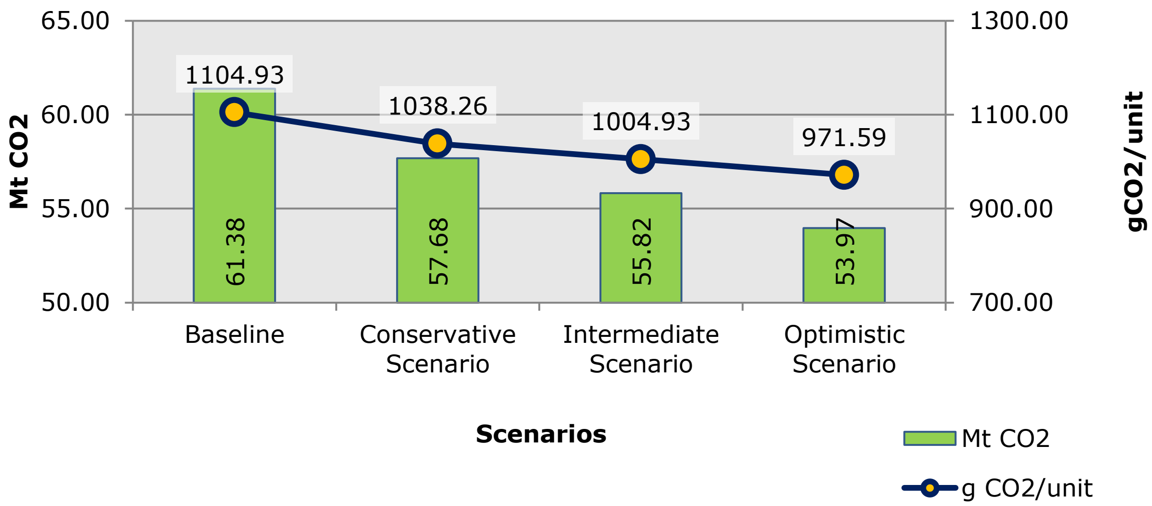
Further, CO_2 emission reduction potential ranges from 6%-12% depending upon the level of average efficiency achieved post R&M/LE in the 13th Plan. In absolute terms CO_2 emission reduction potential ranges from 3.70 Mt CO_2 to 7.41 Mt CO_2 across different scenarios with respect to the Baseline.

Figure 23: Capacity wise break up for state sector coal based units identified for R&M/LE during the 13th Plan



Source: AF-Mercados EMI analysis

Figure 24: CO_2 emission reduction potential through R&M/LE of coal based power plants in the state sector of India during the 13th Plan



Source: AF-Mercados EMI analysis

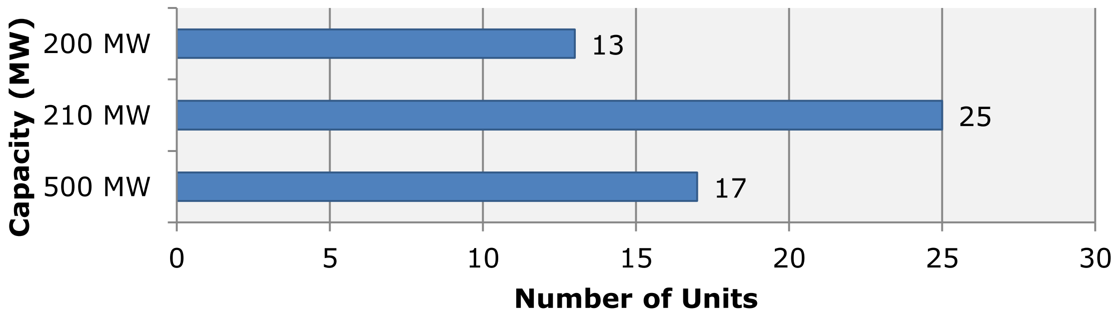
Central Sector Results

a) 12th Five Year Plan

The current operating average net SHR of coal based thermal power plants identified for R&M/LE in the 12th Plan is around 2847 kcal/kWh which translates into an efficiency of around 30%. If all the plants post R&M operate on their design efficiencies, the average net SHR can be improved to 2535 kcal/kWh i.e. efficiency of around 34%.

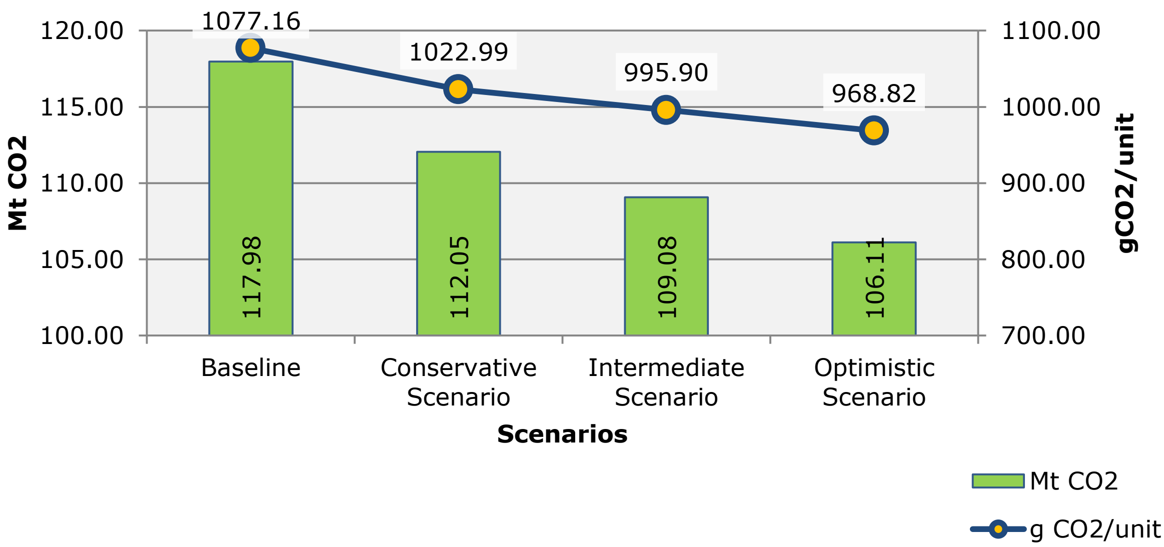
The CO_2 emission reduction potential ranges from 5%-10% depending upon the level of average efficiency achieved post R&M/LE in the 12th Plan. In absolute terms CO_2 emission reduction potential ranges from 5.93 Mt CO_2 to 11.87 Mt CO_2 across different scenarios with respect to the Baseline.

Figure 25: Capacity wise break up for central sector coal based units identified for R&M/LE during the 12th Plan



Source: CEA 2009

Figure 26: CO_2 emission reduction potential through R&M/LE of coal based power plants in the central sector of India during the 12th Plan



Source: AF-Mercados EMI analysis

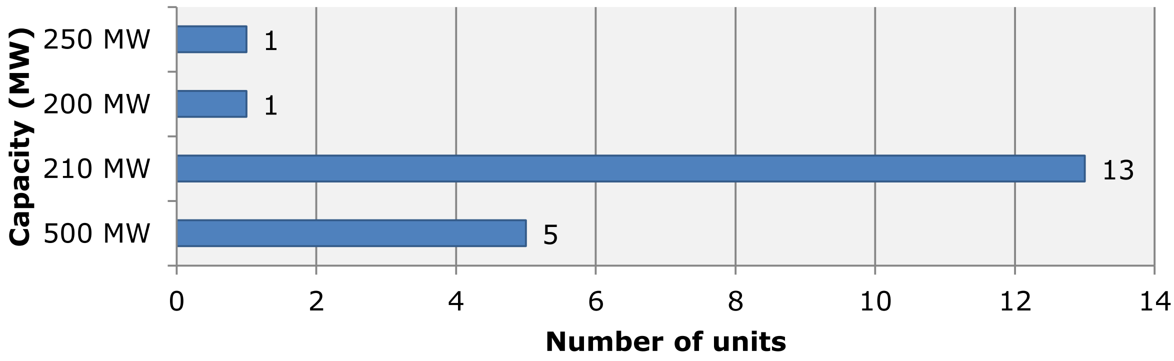
a) 13th Five Year Plan

In 13th Plan, the operating average net SHR of coal based thermal power plants identified for R&M/LE is around 2943 kcal/kWh having efficiency of around 29%. If all the plants post R&M operate on their design efficiencies, the average net

SHR can be improved to 2576 kcal/kWh i.e. efficiency of around 33%.

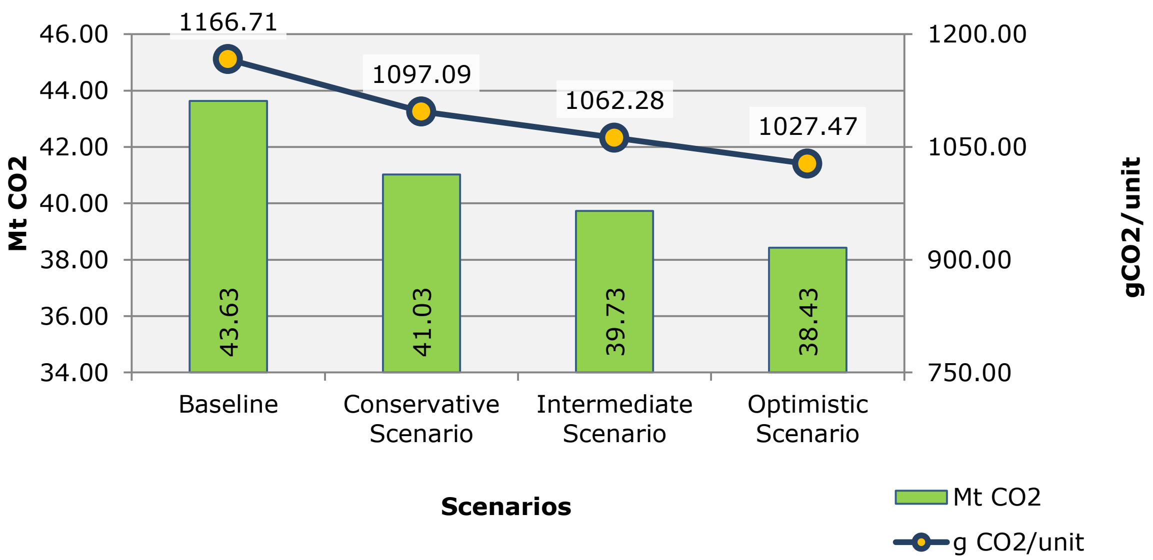
The CO_2 emission reduction potential ranges from 6%-12% depending upon the level of average efficiency achieved post R&M/LE in the 13th Plan. In absolute terms CO_2 emission reduction potential ranges from 2.6 Mt CO_2 to 5.20 Mt CO_2 across different scenarios with respect to the Baseline.

Figure 27: Capacity wise break up for central sector coal based units identified for R&M/LE during the 13th Plan



Source: AF-Mercados EMI analysis

Figure 28: CO_2 emission reduction potential through R&M/LE of coal based power plants in the central sector of India during the 13th Plan



Source: AF-Mercados EMI analysis

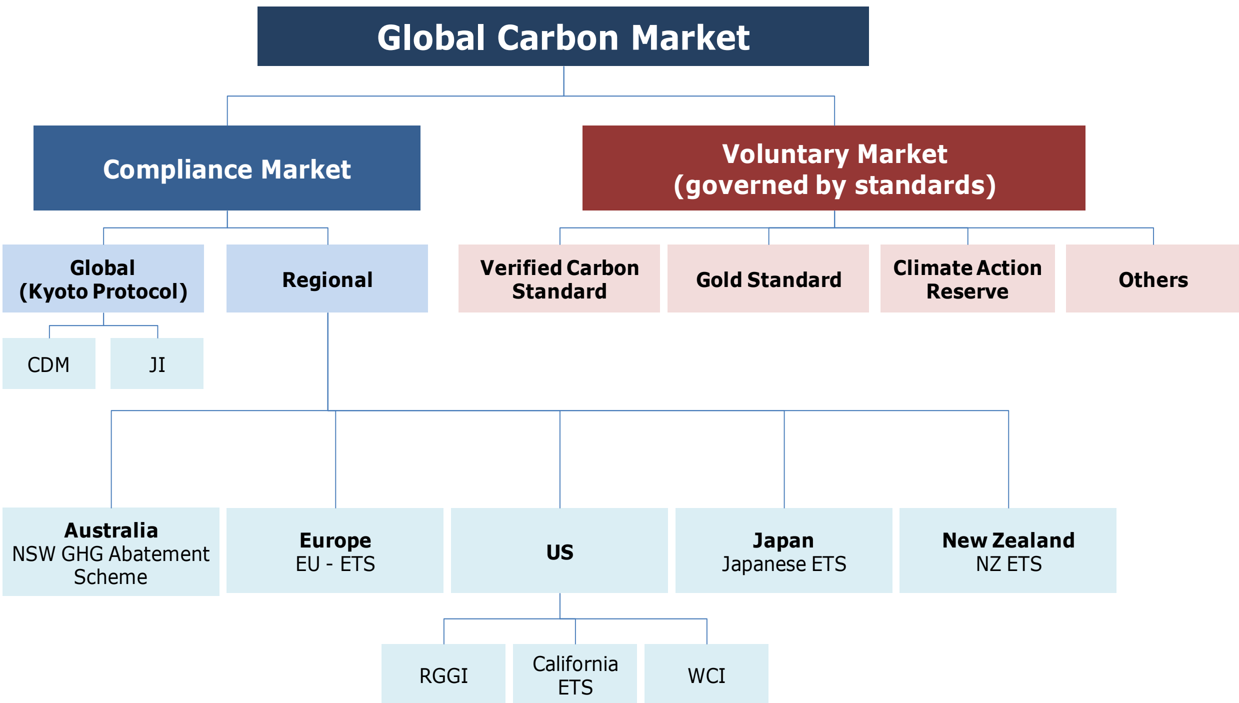
Chapter 13
Possible Framework for Monetizing the GHG Emission Reduction

This chapter presents the global carbon market mechanism and different monetising framework for R&M in India. This chapter also presents the barriers in monetizing GHG reductions from R&M measures and the related strategies to overcome the barriers.

13.1. Global Carbon Market

The Global Carbon Market comprises of both Compliance and Voluntary market as illustrated below. The compliance market was created by mandatory regional, national and international regimes whereas voluntary market exists outside the compliance markets where individuals and companies trade carbon offsets on a voluntary basis.

Figure 29: Global Carbon Market



Source: AF-Mercados EMI Compilation from United Nations Framework Convention on Climate Change (UNFCCC) and various reports

Each of the above market mechanism is explained below:

13.2. Compliance Market

Compliance Market consists of global and regional mechanisms. These are explained below:

1. Global Mechanism

Kyoto Protocol[20]

The Kyoto Protocol was signed in 1997, at the 3rd Conference of the Parties (COP 3) to the Framework Convention on Climate Change in Kyoto, Japan. This treaty provided for legally binding national caps on GHG emissions on developed countries, known as Annex 1 countries that ratified the protocol.

Each participating country is being provided with a specified number of carbon dioxide equivalent (CO_2e) emission units, termed Assigned Amount Units (AAU), which the participating country was allowed to emit during the first Kyoto commitment period (i.e. 2008-2012). The second commitment period (1st January 2013 to 31st December 2020) of Kyoto Protocol has been agreed at the Doha climate change talks, 2012.

To meet these commitments, the participating countries could either undertake a range of domestic policies and measures or acquire emission reduction credits by taking advantage of the three 'flexibility mechanisms' defined under the Protocol. These mechanisms are as follows:

i. International Emissions Trading (IET): IET is the trading of AAUs between two Annex 1 countries, while both JI and CDM are project based mechanisms.
ii. Joint Implementation (JI): JI projects allow Annex 1 parties to implement projects that reduce GHG emissions in other Annex 1 Parties.
iii. Clean Development Mechanism (CDM)[21]: The CDM allows for GHG emission reduction projects in developing countries (non-Annex 1 countries with no emission limitation targets). The emission reduction credits generated by these projects are called Certified Emission Reductions (CERs), wherein one CER equals one tonne of CO_2e.

The emission reductions from CDM and JI projects can be procured by Annex 1 countries to meet their Kyoto commitments.

2. Regional Market

In addition to Kyoto Protocol there are other numerous emission trading schemes established at the regional and national level. Some of these are explained in brief below:

[20] The Clean Development Mechanism, An Assessment of Progress, United Nations Development Programme, November 2006

[21] In the recent CDM Conference of Parties (COP) at Doha, the parties have agreed to extend the CDM mechanism for the second commitment period, which runs from 1 January 2013 to 31 December 2020. The CERs generated through the CDM projects will remain tradable in the second commitment period as well.

a) Australia - New South Wales GHG Abatement Scheme (NSW GHGAS)[22]

The NSW Greenhouse Gas Reduction Scheme (NSW GHGAS) commenced on 1 January 2003. It is one of the first mandatory greenhouse gas emissions trading schemes in the World. NSW GHGAS aims to reduce GHG emissions associated with the production and use of electricity. It achieves this by using project-based activities to offset the production of greenhouse gas emissions. NSW GHGAS establishes annual state-wide greenhouse gas reduction targets, and then requires individual electricity retailers and certain other parties who buy or sell electricity in NSW to meet mandatory benchmarks based on the size of their share of the electricity market.

b) Europe - European Union Emission Trading Scheme (EU ETS)[23]

European Union Emission Trading Scheme (EU ETS), launched in 2005 is the largest multi-country, multi-sector emission trading scheme in the World where all 27 members of European Union (EU) including Croatia, Iceland, Norway and Liechtenstein are under this umbrella. EU ETS covers more than 11,000 power stations and industrial plants in 31 countries as well as airlines. The EU ETS works on the 'cap and trade' principle. A 'cap', or limit, is set on the total amount of certain greenhouse gases that can be emitted by the factories, power plants and other installations in the system. The cap is reduced over time so that total emissions fall. In 2020, emissions from sectors covered by the EU ETS will be 21% lower than in 2005.

c) USA

i. Regional Greenhouse Gas Initiative (RGGI)[24]

Regional Greenhouse Gas Initiative (RGGI) is the first market-based regulatory program in the United States to reduce GHG emissions. RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. Together, these states have capped and will reduce CO_2 emissions from the power sector by 10 per cent by 2018. States sell nearly all emission allowances through auctions and invest proceeds in consumer benefits: energy efficiency, renewable energy, and other clean energy technologies.

ii. Western Climate Initiative (WCI)[25]

The Western Climate Initiative (WCI) is a collaboration of seven U.S. states and four Canadian provinces working together since 2007 to identify evaluate and implement policies to address the threats posed by climate change. A comprehensive strategy has

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[22] http://www.greenhousegas.nsw.gov.au/

[23] http://ec.europa.eu/clima/policies/ets/index_en.htm

[24] http://www.rggi.org/

[25] http://www.westernclimateinitiative.org/

been developed to reduce, at the regional level, GHG emissions to 15% below 2005 levels by 2020. The first phase of WCI program begins in 2012 with a three year compliance period.

iii. California Emission Trading Scheme (California ETS)[26]

In 2006, California passed a law to introduce an emission trading scheme (ETS) as part of a broad package of reforms designed to reduce the state's emissions to 1990 levels by the year 2020 with a further reduction of 50 per cent by 2050. Rules to establish California's emissions trading scheme were finalised in 2011 and the scheme will apply from 1 January 2013.

In addition to the above, many countries such as New Zealand, Japan, South Korea, China, Taiwan and Vietnam have introduced/planning to introduce carbon trading schemes.

13.3. Voluntary Market

Voluntary market provides an alternative to the compliance market wherein transactions are not driven by any country level regulations but driven by companies, NGOs and individuals who on voluntary basis purchase the carbon offsets. Trading volumes and price of carbon offsets in the compliance market is relatively higher than that of voluntary market as compliance market is driven by the obligation of the entities to purchase the offsets whereas voluntary market is driven by the voluntary wish of the entities. Currently, voluntary markets are governed by numerous mechanisms such as Verified Carbon Standard (VCS), Gold Standard, Climate Action Reserve, American Carbon Registry, ISO-14064, Plan Vivo, VER+ etc.

Out of all these mechanisms, VCS is most commonly and widely used GHG program in the global voluntary carbon market.

13.4. National Level Mechanism: Perform, Achieve and Trade (PAT)[27]

The Government of India (GOI) launched the Perform Achieve and Trade (PAT) Scheme under National Action Plan on Climate Change (NAPCC). The PAT Mechanism is a market based mechanism to further accelerate as well as incentivize energy efficiency in the large energy-intensive industries. The scheme provides the option to trade any additional certified energy savings with other Designated Consumers (DCs) to comply with the Specific Energy Consumption (SEC) reduction targets by 2014-15. The Energy Savings Certificates (ESCerts) so issued will be tradable on special trading platforms to be created in the two power exchanges - Indian Energy Exchange and Power Exchange India.

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[26] http://www.cleanenergyfuture.gov.au/why-we-need-to-act/what-others-are-doing/united-states-of-america/

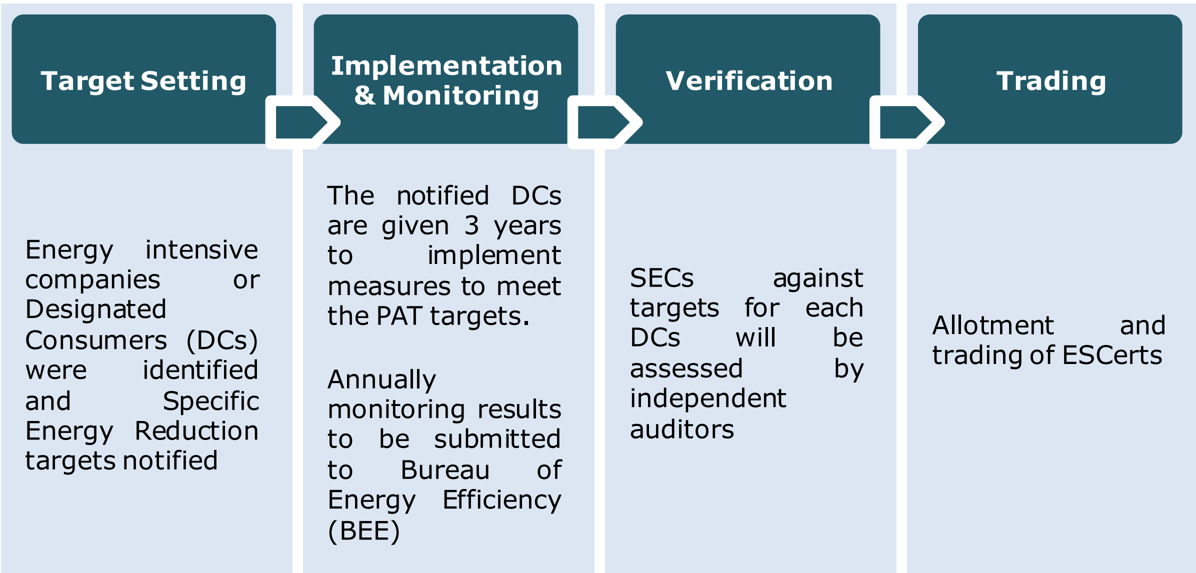
[27] PAT Perform, Achieve and Trade, Ministry of Power, Government of India, July 2012

The PAT framework has the following elements:

- Setting of Specific Energy Consumption (SEC) for each DC in the baseline year
- Target setting for reduction of SEC by target year, 2014-15 from the baseline year
- Verification process by accredited verification agency of the SEC of each DC in the baseline year and in the target year
- Issuance of Energy Savings Certificates (ESCerts) to DCs who achieved SEC lower than the specified value
- Trading of ESCerts

The figure below illustrates the phase-wise scheme of Perform, Achieve and Trade (PAT).

Figure 30: Perform, Achieve and Trade Scheme Phase



Target Setting Phase – In this phase, energy intensive companies, also known as Designated Consumers (DCs) were identified which will fall under the PAT Scheme. The Specific Energy Consumption (SEC) reduction targets have been notified to DCs in March 2012.

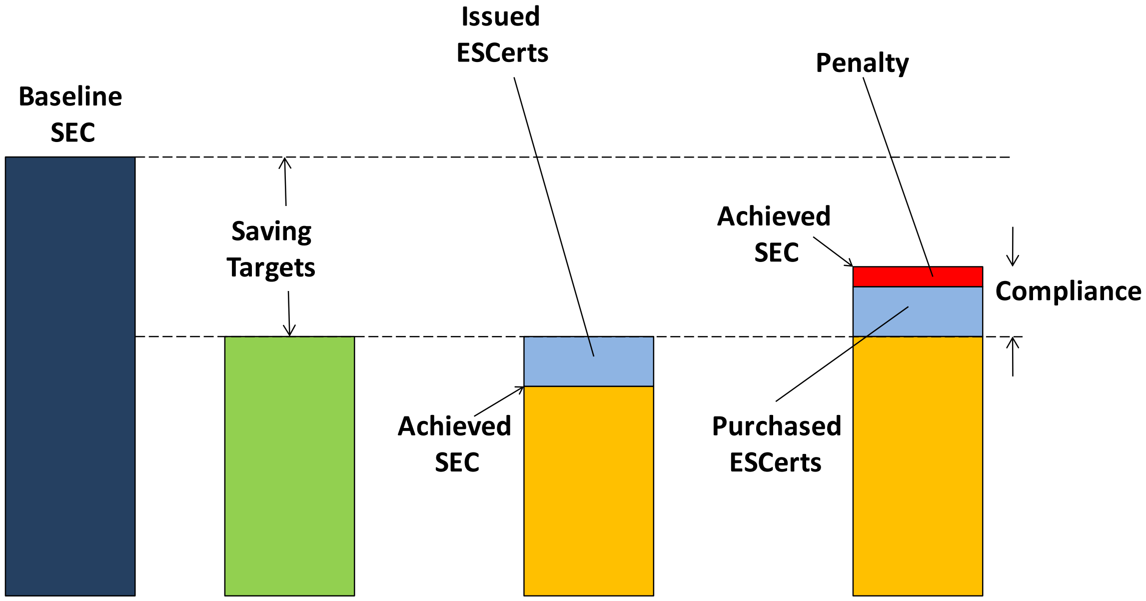
Implementation & Monitoring Phase – The notified companies or DCs are given 3 years (April 2012 – March 2015) for implementing measures to achieve their PAT targets. Annually the monitoring results are to be submitted to the Bureau of Energy Efficiency (BEE).

Verification Stage - At the end of implementation phase, the SECs against their targets will be assessed for each designated consumers by independent auditors. The verification report prepared by these auditors will be presented to Energy Efficiency Services Limited (EESL).

Trading Phase –Trading and allotment of ESCerts will take place during April

2015 – March 2016. Companies which have over achieved their targets would entail them to issue ESCerts and companies with under achieved targets will need to purchase ESCerts to fill the gap between targets and achievements. Failure to do so will attract market based penalties. The penalties would be based on the price of ESCerts and the quantum under achieved targets.

Figure 31: Concept of Target, Compliance, ESCerts and Penalty



Source: PAT Perform, Achieve and Trade, Ministry of Power, Government of India, July 2012

The PAT Scheme covers eight industry sectors (Thermal Power Plants, Fertilizers, Iron & Steel, Cement, Pulp & Paper, Aluminium, Chlor-alkali and, Textiles) based on the intensity or quantity of energy consumed.

With regard to thermal power plants, in first PAT cycle 144 designated consumers from various states have been identified for which the target have already been notified. Thermal Power Plant sector has been categorized on the basis of their fuel input i.e. gas, oil and coal/lignite based plants where there are 107 units under Coal/lignite, 33 and 4 under gas and diesel respectively. The total reported energy consumption of these designated consumers is about 104 million ton of oil equivalent. By the end of the first PAT cycle, the energy savings of 3.211 million ton of oil equivalent /year is expected to be achieved, which is around 48% of total national energy saving targets assessed under PAT. The target reduction for thermal plants has been based on the deviation of average net heat rate (2007-2010). The table below illustrates the reduction norm for the thermal plants:

Table 30: Reduction Norm for thermal power plant under PAT Scheme

Deviation in net SHR from designed net SHR	Reduction target (%) as percentage of deviation in net heat rate
Upto 5%	10%
More than 5% and upto 10%	17%

Deviation in net SHR from designed net SHR	Reduction target (%) as percentage of deviation in net heat rate
More than 10% and upto 20%	21%
More than 20%	24%

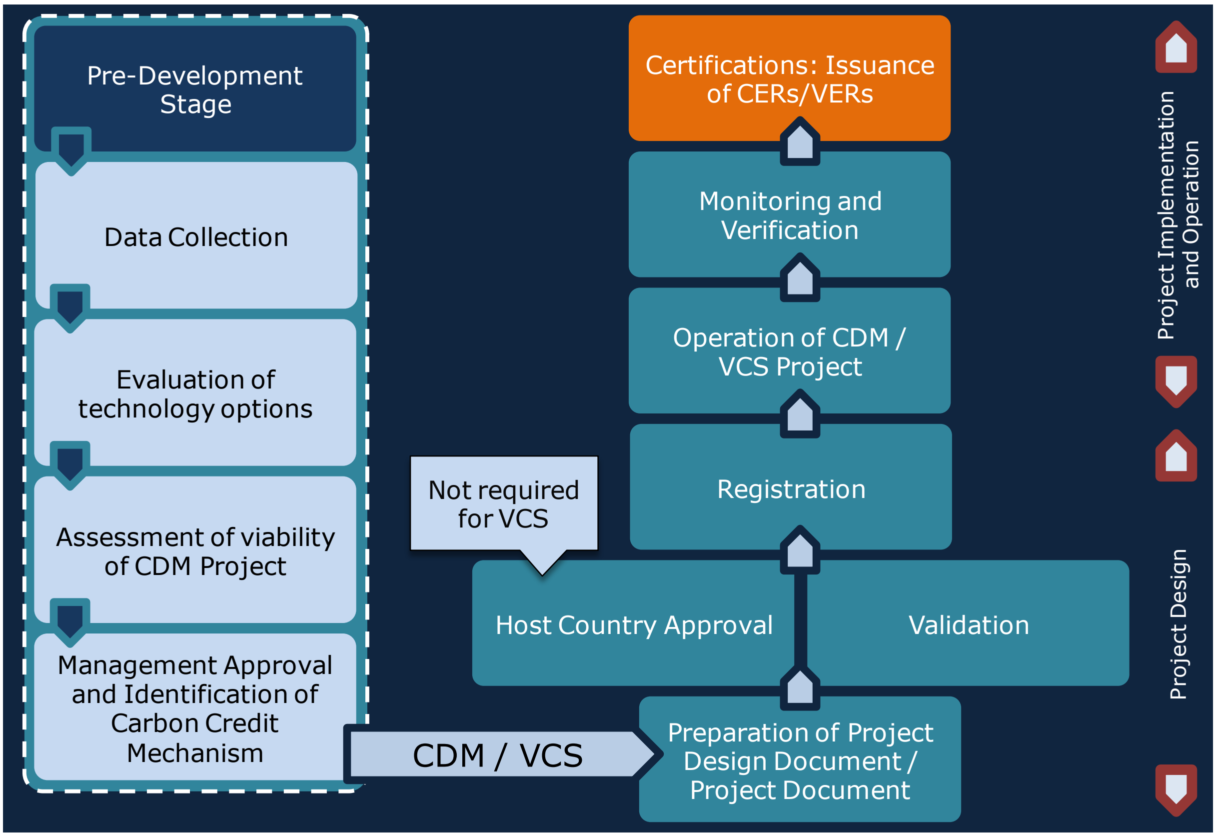
The BEE notification document of July 2012 provides the specific reduction targets for individual units.

These thermal plants can improve the efficiencies of their plants through EE R&M in order to comply with the PAT target and can become eligible for ESCerts, which can be traded at market determined prices.

13.5. Monetizing Frameworks for R&M in India

CDM and VCS are two available GHG monetisation frameworks for R&M in India. The typical procedure for registration under CDM and VCS is almost similar with one fundamental difference between them; that voluntary credit cannot be issued by an entity to meet its legal compliance obligations under the Kyoto Protocol whereas under CDM it can. It is also generally relatively easier to develop new project methodology or register new project under VCS programme than CDM of UNFCCC, as in general the validation, verification process as well as additionality requirement is less stringent for VERs from project under VCS programme than that of CERs of CDM project. The procedure for CDM and VCS is presented below:

Figure 32: Procedure for CDM and VCS



Source: - AF-Mercados EMI compilation from various sources

It is worthwhile to mention that while the CDM mechanism received strong support during the initial year of implementation with the CERs trading at high prices (~USD 20/CER). Recently, due to market distortions, the market prices crashed resulting in making CDM less attractive. The market trend recently has also moved towards regional and country level mechanism to support efficiency improvement. PAT (described already in this report) is one such mechanism available for India. Nevertheless, CDM still is a more widely available mechanism for monetizing GHG emission reduction and is described in subsequent section.

Since the aim of the report is to suggest framework for monetization of emission reduction achieved through R&M, the following section superimpose the CDM/VCS process cycle on the R&M Process Cycle (Annexure IV). Moreover, since under the VCS programme, projects may use methodologies approved under CDM, the following sections describe the monetizing framework for R&M in the context of CDM. The resultant outcome is a step by step guide for generation utilities intending to monetize emission reduction achieved through R&M.

The next section presents R&M-CDM process cycle.

13.6. R&M-CDM Process Cycle

This section details out the steps required to be undertaken by the Indian utilities for developing project under the CDM mechanism. These steps are detailed out as per different stages of R&M process cycle.

a) Identification Stage

During this stage of R&M the plant operators regularly monitor the key plant unit parameters covering at least the following aspects to identify symptoms that may necessitate R&M of power plants: (a) Plant Availability, (b) Plant Load Factor, (c) Auxiliary Consumption, (d) Emission Factors, (e) Level of Outages, (f) Life of the plant etc., (g) Frequency of annual overhaul; (h) frequency of capital overhaul etc. The diagnosis at this stage is based on available plant records and design data. Timely identification and diagnosis of problems is of critical importance and form the foundation for successful R&M of the plant in the future.

Similarly, this stage also forms foundation for developing project under the CDM. In order to initiate CDM project, it is important to establish a credible baseline for the project. Past unit wise data on parameters such as fuel consumption, electricity generation, plant load factor etc. for at least five years prior to implementation of R&M is generally required for developing the R&M project under the CDM.

b) Assessment Stage

During the assessment stage detailed technical evaluation of the plant is undertaken through conducting various studies such as Residual Life Assessment, Condition Assessment studies, Energy Audit etc. The technical evaluation of the plant is followed by the economic evaluation of the plant to decide on the most optimal option for undertaking R&M of the project. This is followed by preparation of Detailed Project Report and preparation of the scope of R&M Project for the selected option.

After the preparation of DPR, utility is required to undertake an internal analysis of the project with and without CDM benefits. Based on this analysis, a Board resolution to develop the project under CDM is required by the utility. It must be noted that to develop the project under CDM, it is required that Detailed Project Report (DPR) is prepared by an independent agency. The DPR must demonstrate that CDM benefits results in making the project viable.

c) Planning Stage

Once the scope of the project is finalised, the utility develops the design specification and proposal package and determines the procurement/bidding strategy. Planning stage covers the entire bid process management i.e. issue of tender(s), pre bid meetings, evaluation of technical and commercial bids, selection of suitable bidder, negotiation of contracts and award of R&M contracts to vendors/suppliers/OEMs.

The CDM process in this stage starts after the issuance of purchase order to the suppliers in accordance with the scope of work formulated in the previous stage.

Within 180 days of issuance of the purchase order utility is required to submit a Prior Consideration Form to UNFCCC. The purpose of this form is to submit the notification of the commencement of the project activity and the intention to seek CDM status.

After the submission of this form, utility is required to prepare the Project Design Document (PDD). The PDD contains a detailed description and specification of the proposed CDM project, including information about the project, baseline scenario and quantification methodology, monitoring plan, stakeholder comments, and environmental impacts. An essential component of the PDD is the determination of the project baseline against which emission reductions are measured. The project proponent/utility must also make the case that the project’s emission reductions are in addition to reductions that would have otherwise occurred. In order to determine the baseline scenario, UNFCCC approved methodologies may be used or a new methodology may be developed by the project proponent (for which approval from CDM EB will be required). In case of Energy Efficient R&M measures there are few existing approved methodologies to estimate GHG reduction through R&M measures such as AM 0061, AM 0062 etc. A detailed discussion on the existing approved methodologies is undertaken in the next sub-section of the report.

Preparation of PDD requires specialised knowledge, therefore it is required that utility may engage a specialised CDM consultant to prepare the PDD and to undertake various procedures as required under the CDM[28].

d) Execution Stage

This stage covers the entire R&M project implementation stage which begins with the receipt of equipments to the site and planning of shutdown of unit. This stage involves the Validation and Registration of CDM project.

After the preparation of PDD, utility is required to appoint a Designated Operational Entity (DOE), approved by the UNFCCC, for independent validation/evaluation of the project. DOE evaluates the PDD and also make the document public for stakeholder consultation/comments on the PDD.

Based on the validation and stakeholder comments, PDD is revised to reflect those comments/suggestions.

This stage also involves approval of the project from the host country and the confirmation that the project activity assists the host country in achieving sustainable development. In case of India, this approval is required from the National CDM Authority (NCDMA). NCDMA evaluates the project in the light of sustainable development objectives of the country and also assess the probability of successful implementation of CDM projects.[29]

After the successful project validation, the revised PDD along with host country approval and other details is submitted for the review of CDM Executive Board (EB) by the DOE. The CDM EB is the ultimate point of contact for CDM Project Participants for the registration of projects and the issuance of CERs.[30]

CDM EB evaluates the PDD, validation report and provides its observation on the same. These documents are also made public for receiving the comments on the same.

The CDM EB may, based on its evaluation approve the project for registration, request a project review, or reject the proposed project.

After the addressal of these comments, project is formally accepted and is registered. Registration implies that the project is now eligible for getting the CERs issued.

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[28] A designated operational entity (DOE) is an independent auditor accredited by the CDM Executive Board (CDM EB) to validate project proposals or verify whether implemented projects have achieved planned greenhouse gas emission reductions. Source: http://cdm.unfccc.int/DOE/index.html

List of DOEs: http://cdm.unfccc.int/DOE/list/index.html

Sectoral scopes related to approved methodologies and DOEs (as on 27 Dec 2012): http://cdm.unfccc.int/DOE/scopes.html

[29] http://www.cdmindia.in/constitution.php

[30] http://cdm.unfccc.int/EB/index.html

e) Closure Stage

After the R&M work is completed, it is very essential to evaluate whether the goals and objectives of the R&M project was achieved or not. For this post-R&M Performance Guarantee Test is conducted. Further, Operation and Maintenance Training is imparted to engineers for efficient operation of the unit that has undergone R&M.

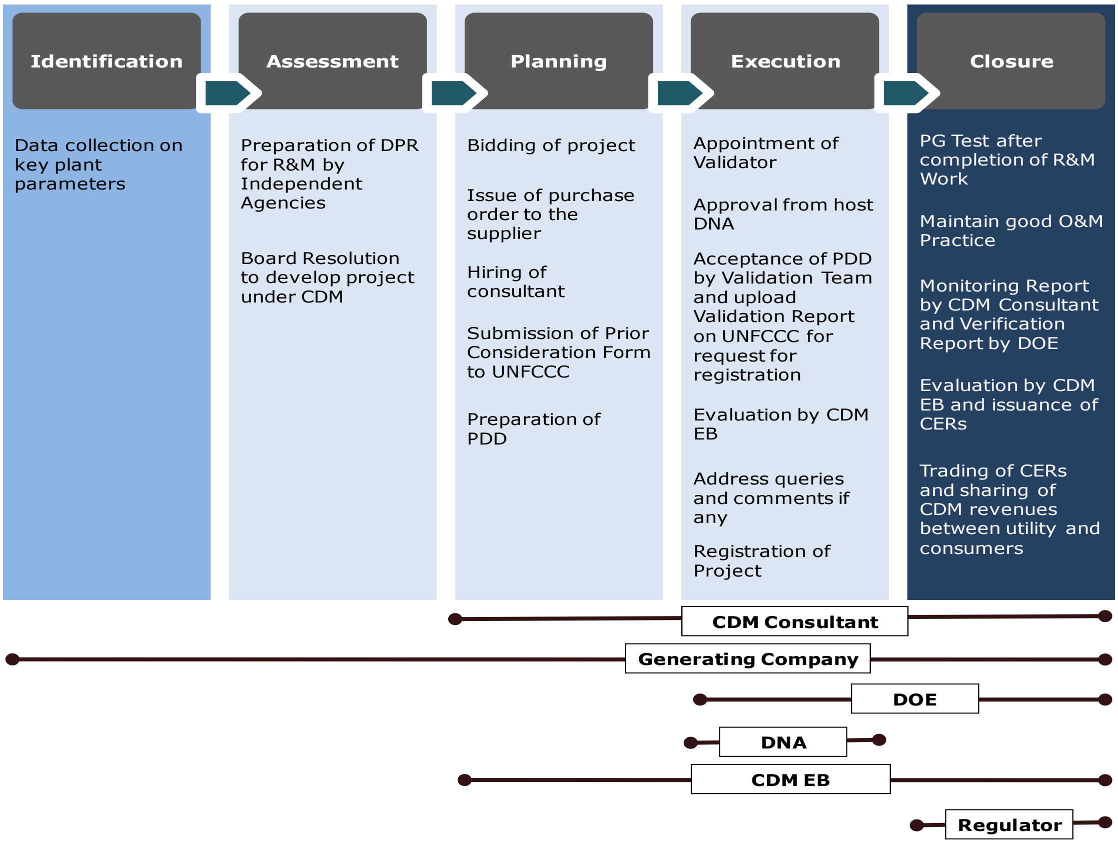
After the completion of R&M works, monitoring of the CDM project is initiated. This includes collection of the required data to quantify the actual emission reduction achieved by the project. The actual monitoring of the project must be in line with that specified in PDD.

The monitoring of the project is followed by the validation stage wherein DOE will verify the emission reduction as proposed by the monitoring report. In order to avoid conflict of interest it is important that a new DOE be appointed for verification. The time period for undertaking Verification process and issuance of CERs can be annually/monthly depending upon the volume of emission reduction or the time frame specified in the PDD.

After the submission of this report EB is requested for issuance of CERs.

It must be noted that adoption of proper O&M practises post R&M is crucial as deterioration in the performance of the plant would reduce the quantity of CERs to be issued to the utility.

Figure 33: R&M-CDM Process Cycle



Source: - AF-Mercados EMI analysis

It is important to mention that in addition to the above; utility needs to fulfil certain overall conditions of CDM in order to derive benefits from the mechanism. The key conditions that must be fulfilled for getting the CDM benefits from R&M are as follows:

i. The projects must result in real, measurable and long-term emission reductions which will be certified by a third party agency.
ii. Emission reductions must fulfil the additionality[31] clause.
iii. Projects must be in line with sustainable development objectives of the host country.
iv. Projects undertaking CDM benefits must make positive impact to sustainable use of natural resources.

Issuance of CERs is followed by the trading of CERs and sharing of the CDM benefits with the consumers, in line with that specified by the State Electricity Regulatory Commission/Central Electricity Regulatory Commission (CERC). As per CERC, Tariff Regulations 2009 – 2014, Regulation 36, the proceeds from carbon credit from approved CDM project shall be shared in the following manner:

i. 100% of the gross proceeds on account of CDM to be retained by the project developer in the first year after the date of commercial operation of the generating station or the transmission system, as the case may be;
ii. In the second year, the share of the beneficiaries shall be 10% which shall be progressively increased by 10% every year till it reaches 50%, where-after the proceeds shall be shared in equal proportion, by the generating company or the transmission licensee, as the case may be, and the beneficiaries.

For trading the CERs; the utility may opt for two methods. They may approach CDM consultants directly or they can trade in the exchange. In case, the utility opts for CDM consultant, the consultants can provide the following services:

i. Identify suitable buyers of CERs (Certified Emission Reductions)
ii. Facilitate in upfront contracting with the buyers
iii. Assist in developing the commercial terms for Emission Reduction

[31] Additionality is the requirement that the greenhouse gas emissions after implementation of a CDM project activity are lower than those that would have occurred in the most plausible alternative scenario to the implementation of the CDM project activity. The alternative scenario may be the business-as-usual case (that is, the continuation of current emission levels in the absence of the CDM project activity), or it may be some other scenario which involves a gradual lowering of emissions intensity.

Purchase Agreement (ERPA)[32]

iv. Assist in developing financial package along with the buyers to handle the risk and investment

In this approach, the utility with the help of CDM consultants can directly come into negotiations with the buyer and trade carbon credits. Alternatively, the utility can sell carbon credit in the exchange. In India, the Multi Commodity Exchange (MCX) entered into an alliance with the Chicago Climate Exchange in 2005 to introduce future carbon credit trading in India. There are certain benefits in trading carbon credit in the exchanges which are given below:

i. Hedge against price risk for sellers and intermediaries
ii. Advance selling of carbon credit can help R&M projects generate liquidity and reduce costs of implementation;
iii. MCX guarantees the trade and hence there is no counterparty risk
iv. MCX platform ensures fair price for both the buyer and the seller
v. The players are on a single platform which eliminates the laborious process of identifying either buyers or sellers with enough credibility
vi. The MCX provides immediate reference price and hence the sellers are not at the receiving end with no bargaining power

The next section elaborates on the different approved CDM methodologies which the utility can utilize for monetisation of GHG emission reduction.

It is also important to mention that while CDM currently has become relatively less attractive; the requirement of any regional mechanism that may evolve is also likely to be similar. Hence adequate preparedness on the basis of above is likely to prove useful.

13.7. Approved CDM Methodologies

The Clean Development Mechanism (CDM) requires application of a baseline and monitoring methodology in order to determine the amount of CERs generated by a mitigation project in a project host country.

There are various methodologies presented by UNFCCC for estimating the GHG reduction through different technological measures in coal based power plants. These methodologies can be classified into two groups:-

a) Methodology that covers the overall efficiency improvement in the power plant through multiple technological options incorporated under a plant R&M program. For instance, "AM0061: Methodology for rehabilitation and/or energy efficiency improvement in existing

[32] ERPA is an agreement between the buyer and seller where the responsibilities, rights and obligations to manage project risks is recorded. It also defines the commercial terms of the project including price, volume and delivery schedule of emission reductions

power plants" incorporates various technological options.

b) Methodologies that cover the individual technology option such as energy efficiency in plant auxiliary systems, boiler efficiency improvement, waste heat recovery, etc. For instance, "AM0062: Energy efficiency improvements of a power plant through retrofitting turbines" is specific to technological intervention in turbines.

Further, it must be noted that some of these methodologies are specific to power plant and the others have a wider scope but can be applied for different R&M measures as well. For instance methodologies such as "AM0061: Methodology for rehabilitation and/or energy efficiency improvement in existing power plants" and "AM0062: Energy efficiency improvements of a power plant through retrofitting turbines" are specific to power plants. While methodology such as "AM0017: Steam system efficiency improvements by replacing steam traps and returning condensate" and "AM0018: Baseline methodology for steam optimization systems" focus on steam systems and covers efficiency improvement in steam and steam optimization systems. Since such opportunities also exist in case of thermal power plants, these methodologies can be used for R&M as well.

The selection of particular methodology will depend upon the site specific conditions and type of technological interventions undertaken during R&M of the plant.

CDM projects can be classified into large scale project and small scale project depending on the scale of the projects. If utility is planning to undertake small R&M works and the expected benefit is low, then the project can be developed under small scale methodology. Further, small scale projects can be applied with simplified modalities and procedures. For small scale project, the following criteria must be fulfilled:

Technologies or measures that improve the efficiency of fossil fuel generating units that supply an electricity or thermal system by reducing energy or fuel consumption by up to the equivalent of 60 GWhe per year.

The eligible existing methodology under small scale project is given below:

Table 31: Technological Measures and Methodologies Applicable under small scale CDM for R&M Projects

Technological Measures	Methodology
Higher efficiency by reduction of fossil fuel consumption	**AMS-II.B:** Supply side energy efficiency improvements – generation

Under large scale projects some of the existing methodologies proposed by UNFCCC that can be applied to estimate GHG reduction through R&M measures are tabulated below.

Table 32: Technological Measures and Methodologies Applicable under CDM for R&M Projects

Technological Measures	Methodology
Efficient coal consumption technologies	**AM0017:** Steam system efficiency improvement
	AM0018: Steam optimization system
	AM0044: Energy efficiency improvement in boiler
	AM0056: Efficiency improvement by boiler replacement or rehabilitation
	AM0061: Methodology for rehabilitation and/or energy efficiency improvement in existing power plants
	ACM0012: Waste Heat Recovery system
Efficient turbine technologies	**AM0062:** Energy efficiency improvements of a power plant through retrofitting turbines.
	AM0061: Methodology for rehabilitation and/or energy efficiency improvement in existing power plants
Waste heat recovery technologies	**ACM0012:** Waste heat recovery system
Efficient auxiliary technologies	**AM0044:** Energy efficiency improvement in boiler

The extracts of relevant methodologies to estimate GHG emission reduction through R&M measures as provided in the CDM Methodology Booklet, 4th Edition, November 2012, UNFCCC website. These are as follows:

1. AMS-II.B: Supply side energy efficiency improvements – Generation

Applicability: Introduction of more-efficient electricity and/or thermal energy generation units or complete replacement of existing power stations, district heating plants and cogeneration units by new equipment with a higher efficiency or retrofitting of existing fossil-fuel-fired generating units in order to increase their efficiency.

Baseline case: Continuation of the current situation; i.e. use of the existing fossil-fuel-fired energy generation equipment with lower efficiency.

Project scenario: Installation of more-efficient energy generation technology and/or complete replacement of existing less-efficient equipment and/or retrofitting of an existing energy generation system reduces fossil fuel consumption and GHG emissions.

Summary of AMS-II.B methodology

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
Technologies or measures to improve the efficiency of fossil fuel generating units that supply an electricity or thermal system by reducing energy or fuel consumption by up to the equivalent of 60 GWhe per year.	Use of the existing fossil-fuel-fired energy generation equipment with lower efficiency	Installation of more-efficient energy generation technology and/or complete replacement of existing less-efficient equipment and/or retrofitting of an existing energy generation system	1. Quantity of fuel used in the energy generating equipment; 2. Quantity of energy output.

2. AM0017: Steam system efficiency improvements by replacing steam traps and returning condensate

Applicability: Optimization of steam distribution, end-use and condensate return to increase the energy efficiency of a steam system.

Baseline case: Use of fossil fuel in a boiler with a low efficiency to supply steam to a steam system.

Project scenario: Use of less fossil fuel in a boiler as less steam is required for the steam system due to improved efficiency. Improvement in the boiler operation leads to reduction in coal consumption for same output. Reduction in coal consumption means less GHG emission.

Summary of AM0017 methodology

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
1. The regular maintenance of steam traps or the return of condensate is not common practice 2. Data on the condition of steam traps and the return of condensate is accessible in at least	Use of fossil fuel in a boiler to supply steam to a steam system with a low efficiency	Use of less fossil fuel in a boiler as less steam is required for the steam system with improved efficiency.	1. Steam and condensate flow, temperature and pressure 2. Boiler efficiency 3. Electricity consumption of the project.

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
five other similar plants.			

3. AM0018: Baseline methodology for steam optimization systems

Applicability: More-efficient use of steam in a production process reduces steam consumption and thereby steam generation.

Baseline case: Use of fossil fuel in a boiler to supply steam to a process with high steam consumption.

Project scenario: Use of less fossil fuel in a boiler as less steam is required for the process with a higher efficiency. This methodology majorly covers efficiency improvement on the boiler. Improvement in the boiler operation leads to reduction in coal consumption for same output.

Summary of AM0018 methodology

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
A project activities that optimize the use of steam in a production process	Use of fossil fuel in a boiler to supply steam to a process with high steam consumption	Use of less fossil fuel in a boiler as less steam is required for the process with a higher efficiency	1. Production output 2. Corresponding steam consumption 3. Boiler efficiency 4. Steam enthalpy 5. Additional electricity / steam / fuel consumption for the project activity 6. Fuel consumption analysis and calorific values

4. AM0044: Boiler rehabilitation or replacement in industrial and district heating sectors

Applicability: Thermal energy efficiency improvement of fossil-fuel-fired boilers, at multiple locations, through rehabilitation or replacement of the boilers.

Baseline case: Boiler(s) with lower efficiency will continue to operate at multiple locations, thereby consuming high amounts of fossil fuel.

Project scenario: Efficiency of the boiler improvement through rehabilitation resulting reduction of fossil fuel consumption and related CO_2 emission.

Improvement in the boiler operation leads to reduction in coal consumption for same output.

Summary of AM0044 methodology

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
1. The boilers that are rehabilitated under the project should have some remaining lifetime 2. The installed capacity of each boiler shall be determined using a performance test in accordance with well-recognized international standards.	Boiler(s) with lower efficiency will continue to operate at multiple locations, thereby consuming high amounts of fossil fuel	The efficiency of boiler(s) is improved through their rehabilitation resulting in a reduction of fossil fuel consumption and related CO_2 emissions	1. Total thermal output of each boiler in the project. 2. Amount of fossil fuel consumed; net calorific value of fossil fuel, emission factor of fossil fuel, oxidation factor of fossil fuel in each boiler in the project.

5. AM0056: Efficiency improvement by boiler replacement or rehabilitation and optional fuel switch in fossil fuel-fired steam boiler systems

Applicability: Complete replacement of existing boilers by new boilers with a higher efficiency in an existing facility with steam demands or retrofitting of existing boilers in order to increase their efficiency; or a combination with one or both activities described above and a switch in the type of fossil fuel used to fuel boilers.

Baseline case: Continuation of the current situation; i.e. use of the existing boilers without fossil fuel switch, replacement of retrofit of the boilers.

Project scenario: Complete replacement of boilers, and/or retrofitting of an existing steam generating system results in higher efficiency and less consumption of fossil fuel (fuel switch may also be an element of the project scenario).

Summary of AM0056 methodology

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
1. Completely replace one or more boilers with some remaining	Continuation of the current situation; i.e. use of the existing boilers without fossil fuel	Complete replacement of boilers, and/or retrofitting of an existing steam	1. Quantity of fuel used in the boilers; 2. Quantity of steam produced;

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
lifetime; and/or 2. Implement fitting of additional new equipment to an existing steam generating system (retrofitting); and 3. Implement optional switch in fossil fuel.	switch, replacement of retrofit of the boilers.	generating system results in higher efficiency and less consumption of fossil fuel (fuel switch may also be an element of the project scenario	3. Temperature and pressure of the steam produced.

6. AM0061: Methodology for rehabilitation and/or energy efficiency improvement in existing power plants

Applicability: Implementation of measures to increase the energy efficiency of existing power plants that supply electricity to the grid. Examples of these measures are: the replacement of worn blades of a turbine by new ones; the implementation of new control systems; replacement of deficient heat exchangers in a boiler by new ones, or the installation of additional heat recovery units in an existing boiler.
Baseline case: Continuation of the operation of the power plant, using all power generation equipment already used prior to the implementation of the project, and undertaking business as usual maintenance.

Project scenario: Implementation of energy efficiency improvement measures or the rehabilitation of an existing fossil-fuel-fired power plant. As a result, less fossil fuel is consumed to generate electricity and less GHG emission.

Summary of methodology AM0061

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
1. The project does not involve the installation and commissioning of new electricity generation units 2. The designed power generation capacity of each unit may increase as a result of the project but	Continuation of the operation of the power plant, using all power generation equipment already used prior to the implementation of	Implementation of energy efficiency improvement measures or the rehabilitation of an existing fossil-fuel-	1. Energy efficiency of the project power plant 2. Quantity of fuel used in the project power plant;

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
this increase is limited to 15% of the former design power generation capacity of the whole plant 3. The existing power plant has an operation history of at least 10 years and data on fuel consumption and electricity generation for the most recent five years prior to the implementation of the project are available 4. Only measures that require capital investment can be included.	the project, and undertaking business as usual maintenance.	fired power plant. As a result, less fossil fuel is consumed to generate electricity.	3. Calorific value and emission factor of the fuel used in the project power plant 4. Electricity supplied to the grid by the project power plant.

7. AM0062: Energy efficiency improvements of a power plant through retrofitting turbines

Applicability: Implementation of measures to increase the energy efficiency of steam or gas turbines in existing power plants that supply electricity to the grid. Examples of these measures are: replacement of worn blades of a turbine by new ones; implementation of refined sealing to reduce leakage; replacement of complete inner blocks (steam path, rotor, inner casing, inlet nozzles).

Baseline case: Continuation of the current practise; i.e. the turbine continues to operate without retrofit.
Project scenario: Retrofitting of steam turbines and gas turbines with components of improved design to increase the energy efficiency in an existing fossil fuel power plant.

Summary of methodology AM0062

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
1. The operational parameters that affect the energy efficiency of the turbine (e.g. steam pressure and temperature, quality of steam in the case of a saturated steam turbine; condenser vacuum, and	Continuation of the current practice; i.e. the turbine continues to be operated without retrofitting	Retrofitting of steam turbines and gas turbines with components of improved design to increase the energy	1. Quantity, calorific value and emission factor of fuel used in the project power plant; 2. Electricity supplied to the

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
combustion temperature for gas turbine) remain the same, subject to a variation of +/- 5 %, in the baseline and the project scenario 2. The methodology is applicable up to the end of the lifetime of the existing turbine, if shorter than the crediting period		efficiency in an existing fossil fuel power plant. Thus, fossil fuel consumption is reduced	grid by the project power plant; 3. Enthalpy of the steam supplied to the turbine, in case of steam turbines

8. ACM0012: Consolidated baseline methodology for GHG emission reductions from waste energy recovery projects

Applicability: Project activities implemented in an existing or Greenfield facility converting waste energy into useful energy.

Baseline case: Carbon-intensive sources will continue to supply heat/electricity/ mechanical energy to the applications of the recipient facility and unrecovered energy from waste energy source will continue to be wasted.

Project scenario: Heat/ electricity/ mechanical energy are generated by recovery of energy from a waste energy source. This leads to GHG emission reduction.

Summary of methodology ACM0012

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
1. In the absence of the project, all waste energy would be flared or released into the atmosphere. 2. For capacity expansion projects, the new capacity should be treated as new facility and therefore the applicable guidance for baseline scenario determination, capping of baseline emissions and demonstration of	Carbon-intensive sources will continue to supply heat/electricity / mechanical energy to the applications of the recipient facility and unrecovered energy from waste energy source will continue to be	Heat/ electricity/ mechanical energy are generated by recovery of energy from a waste energy source and are supplied to the grid and/or applications in the recipient facility	1. Quantity of electricity/ heat supplied to the recipient plant(s). 2. Quantity and parameters of waste energy streams during project.

Applicability condition	Baseline case	Project Scenario	Parameter to be monitored
use of waste energy in absence of the CDM project, should be followed 3. An official agreement is required between the generating facility and the recipient facility of energy generated by project, in case they are different entities	wasted		

As stated earlier the project proponent can also develop/suggest a new methodology to CDM EB for its approval for the same.

13.8. Case Studies

This section presents in brief international/national case studies wherein EE R&M activities were implemented in thermal power stations and these projects were considered for CDM registration.

Under the methodology AM0061, two case studies[33] are available wherein both the projects are registered.

Similarly, under the methodology AM0062, three case studies are available, wherein two projects are registered and the other one has been rejected.

Further, at present, no projects related to thermal power plant has been registered in case of other large scale methodologies mentioned above.

It must be noted that none of the Indian R&M projects have attempted to claim CDM benefits for R&M measures in coal based thermal power plant except Budge Budge Generating Station, CESC Limited and that too under small scale methodology. Further, even internationally the exposure of energy efficiency projects especially related to in R&M of thermal power plants to CDM has been limited. Nevertheless, successful registration of few of the cases presented below highlights that possibility for availing CDM benefits do exist.

1. Case Study on Budge Budge Generating Station (BBGS), CESC Limited, under AMS-II.B Methodology

The table below presents case study on Budge Budge Generating Station (BBGS), CESC Limited which has been successfully registered and had crediting period till April 2012. Details of the project are provided below:

[33] The number of case studies is provided as on 9th July 2013 and the number of projects may vary with time.

Table 33: Case Study on Budge Budge Generating Station (BBGS), CESC Limited

Project Title	Budge Budge Generating Station (BBGS), CESC Limited
Host Country	India
Project Information	The brief background of the project is presented below:- • The basic objective of the project is to reduce energy (fuel) consumption per kWh of energy generation through implementation of energy efficient measures and technologies. • The project activity also was proactively taken up due to the related environmental benefits particularly in the form of Greenhouse Gas (GHG) emission reduction. • Various technologically advanced instruments were installed at BBGS under the energy efficiency improvement programme and the project was implemented between April 2000 and October 2001 in phases. The different components of the project activity are: ○ Replacing existing High Pressure Dosing by 'All Volatile Chemical Treatment' in Boiler ○ Modification in 'Auto Furnace Draft Control' Logic in Induced Draft (ID) Fan Vane-Scoop Combination Control
Status of project	Registered
Reference	For details refer: http://cdm.unfccc.int/Projects/DB/DNV-CUK1151074102.67/view
Emission Reduction	The total emission reductions are 3,8419 tonnes of CO_2 equivalent per annum for ten years.

2. Case Study on AzDRES Energy Efficiency Improvement under AM0061 Methodology

The table below presents case study on AzDRES Energy Efficiency Improvement project which has been successfully registered for availing CERs. Details of the project are provided below:

Table 34: Case Study on AzDRES Energy Efficiency Improvement

Project Title	AzDRES Energy Efficiency Improvement
Host Country	Azerbaijan Republic
Project Information	The brief background of the project is presented below:- • This project involved the rehabilitation of seven 300 MW power generating units in Azerbaijan and incorporation of cooling systems for the eight units. • The AzDRES facility is capable of burning heavy fuel oil and/or

Project Title	AzDRES Energy Efficiency Improvement
	natural gas. • Following R&M measures were considered in the scope of CDM: o Rehabilitation of the turbine equipment to restore its initial efficiency and modernise its command & control system; o Rehabilitation of the boilers to improve their efficiency and reduce the heat losses. o Incorporation of cooling system for all entire eight units of the power plant.
Status of project	Registered
Reference	For details refer: http://cdm.unfccc.int/Projects/DB/DNV-CUK1324273859.59/view
Emission Reduction	The emission reductions projected are 1,023,293 tonnes of CO_2 equivalent per annum for ten years.

3. Case Study on Shandong Shiheng Power Plant Energy Efficiency Improvement Project under AM0061 Methodology

The table below presents case study on Shandong Shiheng Power Plant Energy Efficiency Improvement Project which has been successfully registered for availing CERs. Details of the project are provided in brief below:

Table 35: Case Study on Shandong Shiheng Power Plant Energy Efficiency Improvement Project

Project Title	Shandong Shiheng Power Plant Energy Efficiency Improvement Project
Host Country	People's Republic of China
Project Information	The brief background of the project is presented below:- • This project involves retrofit of steam turbines on Unit 1 and 2 of 315 MW. • The following technological improvement measures were included in the project: o Replacement of the HP-IP (high-pressure and intermediate-pressure) rotors and LP (low-pressure) rotors; o Optimization design and replacement of stator blades and moving blades at HP, IP and LP levels; o Replacement of the HP-IP and LP inner casings; o Replacement of the diaphragm steam seal and nozzle

Project Title	Shandong Shiheng Power Plant Energy Efficiency Improvement Project
	block at all levels.
Status of project	Registered
Reference	http://cdm.unfccc.int/Projects/DB/BVQI1343203714.92/view
Emission Reduction	The emission reductions projected are 72,484 metric tonnes CO2 equivalent per annum.

4. Case Study on Energy Efficiency Improvement of Mae Moh Power Plant through retrofitting turbines in Thailand under AM0062 Methodology

The table below presents case study on Energy Efficiency Improvement of Mae Moh Power Plant through retrofitting turbines in Thailand which has been successfully registered for availing CERs. Details of the project are provided in brief below:

Table 36: Case Study on Energy efficiency improvements of Mae Moh Power Plant through retrofitting turbines in Thailand

Project Title	Energy Efficiency Improvement of Mae Moh Power Plant through retrofitting turbines in Thailand
Host Country	Thailand
Project Information	The brief background of the project is presented below:- The aim of the project activity is to increase the electricity generation efficiency by retrofitting turbines of units 10 and 11. The rated capacities of the turbines are 300 MW each. For the last three years, they were operated at a capacity of around 288 MW and 291MW respectively. • The following technological improvement measures were included in the project: o Retrofitting low pressure steam turbine rotor set at low pressure stage where main retrofitting parts are Low pressure rotor, reaction stage of moving blade, inner casing with stationary blades, low pressure stationary blade ring TS and GS, Diffuser TS and GS, Guide cone TS and GS and Bellow. o In the reaction stage of moving blade, the existing reaction blades are replaced by the high efficiency reaction blades and the low pressure blades are replaced by advanced low pressure blades
Status of project	Registered
Reference	http://cdm.unfccc.int/Projects/DB/TUEV-

Project Title	Energy Efficiency Improvement of Mae Moh Power Plant through retrofitting turbines in Thailand
	RHEIN1355199535.37/view
Emission Reduction	The total emission reductions are 3,94,878 metric tonnes CO2 equivalent per annum for four years..

5. Case Study on #2 Steam Turbine Retrofit Project of Tianjin Guohua Panshan Power Plant Co. Ltd. in China under AM0062 methodology

The table below presents case study on #2 Steam Turbine Retrofit Project of Tianjin Guohua Panshan Power Plant Co., Ltd which has been successfully registered for availing CERs. Details of the project are provided in brief below:

Table 37: Case Study on #2 Steam Turbine Retrofit Project of Tianjin Guohua Panshan Power Plant Co., Ltd

Project Title	#2 Steam Turbine Retrofit Project of Tianjin Guohua Panshan Power Plant Co., Ltd
Host Country	People's Republic of China

Project Information	The brief background of the project is presented below:-
	• This project involved retrofitting of two supercritical steam turbines with rated power of 500MW.
	• The following technological improvement measures were included in the project
	  ○ Retrofitting of the low pressure cylinder to promote its performance and reduce the coal consumption. The components retrofitted include rotor, blades, diaphragm and its set, inner cylinder and shaft butt seal of low pressure cylinder.
	  ○ Steam seal installed on the surrounding bend of first stage of high-pressure cylinder, steam seal of each turbine stage and shaft butt seal of high-cylinder and medium-cylinder were also altered.

Status of project	Registered
Reference	http://cdm.unfccc.int/Projects/DB/JCI1316688124.05/view
Emission Reduction	The estimated emission reduction from the project is 92,463 tCO_2e.

13.9. Barriers in Monetizing GHG Reductions from the R&M Measures

There are various barriers constraining the utility in monetizing GHG emission reduction. These are discussed in detail below:

i. **Weak data monitoring, reporting and maintenance procedures at the unit level**

Most of the utilities do not maintain data related to key performance parameters of the unit, reliability of the unit and its individual components etc. Even if such data is maintained, it is done at the plant level only and not for all the individual units. Due to the lack of historical data it may become difficult to establish credible baseline and therefore utility may not be able to develop the project for claiming CDM benefits.

ii. **Limited Capacity of Utilities with regard to CDM and other similar procedures**

The utility may not have adequate capacity or understanding of the UNFCCC mechanisms or CDM procedures and the benefits that can be availed through CDM. Due to the lack of understanding of CDM procedures, utility may not consider the option of CDM at all or even if this is considered the probability for successful registration of the project and subsequent issuance of CERs is lower. In addition, these mechanisms have been evolving from time to time and hence the utility needs to remain updated about the development.

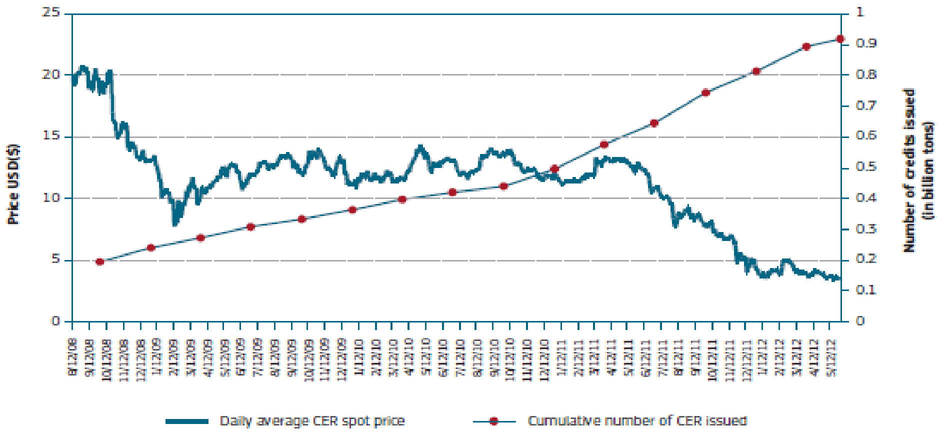
iii. **Absence of existing methodology**

Absence of existing methodology aligned to R&M interventions planned by the utility may also act as a barrier as the utility may not have requisite expertise and awareness to design, seek approval of new methodology.

iv. **Low price of CERs**

Price of CERs have declined significantly over the years which may not provide enough incentives for developing R&M/LE projects based on CDM mechanism. The figure below presents the demand and supply imbalance in the CDM market leading to decline in prices of CERs.

Figure 34: Demand and Supply Imbalance and Declining Prices of CERs



Source: Climate Change, Carbon Markets and the CDM: A Call to Action Report of the High-Level Panel on the CDM Policy Dialogue, 2012

The above has happened due to market distortions that have crept in the last few years. However, this has resulted in emergence of several regional and country based mechanisms that are likely to be available to promote efficiency improvement.

v. **Limited Exposure of R&M projects under the CDM and other similar procedures**

As explained earlier, different methodologies exists which can be applied for R&M projects, but there has been limited exposure of such projects under the CDM.

Under the methodology AM0061, two case studies are available wherein both the projects are registered. Under the methodology AM0062, three case studies are available, wherein two projects are registered and the other one has been rejected. Further, it must be noted that none of the Indian R&M projects have attempted to claim CDM benefits for R&M measures in coal based thermal power plant except Budge Budge Generating Station, CESC Limited and that too under small scale methodology. Thus, the effectiveness of CDM or other available procedures in the context of R&M of coal based thermal power stations needs to be established.

vi. **Sustainability of CERs or emission reduction benefits in light of weak O&M Practices post R&M**

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. Weak O&M practices post R&M may wipe off the benefits of R&M and the actual reduction in GHG emissions may not be in line with that envisaged during the PDD stage. Thus, the number of CERs to be issued for the project may be significantly lower or in extreme cases no CER may be issued if performance, post R&M reaches to the level of Pre- R&M scenario impacting the financial viability of the project.

13.10. Strategies for Monetising GHG Reductions from the R&M measures

The carbon price over the recent years have declined significantly, the agreements by the Parties to the Kyoto Protocol for the second commitment period of emission reductions from 2013 – 2020 is expected to provide the requisite impetus to the carbon market.

Although limited global experience exists for developing R&M/LE projects based on CDM, it would worthwhile to explore the CDM opportunities as it can provide additional revenue to the utilities. The state and central tariff regulations also incentives the utilities, wherein, utilities are allowed to retain majority part of the CDM benefits. Similarly, it is also important to explore benefits through other regional or country based mechanisms that may come up in the future. Therefore, it is important to devise strategies to overcome the challenges faced by the utilities in monetizing carbon emissions. These are detailed below:

i. **Developing pilot projects for monetization**
CEA can provide assistance in developing selected R&M/LE projects on CDM (or under other mechanism as they become available) on pilot basis. This is important as it would provide necessary guidance to the utilities with regard to procedure, methodology etc. of the CDM process or other mechanisms. The learning from the pilot project can then be shared with the utilities to enable them to develop projects for monetization.

ii. **Strengthening of internal data maintenance, acquisition and reporting in the plant**
Internal data maintenance includes regular monitoring and data collection of key operating and performance parameters such as heat rate, specific coal and oil consumption, auxiliary consumption at the unit level (besides the station level). Compilation and analysis of historical data is pre-requisite for any monetization scheme such as CDM as it enables establishment of baseline performance and GHG reduction potential.

iii. **Engaging of specialized agencies/consultants**
Specialized agencies should be engaged by the utility covering assistance on all works related to CDM or similar mechanisms. The role of consultants should be to assist the utilities with all the procedures including preparation of DPR, addressing stakeholder comments etc, during the registration stage and in monitoring the GHG reduction and issuance of carbon reduction certificates. Moreover, the consultants can assist the utilities in development and approval of new methodology in case it is required.

iv. **Preparation and implementation of O&M action plan for sustainability of efficiency improvement benefits**
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 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.

This is important as in case of CDM, registration of CDM project only implies that the project is eligible for getting the CERs but actual issuance of CERs is dependent upon the actual reduction in GHG emissions on ground.

v. **Bundling of units for CDM or other similar schemes/programs**
In case utility is undertaking R&M on multiple projects, all of these units can be bundled together for developing these projects under CDM or other similar schemes/programs. Bundling of units is beneficial as it reduces both the transaction time and cost of the project.

13.11. Incentives/Penalty for R&M projects under PAT Scheme

PAT provides requisite incentive/penalty mechanism to the utilities for undertaking R&M works.

As of now 144 plants have been included under the PAT mechanism and range of efficiency to be achieved has also been specified. The target provided as of now is not very stringent and the plants can achieve some of these targets either by improving their O&M of the plant or by undertaking small R&M works. Since O&M practises at the plant site especially in the state sector is weak, significant efficiency can be gained by just improving the O&M. The plants which have good O&M practices and are already operating at higher efficiency levels may have to undertake small R&M works to achieve the target.

However it must be noted that plants which achieve higher efficiency vis-à-vis the targets will become eligible for ESCerts which can be traded in the market leading to monetisation of the efficiency gained.

The utilities can achieve/overachieve their targets by undertaking R&M works. Thus, R&M become very important in this context as it can enable the utilities to not only achieve but overachieving targets will lead to financial gain to them.

Also going forward, at the end of first PAT cycle, targets are expected to be further strengthened and achieving targets through undertaking R&M works would remain the only viable options for the utility.

As financing and implementing R&M works takes time, it is important that utilities should initiate the requisite R&M works at the plant site to take the benefit of the incentives provided under the mechanism.

Indecisiveness from the utilities to undertake R&M works will not only lead to financial loss to the utilities in the form of penalty paid for non-achievement of targets but also leads to opportunity loss in terms of benefits that could have been accrued in case of overachievement of targets.

Thus, these actions of the utilities would enable the country to move towards low carbon footprints in line with its sustainable development priorities.

Chapter - 14
Conclusion

R&M market is still at a nascent stage in India. It encounters different kinds of risks that need to be carefully identified for each stage of R&M process cycle, which should be effectively addressed to minimise their impact. Effective implementation of R&M projects requires meticulous planning of various components/tasks. This includes undertaking in-depth technical studies for each unit proposed for execution of R&M, financial and economic evaluation of available options, creation of dedicated R&M cell with adequate manpower both at the plant level at the headquarters. Minimising delays in selection/award of contract is the most crucial step in the entire R&M process cycle as it creates a vicious circle wherein delays lead to further deterioration in the condition of plant, leading to occurrence of technical surprises having both cost and time implication and revenue loss to the utility. This not only impacts the utilities but also have negative impacts on the other stakeholders, impacting the entire R&M market. Further, ensuring the sustainability of R&M gains is critical. Various studies in the past have identified serious gaps in the O&M practices of the state utilities which negates the benefits likely from the R&M processes. Hence, adoption of a well-defined O&M improvement/action plan along with R&M is of utmost importance.

Review of international practice indicates need for proper planning through technical studies and assessments to form a project baseline. Planning is also undertaken to introduce temporary arrangements that need to be implemented to ensure smooth operation of the remaining units while other units are taken out of service for R&M. Dedicated R&M teams are formed by the utility to implement such works. Occurrence of technical surprises is common even in the international context. However, mechanisms to deal with such events in the timely manner are provided for in the contracts. Formation of joint committee of suppliers and utility officials is one of the ways to handle such surprises and issues in an amicable manner. The most important observation is the practice of ex-post evaluation and incorporation of feedback from the previous experience in the planning phase of subsequent projects. Incorporation of learning and past experience has played an important role in the successful implementation of R&M projects internationally.

The efficiency improvement achieved through R&M can also be monitored through GHG monetization frameworks i.e. Clean Development Mechanism (CDM) and Voluntary Carbon Standards (VCS). It is worthwhile to mention that while the CDM mechanism received strong support during the initial year of implementation with the CERs trading at high prices (~ USD 20/CER). Recently, due to market distortions, the market prices crashed resulting in making CDM less attractive. With the recent agreement over the second commitment period (1st January 2013 to 31st December 2020) of Kyoto Protocol during the Doha

Climate Change Talks, 2012, it is expected that in the medium to long term developing R&M/LE projects under such mechanisms would provide an attractive option to monetize GHG emission reductions. Further, the market trend recently has also moved towards regional and country level mechanisms to support efficiency improvement. Plants that have been identified in the PAT scheme can improve upon the efficiencies of their plants through R&M beyond the target levels and can become eligible for ESCerts, which can be traded at market determined prices.

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 more important in view of the shortage of fuel experienced in recent times and the necessity to optimally utilize this scarce resource. An approach that balances the risks of various parties involved is much desired.

In addition to the above, an attitudinal change that emphasizes on participatory approach between the utility and the supplier(s) is most important– *the success of contractor should be viewed as the success of the project.* Platforms for interaction among stakeholders to exchange knowledge, information and experience through various modes is as much important as the need for redressal/removal of barriers faced by various stakeholders during the R&M process.

In summary, the "Guidelines for Risk Identification and Mitigation in R&M Projects in Thermal Power Stations in India" and "Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them" developed as part of this report aims to provide direction to the utilities to minimize the risk and surprises during planning and execution of R&M. It is expected that the suggestions proposed for mitigating/avoiding various risks and surprises will facilitate successful management of R&M projects and promote the R&M market in the country.

Annexure 1

Guidelines for Risk Identification and Mitigation in R&M Projects in Thermal Power Stations in India

1. Background

1.1 Renovation & Modernisation (R&M) including Life Extension (LE) of existing old power plants is one of the most cost effective options to achieve additional generation from these plants in a short gestation period.

1.2 The importance of R&M was recognised by the Government of India way back in 1984 when Phase-I R&M Programme for 34 thermal power stations in the country was launched by the CEA as a Centrally sponsored scheme. Since then R&M option has been effectively utilised over the various plan periods. As per the National Perspective Plan of CEA, under 12th Plan, LE works have been identified on 70 thermal units of total capacity 12,066 MW and R&M works have been identified on 65 units (17,301 MW) during the 12th Plan.

1.3 Planning and implementing R&M projects is often witnessed by occurrence of adverse events that can derail the objectives of the project. Identifying and mitigating project risks are crucial steps in managing successful R&M projects. Thus, a well structured and documented Risk Management at each stage of the process is of utmost importance. Mitigation of the identified risks can significantly alter the risk profile of the R&M projects making them an attractive proposition for all stakeholders in the sector.

1.4 With the above background, the objective of the guidelines is to provide direction to the utilities in identifying and addressing the key risks faced in design and implementation of R&M in the country.

2. Concept of R&M and Life Extension Programme for Coal Fired Thermal Power Stations

2.1 Renovation and Modernisation Programme

The main objective of R&M of power generating units is to make the operating units well equipped with modified / augmented latest technology equipment /components/ systems with a view to improving 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 form a part of Operation and Maintenance (O&M) activity. Middle life R&M come up preferably after 1,00,000 hrs of operation.

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

- Generic defects
- Design deficiencies /modifications
- Avoidance of inefficient operation
- Non-availability of spares because of obsolescence of equipment/components.
- Poor quality of coal
- Major replacements of equipment arising due to unforeseen failures and /or generation sustenance not covered under regular O&M
- Stringent environmental regulation
- Safety requirements etc.

2.2 **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) involving non-destructive and destructive tests help reveal the remaining life of various critical components of plants and equipment to enable introducing measures to extend the life of the plant by a further period of about 15-20 years. 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 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 modernization 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.

2.3 **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:

- 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.
- Procurement of spare equipments.
- 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.

3. Intent of the Guidelines for Risk Identification and Mitigation Measures in R&M

3.1 The intent of these guidelines is to identify risks constraining the large scale implementation of renovation and modernization programme of coal based thermal power plants in the country. A holistic assessment of the risks has been undertaken by identifying risks occurring in different stages of R&M cycle i.e. in identification, assessment, planning, execution and closure stage and by understanding their root causes and impact.

3.2 Various strategies have been suggested to effectively handle the risk comprising strategies for risk mitigation, risk avoidance, risk sharing and risk acceptance.

4. Stages of R&M Process Cycle

Various stages of the R&M process and the activities that are undertaken at each stage are described below.

4.1 Identification Stage

During the identification stage the plant units are first identified to be diagnosed further based on certain symptoms. At this stage the plant operators regularly monitor the key plant unit parameters covering at least the following aspects to identify symptoms that may necessitate R&M of the units: (a) Plant Availability, (b) Plant Load Factor, (c) Auxiliary Consumption, (d) Emission Factors, (e) Level of Outages, (f) Life of the plant etc., (g) Frequency of annual overhaul; (h) Frequency of capital overhaul etc. The diagnosis at this stage is based on available plant records and design data. No inspections and/or testing of material, plant or equipment is involved at this stage.

4.2 Assessment Stage

During this stage systematic evaluation of the plant is undertaken through technical studies and tests. This includes the following:- (a) Residual Life Assessment (b) Complete Condition Assessment (c) Performance Evaluation Test (d) Energy Audit (e) Past History of Plant (including maintenance schedules, overhauls and assessment of O&M practices). The technical evaluation of the plant is followed by the economic evaluation of the plant to decide on the most optimal option. This includes (a) Plant retirement (b) Maintain and operate for extended time and retire subsequently (c) Capital Overhaul and refurbishment (d) R&M and Life Extension (e) R&M, LE and Up-rating. Detailed Project Report prepared for assessment of above options also includes a detailed technical and economic analysis of the identified option. This also includes assessment of the sources of fund and the phasing required for execution of R&M option. Based on the technical studies and the option selected for R&M, the scope of R&M Project is prepared. Before the tenderization process begins, utility is expected to submit the details of the assessment to the Appropriate Commission and seek its in-principle approval.

4.3 Planning Stage

Once the scope of the project is finalised, the utility develops the design specification and proposal package and determines the procurement/bidding strategy. Planning stage covers the entire bid process management i.e. issue of tender(s), pre bid meetings, evaluation of technical and commercial bids, selection of suitable bidder, negotiation of contracts and award of R&M contracts to vendors/suppliers/OEMs.

4.4 Execution Stage

This stage covers the entire R&M project implementation stage which begins with the receipt of equipments to the site and planning of shutdown of unit. This stage includes effective monitoring of work, timely decision making on bottlenecks faced, ensuring the quality of work, inspection of material and smooth implementation of work. Implementation support consultant hired by the utility plays a key role in managing all the activities covered under this stage through a structured process.

4.5 Closure Stage

After the R&M work is completed, it is very essential to evaluate whether the goals and objectives of the R&M project were achieved or not. For this post-R&M Performance Guarantee Test is conducted. Further, O&M training is imparted to engineers for efficient operation of the unit that has undergone R&M.

4.6 The indicative timeframe suggested by CEA in the National Perspective Plan for Renovation, Modernisation and Life Extension of Thermal Power Stations(Upto 2016-17) may be adopted for implementing LE&U schemes:

i. Appointment of consultant by utilities - 3 months
ii. RLA / Energy Audit - 6 months
iii. Freezing the scope of work/activities for LE&U - 3 to 4 month
iv. Preparation of DPR - 6 to 8 months

v.	Placement of order of LE&U -	6 to 8 months
vi.	Supply of critical spares -	16 to 20 months from placement of order
vii.	Shut down of unit -	6 - 8 months.

5. Risk Identification and Management Strategies

5.1. Identification Stage

The risks identified across identification stage of R&M process cycle and the strategies to handle the identified risk are presented below:

5.1.1. Reactive approach to Identification of Plant for R&M (Management Risk)

a) **Risk Description**

This risk arises due to delay in timely decision for R&M works. Ideally decision to undertake comprehensive R&M should be based on the diagnosis of the early warning symptoms. This includes diagnosis of the reasons for deterioration in plant performance parameters such as Plant Availability, Station Heat Rate (SHR), Auxiliary Consumption etc. and the ageing analysis of the unit and critical components i.e. the number of remaining years left before the plant completes its economic/designed life of operation.

b) **Root Cause Analysis**

This risk can be attributed to the weak monitoring processes at the plant and institutional level. In several cases the decision to undertake R&M is taken either when the plant is already shutdown or the performance of the unit has significantly deteriorated or the plant has outlived its economic/useful life.

c) **Impact of Risk**

This risk leads to continued deterioration in the condition of the plant and its performance. Higher is the delay in the decision to undertake R&M, more adverse is the impact on the performance of the plant which ultimately leads to longer time and higher cost for undertaking R&M of the plant.

d) **Strategy to Manage the Risk**

Strengthening of internal data acquisition, monitoring and alert systems to track unit performance (Risk Avoidance)

Some of the critical actions in this regard involve:

i. Adherence to the annual maintenance/overhaul schedule and capital overhaul schedules. This should also be accompanied by updating the maintenance log recording the history of such overhauls, key issues faced and resolutions implemented.

ii. Regular collection of unit level data pertaining to key performance parameters such as Load Factor, Availability, Turbine Heat Rate, Secondary Fuel Oil Consumption, Auxiliary

Consumption, Emissions (SO_x, NO_x etc.); reliability and condition of individual components; and flagging of warning signals in the management reports.

iii. Identification of the components/factors causing forced outages along with reasons for such failures

For this, input from O&M department is critical and recording of routine data such as material properties, geometries, crack sizing, hardness, operational parameters etc. during operation, annual/ capital maintenance, will be useful for undertaking technical studies/R&M in future.

5.1.2. Lack of Long Term Generation Plan and Awareness of Available Market Options (Management Risk)

a) **Risk Description**

Key priorities of the state in the context of energy sector are: (i) to provide adequate and affordable power to the consumers; (ii) be energy secure and environmentally benign; and (iii) ensure financially sustainable utilities. The states and the power utilities in the country must have long-term plan (Optimal Generation Plan) for achieving the above mentioned goals. The decisions related to R&M must be a consequence of this long-term plan.

The risk arises when decisions related to R&M are taken up in isolation without considering other available options.

b) **Root Cause Analysis**

The root causes for the above behaviour are as follows:

i. Lack of power sector vision at the state level and vision at the utility level

ii. Conventional focus on augmentation of new supply as a means to meet the increasing power demand

iii. Lack of awareness of possible market options

c) **Impact of Risk**

The risk results in sub-optimal investment decisions. In addition, this risk directly impacts the long term sustainability of the plant affecting its performance and availability. As a consequence, this also affects the financial performance of the generating company.

d) **Strategy to Manage the Risk**

The rationale for R&M of a project should be established at the state level taking into account all the alternative competing options. (Risk Avoidance)

R&M decision should take into account all the available market options including new power plants (at same site or at a different location), procurement of power through medium and long-term Case I bids, availability of supply from renewable energy sources, purchase from open market etc. This should form the basis of the decision i.e. whether to: (i) Retire; (ii) Maintain and Operate for few years and eventually retire; (iii) Capital Overhauling and Refurbishment; (iv) R&M and Life Extension; and (v) R&M, LE and Uprating.

The final decision of R&M should also be considered in consultation with the Discoms, wherein the refurbished plant should fit with the Discoms long-term power procurement plan and merit order schedule.

5.1.3. Lack of Confidence and Uncertainty with Regard to R&M Projects (Market Risk)

a) **Risk Description**

Due to limited experience sharing and success stories in India, a number of generating companies are uncertain about the outcomes of the R&M. Hence, appreciation of benefits associated with R&M is limited. This leads to a risk wherein the utility may not consider R&M as an option, even though it makes economic sense.

b) **Root Cause Analysis**

The root causes include:

i. Limited experience of R&M related to larger size plants especially 210 MW and above. This is critical as going forward 500 MW fleet shall also require R&M.

ii. In certain cases, post R&M performance of the plants has not been in line with that envisaged at the planning stage leading to the negative outlook of the utility towards R&M.

iii. Limited dissemination of successful cases.

iv. Success of R&M has been limited in case of earlier installed 120 MW sets in the country due to their inherent design problems.

c) **Impact of Risk**

This risk either results in delay or discarding of R&M as an option even when it would have made economic sense. This also adversely impacts the R&M market in the country.

d) **Strategy to Manage the Risk**

i. **Need for Experience Sharing (Risk Mitigation)**

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.

ii. **Need to Develop Market for R&M in the Country (Risk Avoidance)**

The CEA needs to facilitate development of R&M market in the country through appropriate signals. This includes:

- Communicating the overall R&M market size to various stakeholders. This will promote vendor development and interest in the R&M market from India and outside.
- Initiate measure to address concerns of the stakeholders including bidders/suppliers and technical consultants.

CEA has already initiated the above study with support from the World Bank. The result of these will be available during 2013-14.

5.2. Assessment Stage

The risks identified across assessment stage of R&M process cycle and strategies to manage the identified risks are presented below:

5.2.1. Delay in obtaining Unit Shut down for Undertaking Technical Studies (Institutional Risk)

a) **Risk Description**

Robust baseline assessment through technical studies is the foundation for the success of R&M project. In order to carry out comprehensive assessment of the remnant life and condition of the plant, various standardised tests are required to be performed (destructive and non-destructive) involving a shutdown of approximately 2 to 3 months.

This risk arises if the utility is unable to obtain requisite approvals from the relevant authorities (State Government or Regulatory Commission) for shutdown of the plant for carrying out such studies.

b) **Root Cause Analysis**

Significant energy and peak deficit scenario in most of the states coupled with lack of planning for procurement of power from other sources inhibits shutdown of state owned units especially for carrying out such studies.

c) **Impact of Risk**

The above risk leads to the following:

i. Delay in initializing the R&M activity, causing further deterioration in the plant condition and performance
ii. Shorter shutdown period results in inadequate assessment of the condition of the plant and residual life of various components derailing/impacting the entire R&M project.

d) **Strategy to Manage the Risk**

i. **Advance Planning for Scheduling of Technical Studies (Risk Avoidance)**

The following steps are required at the plant level:

- Efforts should be made to coincide the time period of technical studies with that of annual maintenance/overhauling of the unit. Thereby, a separate shutdown may not be required for carrying out technical studies.

- In case a separate shutdown is required, it 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. In addition current power market provides several avenues for procurement of power in the short and medium term, which should be considered.
- Further, efforts should be made to plan such studies during off-peak demand months when the stress on the generating systems is low. This however, should be considered in view of the market conditions. As in certain cases it is noticed that when multiple plants undergo R&M during off-peak periods, the stress on the suppliers increases resulting in delays. Hence, availability of the vendors should be assessed before actual commencement.

ii. **Additional Allocation of Power to States from Unallocated Quota of Central Pool for carrying out the studies (Risk Avoidance)**

In order to obviate this risk the following is required:

As per clause 6.2 (ix) of the MoP Guidelines for R&M in National Perspective Plan for Renovation and Modernisation and Life Extension of Thermal Power Stations (upto 2016-17), 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.

5.2.2. Inadequate Technical Assessment/Studies (Technical Risk)

a) **Risk Description**

This risk arises on account of the following:

i. Requisite studies or tests not performed
ii. Assessment undertaken only for major components of the plant
iii. Proxy Assessment in case of multiple units, wherein studies are undertaken only for one unit to finalise scope of other units

b) **Root Cause Analysis**

The root causes for the above are:

i. Studies undertaken only for the major components of the plant- It is observed that in many cases RLA/CA study is undertaken for boiler and turbine but no detailed study is undertaken to diagnose critical areas in BoP and auxiliaries. Further, studies such as energy audit may not be undertaken at all.

ii. Due to lack of past operating and performance data with the utility, it may difficult to identify improvement areas for certain components in the unit/machine as every component cannot be tested.

iii. Utilities may also not be keen to undertake detailed assessment as they generally underestimate the importance of data or in interest of time these studies may be omitted.

iv. Scope of work prepared for carrying out technical studies may be weakly defined especially for critical plant components operating in creep and fatigue range. Further, deliverables based on such technical studies are not defined appropriately by the utilities

v. In case of multiple units, it is sometime assumed that since both units are operating under same condition, assessment of any one of the units would suffice the purpose. This is often done to save time and cost during the initial stages

c) **Impact of Risk**

The impact of this risk is reflected in the form of surprises or additional scope of work at the project execution stage leading to increase in cost and time of the project.

d) **Strategy to Manage the Risk**

Comprehensive Studies for the unit planned for R&M should be mandatory. The scope of the study should cover both the Main Plant Equipment as well as the Balance of Plant. (Risk Avoidance)

A comprehensive R&M assessment should aim to undertake the following for each unit being considered for R&M or LE: (i) Data Gathering; (ii) Plant Walk-down; (iii) Energy Audit; (iv) Pre-R&M Performance Testing; (v) Residual Life Assessment; (vi) Steam Path Audit; (v) Stress Analysis of Critical Piping; (vi) Potentially Non-destructive and Destructive Evaluation; and (vii) Review of O&M Practices.

Additionally, diagnostic studies should also review the procedures, training system and other similar aspects.

Further, in order, to minimize the impact of this risk it is advisable to undertake comprehensive R&M assessment for each unit planned for R&M, and review both the main plant equipment and the BoPs. Also, it is suggested that project financiers should consider submission of the reports/results of such studies as a pre-requisite for funding the project.

In this regard CEA has prepared standard documents for carrying out RLA/CA/EA studies which may be used by the utilities.

5.2.3. Weak Analytical Framework for Selection of R&M Options (Management Risk)

a) **Risk Description**

This risk arises if the utility is not able to identify and/or evaluate different options and select the best possible option depending upon the conditions of the plant, financial constraints, etc.

b) **Root Cause Analysis**

The root causes of the above behaviour are:

i. Poorly defined objectives for undertaking R&M
ii. Focus only on the technical criteria, with limited focus on financial and economic returns
iii. Limited project appraisal skills

c) **Impact of Risk**

The above risk leads to selection of sub-optimal option that may result in unmet objectives and outcomes, and/or higher time and cost.

d) **Strategy to Manage the Risk**

Comprehensive Identification and Assessment of Options including computation of financial returns, payback period, shutdown time required and conformance to the set objectives (Risk Avoidance)

A detailed cost benefit analysis by estimating the net present value (NPV), rate of return (IRR), payback period and cost-benefit ratio, should be undertaken by the utility for different 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 justification of the R&M project needs to be established clearly demonstrating that the R&M project is competitive against all feasible power generation supply options.

5.2.4. Appropriate Commission not apprised of the R&M Project Plan (Regulatory Risk)

a) **Risk Description**

The risk arises when the Appropriate Commission is not apprised about the R&M project.

b) **Root Cause Analysis**

This risk can be attributed to complacency resulting in oversight or lack of awareness of regulatory requirement.

c) **Impact of Risk**

The impact of this risk would be that the generating company may not be able to recover the investment or the cost it incurs on undertaking R&M of the plant.

d) **Strategy to Manage the Risk**

Practice of obtaining in-principle approval from the Appropriate Commission should be encouraged (Risk Avoidance)

Review of the tariff regulations notified by various states indicate that in-principle approval of R&M investment is not a mandatory requirement;

however experience suggests that it is a desirable practice that helps avoid controllable risks at a later stage.

5.2.5. Limited Capacity of Utilities in Undertaking R&M works (Operational Risk)

a) **Risk Description**

The risk arises due to the limited skills and expertise of the generating company to plan and implement R&M. In addition, absence of dedicated cell/department at the company level also contributes to the risk.

b) **Root Cause Analysis**

The risk arises on account of the following:

i. Limited training of utility professionals in the area of planning and execution of R&M projects

ii. Inadequate exposure of the utility staff to Indian and outside R&M experience

iii. Adequate personnel not dedicated to the R&M activity. It is often seen that most of the available manpower is dedicated to the already ongoing and large new capacity augmentation programs.

iv. People working in R&M project get transferred to other departments in the middle of the project.

c) **Impact of Risk**

Every stage of the R&M process cycle is impacted leading poor execution of project.

d) **Strategy to Manage the Risk**

Creation of dedicated R&M Cell and Engaging Specialised Consultants (Risk Avoidance)

In order to effectively deliver a successful R&M project, the following steps are required:

i. **Creation of dedicated R&M cell by the utility at the headquarter and the plant level**

In order to effectively deliver on the R&M project it is important to create a separate R&M cell with adequate and dedicated manpower for the project. This team should involve a mix of plant level officials dealing with the different plant level departments like Boiler, Turbine, Electrical, C&I, CHP, Milling system and AHP etc.

Further, officials having prior R&M experience should also be included in the team. To ensure timely decisions and approvals within the organization it is important that this team is formed at both headquarter and plant level.

ii. **Engaging of design and implementation support consultants**

Specialized agencies should be engaged by the utility (on the basis of competitive bidding) covering assistance on all works from design to implementation. This could be either one agency or multiple agencies.

iii. **Avoidance of transfer of personnel involved in R&M Project in the middle of R&M work**

Abrupt transfers of personnel in an ongoing R&M project create unnecessary distress and slow down the progress till the new personnel gets acquainted with the project. It is imperative to involve people selected for R&M Cell to work from the beginning to end of the project so that timely decisions can be taken.

5.2.6. Weakly Defined Scope of Work (Contractual Risk)

a) **Risk Description**

This risk arises if the scope of work is broad and does not clearly define the role and responsibility of different stakeholders including the works to be performed by each party.

Further, if the scope of work or design specifications is prepared in a way to favour a particular supplier or include propriety items.

b) **Root Cause Analysis**

The risk arises due to the lack of proper and detailed assessment of the requirement of works at the start of the project by carrying out limited technical studies.

c) **Impact of Risk**

Lack of clarity in the roles and responsibilities of the involved parties in the scope of work leads to contractual disputes causing delay in project execution.

d) **Strategy to Manage the Risk**

Scope of Work to be as precise and comprehensive as possible (Risk Mitigation)

In order to mitigate this risk a multi-pronged approach is required which is explained below:-

i. Role of Design Consultants- Besides their role in undertaking the technical studies, it is required that design consultants should also be involved in preparing the final scope of work for the study.

ii. Involvement of plant level officials- It is required that officials/engineers involved in the operation and maintenance of the plant should be involved while finalizing the scope of work as they have deeper knowledge of the condition of the plant.

iii. Involvement of engineering team-Engineering team of the utility should also be involved while finalizing the scope of works.

iv. Discussions with vendor/s- Suppliers (especially the original equipment suppliers) should be consulted in the early planning process to understand the viability of options for R&M envisaged including new technologies which can be used. However, it is required that scope should not be biased towards any one or more supplier. Further, in case of bidding, the bid clarification stage would provide the opportunity to bidders to flag biases if any and would help in strengthening of the scope of works. In case of nomination basis, direct discussion with the vendor can provide inputs in finalization of scope.

v. Avoid proprietary items in the scope of work- While preparing specifications for different components efforts should be made to avoid proprietary items.

Involvement of multiple agencies as suggested above and conducting comprehensive R&M studies are vital components for preparation of best possible specifications of the project.

5.2.7. Utility Unable to Mobilise Funds (Funding Risk)

a) **Risk Description**

This risk arises when the utility is unable to arrange adequate funding for undertaking R&M of the project or faces constraints in raising funds for the project.

b) **Root Cause Analysis**

The risk arises due to the poor financial condition of state utilities that makes it difficult to obtain financing especially from commercial sources. Further, due to declining profitability, it is difficult for state utilities to even arrange equity funds from their internal reserves.

c) **Impact of Risk**

The overall impact is that utility is unable to materialize its plan for undertaking R&M. The consequent delay on account of the above results in further deterioration in the plant performance.

d) **Strategy to Manage the Risk**

Use of innovative financing approaches/models (Risk Mitigation)

In order to attract public or private investment for R&M projects different financing models should be taken up by the state utilities. These include:

i. Lease, rehabilitate, operate and transfer (LROT):- Under this option, the 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. However, legal title and ownership of the plant remain with the utility. After the completion of the contracted lease period, either the lease may be renewed or the station may be transferred to the power utility.

ii. Joint Venture between Power utility and public or private company: -In this option, a new company would be formed as a joint venture (JV) of the state power utility/ State Government and selected private/public collaborator. The JV Company would then undertake the R&M/ LE works and also own, operate and maintain the power station. The private collaborator could also be an equipment supplier. Each partner shall hold minimum 26% equity in the JV Company.

5.3. Planning Stage

The risks identified across planning stage of R&M process cycle and strategies to manage the identified risks are presented below:

5.3.1. Low Level of Participation by the Vendors in the Bidding Process (Market Risk)

a) **Risk Description**

This risk arises when the utility adopts the bidding process for selection of vendors and receives a poor response to its bid(s).

b) **Root Cause Analysis**

The risk occurs due to the following reasons:-

i. Limited firms involved in the R&M market as most of the domestic and foreign companies have focused on new capacity addition in comparison to R&M projects.
ii. Limited new vendor development initiatives - Insufficient/inadequate market signals to the prospective vendors. Most of the utilities in the past have preferred to execute R&M projects on nomination basis.
iii. Stringent qualification requirements and guarantees impending larger participation.
iv. Prohibitive contractual conditions.

c) **Impact of Risk**

The utility is forced to select vendor from the limited pool of options available. The risk has a broader market impact in terms of the development of competitive R&M market in the country.

d) **Strategy to Manage the Risk**

Focussed efforts should be taken up to involve potential players in the R&M market by the utilities and the CEA (Risk Mitigation)

The following interventions should be taken up:

i. Qualification requirements in the tender documents should be designed in a manner that encourages participation of players including the new players. These should not be overly stringent.

ii. The level of guarantees should not be excessive and should be based on fair balance between risk and rewards.

iii. Pre-bid meetings and two stage bidding process can be adopted by the utility to address the concerns of the suppliers prior to submission of price bid.

iv. Utilities should make efforts to reach out to the potential vendors and disseminate information about the bid.

v. In this regard CEA has prepared standard bid documents which may be used by the utilities.

5.3.2. Higher than Expected Price Discovery (Market Risk)

a) **Risk Description**

This risk arises if the price discovered through competitive process or through nomination basis is significantly higher in comparison to that envisaged during the Planning Stage.

b) **Root Cause Analysis**

The risk arises due to the following factors:-

i. Lower vendor participation or selection of vendor through nomination basis, lead to limited bargaining power of the utility resulting in high procurement cost

ii. Unrealistic assessment of cost of various components not undertaken at the DPR stage.

iii. Weakly defined scope of work and uneven sharing of risks between the utility and vendor.

iv. Stringent performance guarantees imposed/expected from the vendors ultimately leads to high prices for the project.

v. Pre-R&M condition of the equipment is not well-established. Usually, the information provided is not enough to determine clearly the design of the equipment and its performance, and its operating history.

vi. Time gap between the technical studies and commencement of actual implementation, as the units do not get maintenance priority in the interim resulting in deterioration in plant performance.

vii. Lack of drawings and historical data of the plant discourages vendors and/or increases their risk perception towards the proposed R&M of the unit/plant as they are not able to sufficiently familiarize with the condition of plant before bidding.

c) **Impact of Risk**

The impact of the above risk results in the following:

i. Compromises on the scope of work - In order to reduce the price discovered the earlier set scope of work may be reduced. This includes dropping uprating option, or dropping of up-gradation of BoP or other similar measures.

ii. Re-evaluation of option – In view of the high price discovery, the utility may re-evaluate the options and may drop R&M of the plant.

d) **Strategy to Manage the Risk**

Adequate flexibilities in the contract should be provided to accommodate reasonable/acceptable changes (Risk Mitigation)

In order to mitigate this risk following steps are required:-

i. Discussions with Vendor/s- Suppliers should be consulted during the preparation of DPR (and cost estimates) to understand the viability of options for R&M envisaged including new technologies which can be used and to understand the market prices of various components.

ii. Proper Communication with the Vendors- This is the most important step as this would enable the vendor to realistically evaluate its cost and benefit and associated risks involved in the project. This includes the following:

- Provision of previous year data pertaining to plant performance, results of technical studies etc. to the prospective vendors along with the bidding documents.
- Suppliers interested in bidding for the project should be encouraged to undertake plant visits to understand or review the site conditions.
- Conduct of pre-bid meetings and two stage bidding process can be adopted to address the concerns of the suppliers prior to submission of price bid.

iii. While preparing DPR of the project some contingency should be provided for price discovery and scenario analysis should be undertaken to understand the maximum price increase that can be allowed so that the identified/selected option remain the best possible option. If the price discovered is such that it makes the option unviable, utility should try to select the second best possible option. Thus, at this stage, the decision to go ahead for R&M should be re-evaluated and considered in the light of proposed changes.

iv. Utility may also decide for rebidding (although it has its own risks) the project with suitable modifications i.e. change in qualification criteria to increase participation, change in the selected R&M option etc. However, efforts should be made for suitable negotiations with the lowest bidder before resorting to such option.

v. Striking a right balance between the performance guarantees and penalties- There should be adequate sharing of risks between the utility and the supplier, shifting additional risk (beyond what the supplier has direct control on) only increases the overall price of the contract.

5.3.3. Rebidding/Re-award/Delay in Award of R&M Packages/Contract (Market and Operational Risk)

a) **Risk Description**

This risk arises if the utility consumes significant time in awarding the contract or has to rebid any of its contract or packages.

b) **Root Cause Analysis**

The risk arises due to the following factors:

i. Qualification requirements, specifications desired or scope of work etc. are not clearly specified or utility has been constantly reassessing its options and changing the scope.

ii. Bid responses are in a manner wherein comparison of different bids is not possible.

iii. Discovery of higher than expected prices and subsequent modification in scope, qualification requirement etc.

iv. Supplier issues - Delay in start of work or non-availability of manpower or dispute among sub-contractors.

c) **Impact of Risk**

This risk leads to significant delay in execution of project, cost overruns and risk of change in baseline parameters.

d) **Strategy to Manage the Risk**

i. **Rebidding should ideally be avoided through robust project preparation, however in cases where it still emerges as the only option, potential bidders should be encouraged to assess the current plant condition and assume the responsibility of the task. (Risk Acceptance)**

Further, the following should be considered:

- The specialized design and implementation support consultants should be accountable and responsible for clearly examining the qualification requirements, scope of work etc, and must flag these issues at the start to avoid such situations.
- Pre-bid meetings and two stage bidding process can be adopted by the utility to address concerns of the suppliers and incorporating their suggestions to improve specifications.
- Requisite safeguards should be adequately provided for in the contract through bank guarantees and liquidated damages.
- Potential conditions that may lead to rebidding/re-award should be comprehensively assessed and incorporated in the

next bidding round. In cases where work has been partially performed (by the earlier selected bidder), the information should be shared with potential bidders so that they assume the responsibility of the work. In such cases, the potential bidders should also be encouraged to visit the site for undertaking their own assessment.

ii. **Management should undertake timely decision for award of contract by formulating qualification requirements and evaluation procedures along with appropriate timelines before seeking interest from the vendor (Risk Avoidance)**

To avoid such situations, it is required that qualification requirements and evaluation procedures along with appropriate timelines should be clearly formulated before seeking interest from the vendor. Role of design consultant in clearly specifying such requirements becomes essential. Further, ISC should facilitate timely decision by providing advice with regard to evaluation and selection of successful bidder to enable decision making at the utility's end.

5.3.4. Implementation Contract Awarded to Vendor involved in carrying out Technical Studies (Management Risk)

a) **Risk Description**

This risk arises if the same entity is involved in formulation of technical specifications/scope of work and execution of R&M project.

b) **Root Cause Analysis**

The Original Equipment Manufacturer (OEM) is generally the first point of contact in case of any R&M based requirement on account of various reasons – availability of engineering drawings and familiarity with the plant.

c) **Impact of Risk**

Lack of independent assessment and presence of potential conflict of interest may not lead to the best possible outcome for the utility.

d) **Strategy to Manage the Risk**

A single entity should generally be avoided to assume both the role of design consultant as well as the supplier. (Risk Avoidance)

Independent assessment through specialized agencies to develop the technical specifications and the scope of work should be mandatory. Further potential conflict of interest wherever possible should be avoided.

5.4. Execution Stage

The risks identified across execution stage of R&M process cycle and strategies to manage the identified risks are presented below:

5.4.1. Weak Decision-Making Framework (Management Risk)

a) **Risk Description**

This risk arises if there is significant delay in undertaking decisions to resolve issues faced during the execution of the work.

b) **Root Cause Analysis**

The risk arises due to the following:

i. Lack of planning and ownership of the R&M project by the utility officials due to frequent change in the officials handling R&M works, lack of technical and professional management skills to address the issue/situation, lack of accountability structure etc.

ii. Lack of authority of the officials involved.

c) **Impact of Risk**

This leads to contractual disputes and delay in execution of the work.

d) **Strategy to Manage the Risk**

Creation of clearly defined decision making and reporting structures with nominated officials authorized to undertake decisions (Risk Mitigation)

Decision making and reporting structure should be clearly specified. This should include roles, responsibility and authority to various officials involved in R&M.

Further, contract review meetings to assess the progress and deviations if any from the schedule of work should be held weekly.

Here in the role of Implementation Support Consultant is of utmost important as it is required to facilitate smooth coordination and timely action for resolving of pending issues.

Alongside, empowered team of both the utility and the suppliers should be nominated to ensure timely resolution of disputes and issues, as and when they arise.

5.4.2. Occurrence of Technical Surprises (Technical Risk)

a) **Risk Description**

A thermal power plant undergoing R&M, despite undertaking comprehensive prior plant assessment might face unforeseen events once the unit is shut down and opened up for R&M. Such unforeseen events are called Technical Surprises. As the units are very old or nearing the useful life of operation, such technical surprises are quite common. The utility due to such surprises is faced with unexpected change or unforeseen additions in the scope of work leading to cost and time overruns. In order to address this risk it is suggested that CEA guidelines for "Early Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them" may be referred.

b) **Root Cause Analysis**

The risk arises due to the following:

i. Inadequate assessment and weak scope of work.
ii. Huge time lag between the technical studies and actual award of contract.
iii. Refurbishment of old equipment or spares may not be possible due to technological obsolescence.
iv. Identification of additional scope of work at the execution stage not in the nature of surprise but required for better operation of plant at the later stage
v. Due to nature of R&M that certain surprises are encountered when the machine is actually opened.

c) **Impact of Risk**

The above risk results in the following:

i. Scope deviation: Additional scope of work to be addressed
ii. Contractual disputes due to weakly defined scope of works, and non-agreement between the utility and vendor
iii. Situation of indecisiveness due to inflexible contracts making it difficult for any alteration at the execution stage
iv. Delay in execution of work and increase in cost of the project.

d) **Strategy to Manage the Risk**

i. **Undertaking comprehensive assessment through technical studies with clearly defined scope of work (Risk Mitigation)**

Effective assessment at the start of the project is the key to minimise technical surprises. The nature and occurrence of technical surprises depend upon the depth with which technical studies are undertaken. In order to minimize technical surprises, the foremost step is to undertake comprehensive assessment of both main plant equipment and the BoP through studies for each unit planned for R&M. Based on the studies, efforts should be made to define the scope as clear and comprehensive as possible along with the roles and responsibilities of each stakeholder.

ii. **Creation of technical surprise plan (Risk Acceptance)**

A well-defined technical surprise plan should be prepared for effectively handling technical surprises, as and when they occur. The design consultant involved in undertaking comprehensive assessment, DPR and subsequent scope of work should also prepare a technical surprise plan. This is required as replacement/repair of some components may come up at the time of execution as everything cannot be analysed / tested during the studies. This should be prepared in consultation with the plant level officials involved in operation, repair and maintenance of the plant to understand the potential surprises as they have the experience of the actual condition of the plant. This includes a list of possible surprises, ensuring availability of spare parts to minimize delays, addressing upfront the likely contractual aspects of additional supplies and works etc.

Further, this should also include the unit rates for equipment/parts and total financial implications of the same. In this regard CEA has prepared standard documents for Detailed Project Report which may be considered by the utilities.

iii. **Establishing a clear decision making framework (Risk Mitigation)**

After the occurrence of technical surprises the indecisiveness of the utility can result in significant delay in the execution of work. It is important to specify the decision making process with clearly defined roles and responsibilities along with authority of different officials to enable timely resolution of the issues encountered.

5.4.3. Weak Dispute Resolution Mechanism constraining the Execution of Work (Contractual Risk)

a) **Risk Description**

This risk arises due to occurrence of disputes including contractual disputes that affect the execution of work.

b) **Root Cause Analysis**

The risk arises due to the following:

i. Misinterpretation of the scope of work by either party i.e. utility or supplier.
ii. Delay by supplier or claim of compensation by the supplier for any additional work outside the scope of work.
iii. Delay in decision making by the utility or delay in providing shutdown of the plant.

c) **Impact of Risk**

The risk impact the harmony in work and results in halting or delay of the work.

d) **Strategy to Manage the Risk**

Creation of Dispute Resolution Committee at the start of project to address disputes between the Utility and the Contractor in a timely manner (Risk Mitigation)

In order to resolve disputes between the contractor, sub-contractor and utility, it is important to create a Dispute Resolution Mechanism. Under this mechanism a Dispute Resolution Committee (DRC) should be formed at the start of the project with fair participation from both utility and contractor. The institutional set up, powers and roles along with the time schedule (within which case can be referred from the occurrence of the dispute, hearing of the dispute and the final decision) of the DRC should be specified in the tender document itself. Any dispute which cannot be amicably settled between the parties can be referred to the DRC.

5.4.4. Mismatch (or delay) in Supply of Critical Equipment and the Shutdown Period (Market Risk)

a) **Risk Description**

This risk arises when there is delay in supply of key components and equipments by the supplier and delivery schedule of the equipments is not in sync with the shutdown period of the plant.

b) **Root Cause Analysis**

This risk arises due to the following:

i. One of the major issues faced by the suppliers is the difficulty in procurement of sub-vendor items. This difficultly stems from the following: (a) non-existence of original vendors for such items; (b) non-availability of original equipment details, specifications etc.; (c) obsolete design and (d) inadequate information available about modification done/spares used earlier. This leads to delay in supply of material on a timely basis.

ii. Non-performance or underperformance on part of the vendor due to its overbooked manufacturing capacity

iii. Technological obsolescence may require customized manufacturing for certain components leading to delay in supply of components

iv. In-adequate planning on part of the utility

c) **Impact of Risk**

The risk results in delay in implementation of project and hence longer shutdown period.

d) **Strategy to Manage the Risk**

i. **Availability of key components should be ensured before the start of the project and should be in accordance with the pre-defined plan finalized before the commencement of work (Risk Mitigation)**

The planning for pre-shutdown activities should be done meticulously. Availability of key components along with the sequential delivery of the components should be ensured before start of implementation/before shutdown is provided. Further, delivery of materials should be linked to the shutdown period of the plant.

ii. **Provision of Penalties for delay in completion of work (Risk Sharing/Transfer)**

Adequate penalties should be built into the contracts for delay in completion of works by the vendor

iii. **Sequential delivery of materials to the R&M site (Risk Mitigation)**

Sequential delivery of materials should be agreed upon by both the utility and vendor and built into the contract. In the contract clauses, provision for non-acceptance and disallowance of material to the project site if not delivered sequentially should be included in order to avoid unnecessary delay in R&M work.

5.4.5. Weak Supervision, Quality Control and Assurance (Operational Risk)

a) **Risk Description**

This risk arises if material supplied or work performed by the vendor is of substandard quality. This risk also arises due to the weak quality review procedures of contractor to review quality delivered by the subcontractors.

b) **Root Cause Analysis**

The risk arises due to the following:

i. Lack of expertise in assessing the quality of material/service supplied by the supplier
ii. Quality audits not performed by the utility at the supplier's site
iii. Lack of assessment of the vendor's quality procedures with regard to its sub-vendor
iv. Lack of appreciation on the necessity of formal quality control and quality assurance procedures

c) **Impact of Risk**

Substandard equipment and installation service has a direct impact on the long term performance and life of the plant.

d) **Strategy to Manage the Risk**

Approval of detailed Quality Plans and Engaging Quality Control and Quality Assurance Consultants by the Utility (Risk Mitigation)

The detailed Quality Plans for both manufacturing and field activities should be submitted separately by the contractors to the utility for approval before the start of the project. The approved quality plan should then form as an integral part of the Contract document. The contractor must submit the quality plan for the project including the Quality Plan proposed for each sub-contracted item along with the procedures followed by the contractor to finalize and assess the quality assurances of the sub-contractors.

Implementation Support Consultants (ISC) or Independent Quality Assurance Consultants (QAC) should be appointed to confirm that implementation is as per the design requirements and that the documented quality plans are being adhered to. Consultants would also certify quality of materials and works before the payments are made as per contractual milestones. The QAC would also be responsible for the inspection of material quality at the workshop/facility of supplier.

5.4.6. Failure to Comply with Environmental Standards and Perceived Negative Externalities (Socio-Environmental Risk)

a) **Risk Description**

The risk arises if the units undergoing R&M are not able to achieve the target emission standards even if efficiency gains are achieved. Further, the risk also arises if rehabilitation work is perceived to have adverse environmental and social impact on the habitants in the project vicinity.

b) **Root Cause Analysis**

The risk arises due to the following:

i. Inadequate environmental and social impact assessment by the utility.

ii. Most of the units do not have requisite infrastructure for environmental monitoring and some are unable to install/ replace existing Electrostatic Precipitators (ESPs) due to paucity of funds or lack of space

iii. Environmental norms are increasingly becoming stringent.

c) **Impact of Risk**

The above risk leads to the following:

i. Non- compliance of environmental regulations, which in turn may lead to closure of the plant.

ii. Delayed execution/ or abandonment of R&M due to agitation or demonstration from the community or civil societies.

d) **Strategy to Manage the Risk**

i. **Renovation of ESP system of the power plant (Risk Mitigation**)

In order to meet the statutory environmental regulations there is a need to renovate ESP system of the power plant. This includes the following:

- Periodic environment audit of power plant
- Timely renewal of “consent to operate” from statutory authorities as per prevailing requirements

ii. **Undertaking socio-environment impact assessment to assess the impact of the project (Risk Mitigation)**

- Utility should carry out Rapid Social Impact Assessment Study to identify potential adverse impacts of the Thermal Power Plant on the immediate habitations and screening or the social development issues of the immediate habitations. Further, Environmental Audit and Due Diligence Studies should also be carried out to improve environmental performance of the plant (pollution prevention and control measures, waste minimization, occupational health and safety) and develop strategies to mitigate environment risk and liabilities.

- Appropriate CSR framework or policy should be formulated by the generating company for the sustainable development of the inhabitants surrounding the power plant and to address negative externalities from the plant, if any.
- Generating company should engage with the local community and efforts should be undertaken to disseminate project impact assessments and benefits to nearby villages by deploying an appropriate strategy for communication.

5.4.7. Delay in Provisioning of Unit Shut down for Executing R&M works (Institutional Risk)

a) **Risk Description**

This risk arises if the utility is unable to schedule timely shutdown for executing R&M either due to grid conditions or delay in obtaining timely approvals from the relevant authorities (State Government or Regulatory Commission) for shutdown of the plant.

b) **Root Cause Analysis**

Significant energy and peak deficit scenario in most of the states coupled with lack of planning for procurement of power from other sources inhibits shutdown of state owned units for executing R&M works.

c) **Impact of Risk**

The above risk leads to the following:

i. Contractual disputes and delay in execution of work.
ii. Change in baseline parameters due to time gap between the studies and actual execution.
iii. Deterioration in the material quality already supplied by the vendor
iv. Deterioration in condition of plant and occurrence of technical surprises

d) **Strategy to Manage the Risk**

i. **Advance Planning for Scheduling of Shutdown for Execution of Works (Risk Avoidance)**

Shutdown for executing R&M works must be planned well in advance and distribution utilities must be informed accordingly.

ii. **Additional Allocation of Power to States from**

Unallocated Quota of Central Pool (Risk Avoidance)

As per clause 6.2 (ix) of the MoP Guidelines for R&M, 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 clause/guideline.

iii. **Implementation of partial R&M activities during Annual shutdown periods (Risk Avoidance)**

R&M can also be implemented during planned shutdown for annual maintenance over two to three years' time period especially if the work does not include opening of steam turbine and significant repairs in the boiler and the generator. However, it must be noted that for executing R&M works during annual shutdown period spread over many years, a proactive approach coupled with comprehensive planning will be required by the utility.

5.5. Closure Stage

The risks identified across closure stage of R&M process cycle and strategies to manage the identified risks are presented below:

5.5.1. Sustainability of R&M Gains (Operational Risk)

a) **Risk Description**

This risk arises when the performance gain become difficult to sustain due to weak O&M practices and poor support services by the vendor after R&M has been completed.

b) **Root Cause Analysis**

This risk arises due to the following:

i. Lack of proactive approach in operating and maintaining the plant

ii. Lack of awareness about the new techniques, processes and procedures

iii. Lack of sufficient funds due to which mandatory spares are not being purchased and stocked in advance by the utility

iv. Weak recognition of support services as an important parameter during evaluation of bids and formulation of contract

v. Difficulty in obtaining unit shut down for annual maintenance or periodic capital overhaul due to significant energy shortages in the state

c) **Impact of Risk**

The above risk leads to the gradual deterioration of the condition and performance of the plant and hence the gains expected from undertaking R&M may not be achieved over a longer period of time.

d) **Strategy to Manage the Risk**

i. **Preparation and implementation of O&M action plan on priority basis and engaging specialized agency for O&M of the plant, post R&M. (Risk Mitigation)**

- 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. Further, the plan so formulated should be approved at the highest authority and credible actions should be taken to implement the plan on priority.
- Contractor should revise the existing O&M manual as per the new system/unit requirements.
- Adequate training should be provided by the contractor before handing over the plant to the utility.
- The list of mandatory spares along with its unit prices should be included in the total price of the R&M contract. This mitigates the financial risk related to procurement of mandatory spares post R&M of the project.
- Generating company can also outsource O&M of the plant; post R&M to a specialized agency. There are models available for participation of private players in O&M.
- Generating company can also include O&M supervision in the contract of executing agency.

ii. **After sale services to be made an integral part of the contract (Risk Mitigation)**

After sale services provided by the vendors should be considered as an important element during the bidding stage and support services for some specific period of time (say one to two years) should be incorporated in the contract.

5.5.2. Post R&M Guarantees not achieved (Technical Risk)

a) **Risk Description**

This risk arises if the performance test fails and the requisite performance guarantees are not achieved or if the performance guarantee test is not conducted or delayed incessantly.

b) **Root Cause Analysis**

The root causes for the above are as follows:

i. Failure on part of supplier to meet the commitments

ii. Lack of confidence on the achievement of the requisite targets leading to delay in conducting of PG test

c) **Impact of Risk**

The risk results in the following impacts:

i. Envisaged R&M benefit not achieved during the assessment stage
ii. Contractual disputes
iii. Levy of performance guarantee penalties on the supplier
iv. Problems in regulatory approval and recovery of costs incurred on the R&M of the plant
v. Consequent financial loss to the utility
vi. Non-achievement of performance post R&M may lead to cancellation of future R&M works by the utility

d) **Strategy to Manage the Risk**

Rectification or replacement of components to meet guaranteed parameters at no extra financial cost to utility and Levy of Liquidated Damages for shortfall in performance (Risk Mitigation)

i. Guaranteed Performance Parameters with Liquidated Damages should be included in the contract document.
ii. Supplier should be asked to rectify/replace the components affecting the performance of the plant at no extra financial cost to the utility.
iii. In case of non-achievement of performance guarantees, utility should levy the requisite penalties as provided in the contract.
iv. Performance Guarantees Test should be a critical milestone defined in the contract.

5.5.3. Disapproval of Costs Incurred During R&M (Regulatory Risk)

a) **Risk Description**

This risk arises if the regulator does not approve the expenditure incurred by the utility for undertaking R&M works on account of gaps/inadequacies in the submission.

b) **Root Cause Analysis**

The root cause is that the expenditure incurred by the utility is high in comparison to that approved in-principal during the initial stages or in the DPR of the project and utility is unable to justify the prudence of excess expenditure incurred.

c) **Impact of Risk**

This risk would lead to under recovery or non-recovery of cost incurred by the generating company leading to financial losses.

d) **Strategy to Manage the Risk**

Involvement of Regulator should be ensured from the inception of

the project with regular updates about the progress of the project. (Risk Avoidance)

The need for apprising the regulator about the R&M plan is important as the recovery of the cost incurred towards R&M is approved by the Regulator. This involves:

i. Obtaining in-principle approval from the Regulator
ii. Updating the regulator on progress and achievement of critical milestones
iii. Updating the regulator in case of abnormal or unexpected changes leading to cost and time overruns
iv. Sharing of information about the outcomes, performance achieved vis-à-vis the guaranteed parameters with the regulator

5.5.4. Absence of Ex-Post Evaluation and Feedback Loop (Operational Risk)

a) **Risk Description**

This risk arises if the generating company does not undertake ex-post evaluation of the R&M works and fails to incorporate the experience or unable to improve upon the execution of R&M works for its ongoing units. Also, this leads to lack of institutional memory when the staff involved in R&M moves out.

b) **Root Cause Analysis**

Undertaking post evaluation of projects is not considered as a standard practice by the generating companies in India.

c) **Impact of Risk**

The impact of this risk is that the generating companies would be unable to improve upon the execution of R&M projects based on its learning or experiences.

d) **Strategy to Manage the Risk**

Experience gained must be documented and incorporated in subsequent units planned for R&M works (Risk Mitigation)

Generating companies must undertake ex-post evaluation of the R&M works and should document its experiences. This is important especially in cases where multiple units are taken up for R&M. The learning/experiences gained from the first unit must be incorporated in the implementation plan of the subsequent units.

6. Implementation of the Guidelines

The identified risks and suggested strategies presented in these guidelines should be considered by the utilities for implementation after suitably modifying it as per their local conditions or set up of their power plants.

The utilities should evaluate the risks identified before the commencement of the R&M and formulate appropriate strategies in line with those suggested in these guidelines to manage the identified/evaluated risks.

It is expected that these guidelines would serve as a guide for the utilities to improve planning and execution of R&M projects by minimizing the risk experience during various stages of the R&M.

Annexure 2

Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and Ways of Addressing Them

1. Background

1.1 Renovation & Modernisation (R&M) including Life Extension (LE) of existing old power plants is one of the most cost effective options to achieve additional generation from these plants in a short gestation period.

1.2 The importance of R&M was recognised by the Government of India way back in 1984 when Phase-I R&M Programme for 34 thermal power stations in the country was launched by the CEA as a Centrally sponsored scheme. Since then R&M option has been effectively utilised over the various plan periods. As per the National Perspective Plan of CEA, under 12th Plan, LE works have been identified on 70 thermal units of total capacity 12,066 MW and R&M works have been identified on 65 units (17,301 MW) during the 12th Plan.

2. Concept of R&M and Life Extension Programme for Coal Fired Thermal Power Stations

2.1 Renovation and Modernisation Programme

The main objective of R&M of power generating units is to make the operating units well equipped with modified / augmented latest technology equipment /components/ systems with a view to improving 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 form a part of Operation and Maintenance (O&M) activity. Middle life R&M come up preferably after 1,00,000 hrs of operation.

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

- Generic defects
- Design deficiencies /modifications
- Avoidance of inefficient operation
- Non-availability of spares because of obsolescence of equipment/components.
- Poor quality of coal
- Major replacements of equipment arising due to unforeseen failures and /or generation sustenance not covered under

regular O&M

- Stringent environmental regulation
- Safety requirements etc.

2.2 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 help reveal the remaining life of various critical components of plants and equipment to enable introducing measures to extend the life of the plant by a further period of about 15-20 years. 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 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 modernization 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.

2.3 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:

- 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.
- Procurement of spare equipments.

- 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.

3. Defining Technical Surprises

3.1 A thermal power plant undergoing R&M, despite undertaking prior plant assessment through Residual Life Assessment (RLA), Condition Assessment (CA), Energy Audit (EA) and Performance Evaluation Test (PET) of units; might face unforeseen events after the unit has been shut down and opened up for R&M. Such unforeseen events are defined as Technical Surprises

3.2 Occurrence of technical surprises can have adverse impact on scope, schedule, cost and quality of R&M projects. Therefore, it is important to devise strategies for the early identification of technical surprises to address them at its nascent stage.

3.3 With the above background, the objective of these guidelines is to provide direction to the utilities in early identification of potential technical surprises in R&M projects and ways of addressing them.

4. Intent of the Guidelines

4.1 The intent behind the guidelines is to identify potential surprises which may occur during implementation of R&M of coal based thermal power plants in the country. A detailed assessment of potential surprises has been undertaken wherein different types of surprises that can occur for each of the key components of the plant system have been identified. Further, root cause analysis for occurrence of technical surprises and its impact on the project has also been provided.

4.2 Various strategies have been suggested to effectively minimize and handle the surprises which include both preventive strategies and managing strategies. These strategies are provided according to different stages of R&M process cycle.

5. Stages of R&M Process Cycle

Various stages of the R&M process and the activities that are undertaken at each stage are described below.

5.1 Identification Stage

During the identification stage the plant units are first identified to be diagnosed further based on certain symptoms. At this stage the plant operators regularly monitor the key plant unit parameters covering at least the following aspects to identify symptoms that may necessitate

R&M of the units: (a) Plant Availability, (b) Plant Load Factor, (c) Auxiliary Consumption, (d) Emission Factors, (e) Level of Outages, (f) Life of the plant etc., (g) Frequency of annual overhaul; (h) Frequency of capital overhaul etc. The diagnosis at this stage is based on available plant records and design data. No inspections and/or testing of material, plant or equipment is involved at this stage.

5.2 Assessment Stage

During this stage systematic evaluation of the plant is undertaken through technical studies and tests. This includes the following:- (a) Residual Life Assessment (b) Complete Condition Assessment (c) Performance Evaluation Test (d) Energy Audit (e) Past History of Plant (including maintenance schedules, overhauls and assessment of O&M practices). The technical evaluation of the plant is followed by the economic evaluation of the plant to decide on the most optimal option. This includes (a) Plant retirement (b) Maintain and operate for extended time and retire subsequently (c) Capital Overhaul and refurbishment (d) R&M and Life Extension (e) R&M, LE and Up-rating. Detailed Project Report prepared for assessment of above options also includes a detailed technical and economic analysis of the identified option. This also includes assessment of the sources of fund and the phasing required for execution of R&M option. Based on the technical studies and the option selected for R&M, the scope of R&M Project is prepared. Before the tenderization process begins, utility is expected to submit the details of the assessment to the Appropriate Commission and seek its in-principle approval.

5.3 Planning Stage

Once the scope of the project is finalised, the utility develops the design specification and proposal package and determines the procurement/bidding strategy. Planning stage covers the entire bid process management i.e. issue of tender(s), pre bid meetings, evaluation of technical and commercial bids, selection of suitable bidder, negotiation of contracts and award of R&M contracts to vendors/suppliers/OEMs.

5.4 Execution Stage

This stage covers the entire R&M project implementation stage which begins with the receipt of equipments to the site and planning of shutdown of unit. This stage includes effective monitoring of work, timely decision making on bottlenecks faced, ensuring the quality of work, inspection of material and smooth implementation of work. Implementation support consultant hired by the utility plays a key role in managing all the activities covered under this stage through a structured process.

5.5 Closure Stage

After the R&M work is completed, it is very essential to evaluate whether the goals and objectives of the R&M project were achieved or not. For this post-R&M Performance Guarantee Test is conducted. Further, O&M training is imparted to engineers for efficient operation of the unit that has undergone R&M.

5.6. The indicative timeframe suggested by CEA in the National Perspective Plan for Renovation, Modernisation and Life Extension of Thermal Power Stations(Upto 2016-17) may be adopted for implementing LE&U schemes:

i.	Appointment of consultant by utilities -	3 months
ii.	RLA / Energy Audit -	6 months
iii.	Freezing the scope of work/activities for LE&U -	3 to 4 month
iv.	Preparation of DPR -	6 to 8 months
v.	Placement of order of LE&U -	6 to 8 months
vi.	Supply of critical spares -	16 to 20 months from placement of order
vii.	Shut down of unit -	6 - 8 months.

6. Type of Technical Surprises

The following section provides a description of potential technical surprises that may be encountered during implementation of R&M works in thermal power plants.

Table 38: Areas of potential surprises in various components of plant system

S No.	Plant System	Areas of Potential Surprises
Boilers and Auxiliaries		
1	Boiler Tubes	Boiler tube failure is quite common in thermal plants; the quantity requirement may change due to the time lag between the assessment and execution of R&M works. This may result into additional requirement of boiler tubes than those listed in the contract.
2	Wind Box	In case of replacement of the wind box chamber, the size of the new chamber may change. In such cases, problems may be encountered in fitment of new chamber.
3	Furnace	In the interim period between RLA study and actual R&M execution, bulge in the furnace may occur due to minor explosion resulting in increased vulnerability of furnace to failure. Additionally, problem in buck stay system may be overlooked during the time of technical studies.
4	Boiler Drum	Leakages in manhole, handhole gaskets and in safety valves may be overlooked during the studies. This impacts the overall boiler efficiency.
5	Super Heater	In R&M, to increase the efficiency and to improve the performance of boiler, the coils of the Super Heater needs to be replaced. Additionally problem and assessment of

S No.	Plant System	Areas of Potential Surprises
		Superheater safety valves may be overlooked during the time of technical studies. While preparing scope of work exact requirement for replacement of coils for Low Temperature Super Heater (LTSH) and Platen Super Heater may not be clearly specified by the utility. During the designing stage, aspects related to shape, gauge, material and size of the new coil fabrication may be overlooked.
6	Reheaters	a) Deterioration of coils and sagging of assembly due to constant high temperature and pressure, developed during the time gap between RLA study and commencement of R&M works. b) Specific details of coil replacement for reheaters may not be clearly mentioned in the scope of works. In addition, condition assessment of reheater safety valves is normally overlooked.
7	Economiser	In case of replacement of economizer tubes, size shape and gauge of tubes may differ from those installed initially, resulting in problem of fitment.[34]
8	Superheater and Reheater Safety Valves	There may be cracks in the seat and spindle of the safety valves which may be overlooked during the studies
9	Air Pre-heater	Due to high corrosive nature of boiler flue gases, there is corrosion in the Air Pre-heater which leads to loss of effective support of the plates in the basket and bents in tubes. Diagnosis of the actual condition may be overlooked during technical studies.
10	Soot Blowers	Diagnosis of condition of the soot blowers is often ignored during the scope assessment and finalization stage. In case of replacement, space constraints may be encountered which may not have been assessed at the time of placing of the order.
11	Fuel Oil / Oil Firing System	Pipe rerouting for Heavy Furnace Oil (HFO) and Light Diesel Oil (LDO) Pump may be required which may be overlooked during the

[34] This problem is non-existent when one to one replacement of the entire economizer is taken up.

S No.	Plant System	Areas of Potential Surprises
		assessment.
12	F.D. Fan	Improper assessment of the foundation and capacity of Forced Draft Fans in case of increase in the size of the boiler furnace. Further, there can be damages in the coupling and impeller assembly and blades of the fans during the interim period between RLA studies and R&M execution.
13	I.D. Fan	a) Over the years, many leakages develop in the system and the utility instead of analyzing the root cause of the leakages, generally decides to increase the size/capacity of I. D. Fan which may not be the requisite solution. b) Surprises related to shaft cracks due to excessive stress and damages in coupling assembly may be observed if it is not properly diagnosed during the studies. Further, there may be deterioration of ID Fan during the interim time period between the studies and execution of R&M works.
14	P.A. Fan	a) If the utility decides to increase the boiler capacity, the required new rating for the new P.A Fans may not be assessed by the utility. b) Further, typically the Primary Air Fan faces damages in shaft, coupling assembly and in the impeller which sometimes is overlooked during the plant assessment.
15	Scanner Fan	In case of complete replacement of Scanner fans compatibility issues may be observed.
16	Electrostatic Precipitator	Electrostatic Precipitator is an integral part of coal fired thermal plants to control particulate emissions and with increasingly stringent norms for emission, renovation and modernization of ESP is an important part of the scope of work. Some of the technical surprises observed are: a) Space constraint for installing additional ESP may not be considered at the time of designing of the project, b) Unavailability of spares due to technological obsolescence,
17	Mill and Burner	a) In case of increase in capacity of the boiler, the revised size required for the

S No.	Plant System	Areas of Potential Surprises
		mill and burner may be overlooked. b) Due to improper assessment of long term calorific value of coal, the size of mill and burner planned for installation may be inadequate. c) Possible technical surprises can arise due to improper assessment of calorific value of coal which has deteriorated over the years the unit was in operation. d) Improper Condition Assessment /Performance Evaluation Test along with time gap between the studies and actual execution.
Turbine & Auxiliaries		
18	Steam Turbine	In Steam Turbine, potential technical surprises observed are given below: - Cracks in rotors and discs, - Corrosion and fatigue of blades and pitting - Technological obsolescence of spare parts especially in case of turbine valves, - Failure on part of vendor to up-rate turbine efficiency due to improper design and - Lack of timely decision by the utility with regard to finalization of turbine design
19	Condenser	a) Further weakening of condenser performance due to deterioration of tubes, leakages and insufficient heat transfer during the large time gap between RLA studies and actual R&M implementation. b) Non-availability of condenser spare parts due to technological obsolescence. c) Non-specification of exact number of coils to be replaced in the scope of work.
20	Circulating Water Pump	Circulating Water Pump (CWP) faces damages in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Lack of capacity assessment of CWP in case utility decides to increase the capacity of the plant, may lead to technical surprise at later stages as the old CWP may not be able to circulate the water throughout the system efficiently.
21	Low Pressure Heaters	There can be space constraint in case of

S No.	Plant System	Areas of Potential Surprises
		installation of new one and compatibility issues in case of new spares.
22	High Pressure Heaters	There can be mismatch of the outlet and inlet flanges and the new HP heater may not fit to the existing heater space later during R&M execution. HP Heater extraction Non Return Valve (NRV) is also normally ignored by the utility which may create problem later on.
23	Boiler Feed Pump (BFP)	BFP is the interface with the Feedwater system, the Deaerator, and the steam condensate return system. Improper design of BFP can have cascading effect if the utility decides to go for up-rating of the unit and do not assess the capacity and ability to provide feed water to boiler drum at the required temperature and pressure. Moreover detailed requirements of its spares may not be assessed leading to additional requirement during execution.
24	Drip Booster Pump (DBP)	Usually DBP suffers problems in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Moreover proper size, capacity and its compatibility with the existing connected system like valves and piping system may be overlooked.
25	Condensate Extraction Pump (CEP)	CEP suffers problems in shaft, coupling assembly and in the impeller which may be overlooked during the plant assessment. Moreover proper size, capacity and its compatibility with the existing connected system like valves and piping system may be overlooked.
Balance Of Plant (BoP)		
26	Coal Handing Plant	Possible technical surprises which the utility might face are: a) Replacement of few hammers may be mentioned in the scope of work but during execution more units may need to be replaced. b) Replacements of few crushers may be mentioned in the scope of work but during execution entire unit may need to be replaced. c) Weak foundation strength of coal crushers d) Usually the building structure and

S No.	Plant System	Areas of Potential Surprises
		pressure house is in dilapidated condition and is not part of scope. e) Increase in size of marshalling yard for accommodating additional Wagon Tippler is given in DPR but space constraints may not be considered. f) Inadequate assessment of coal bunkers supporting structure strength g) The scope may be for replacement of few rollers and idlers of conveyer belt however later additional replacements may be required during execution. h) Replacement of metal detectors and magnetic separators are usually not part of RLA studies and may need replacement during R&M execution. i) Further there can be more deterioration during the interim period after RLA studies.
27	Compressed Air System	a) Lack of proper assessment of the compressed air system. b) Additional installation of auxiliary pipes may be required.
28	Cooling Water System	While planning for installing new higher capacity Cooling Water Pump, compatibility of associated components may not be taken into account due to which pump cannot be operated at rated capacity.
29	Control And Instrumentations System	Significant technological advancement is observed in case of C & I. Most of the utility therefore prefers to undertake complete replacement of C&I system and hence may not face any significant technical surprises. In case entire system is not replaced, there may be reliability and compatibility issues of the new system with the old one.
30	Ash Handling Plant	Ash Hopper over time develops cracks in supporting columns and in some cases there are bents in balancing bolt which the utility may overlook during studies. Further, there may be space constraints for installation of new Ash Hopper which may be overlooked.
Civil Work		
31	Civil works	Proper evaluation of the foundations of all major equipments like boiler, turbine, ESPs

S No.	Plant System	Areas of Potential Surprises
		etc. is sometimes overlooked which may lead to technical surprises during the execution.
		Site accessibility and space constraint are important factors for delay of R&M works which are generally not considered before the start of the project. Lack of planning with regard to the movement of crane at the start leads to the occurrence of technical surprises and delay in execution of work.
Electrical System		
32	Generator	Technical surprise arises due to lack of design documents and information of the sub-vendor with regard to generator and its auxiliaries.
33	Stator	Damages in the generator stator may be observed during the execution stage which may get overlooked at the time of studies or may develop during the interim period between RLA studies and execution.
34	Rotor and Excitation System	There can be cracks in overhang portion of the rotor which might be overlooked during RLA studies or may develop during the interim period between RLA studies and execution.
35	Transformers (Generator Transformer, Unit Auxiliary Transformer, Station Transformer, HT and LT Transformer)	Insulation strength of paper (Furfural Test) of transformer is normally not conducted in RLA studies and there may be possibilities of flashovers. Another possibility of technical surprise is that connections from bus duct to transformer may be damaged which may be overlooked during assessment.
36	Motors (HT and LT Motors)	Technical surprise may arise due to improper assessment with regard to compatibility of HT/LT motors with the up-rated system.
37	Cables (HT and LT Cables)	In most cases the old cables are usually replaced with new ones. Cable tray fowling with the existing structure may need rerouting during execution. Although the scope may include replacement of paper insulated cable and some PVC cables having multiple joints with XLPE cables but exact requirement (in kms) may not be provided.
38	UPS, Battery and Battery Charger	Scope of UPS, battery and battery chargers may not be clearly defined. During the plant assessment the condition of battery and

S No.	Plant System	Areas of Potential Surprises
		battery charger can be found to be operating properly but due to time lag between studies and actual R&M execution, the deterioration may set in.
39	Plant illumination	Energy efficiency opportunities in illumination system of the plant (i.e. replacement of bulbs with CFL, LEDs etc) may not be assessed.

7. Root Causes for Occurrence of Potential Surprises

The following sections detail out the root causes for occurrence of technical surprises.

7.1 Weak data monitoring, reporting and maintenance procedures at the unit level

Most of the utilities do not maintain data related to key performance parameters of the unit, reliability of the unit and its individual components etc. Even if such data is maintained, it is done at the plant level only and not for all the unit level. Due to the lack of historical data it becomes difficult to understand the exact condition of the unit and this acts as one of the primary reasons for occurrence of technical surprises (arising due to lack of information for any third party invited for R&M of the unit). Lack of overhauling records with the utility is another related aspect. Due to the lack of such records suppliers are unable to comprehensively understand the exact condition of various equipments i.e. components that were replaced during the operating life of the plant, replacement time and history and remaining useful life of such equipments.

7.2 Unavailability of original design drawings with the utilities

Absence of design drawings with the utilities makes it difficult for both the utility and suppliers to undertake R&M and leads to technical surprises at the execution stage.

7.3 Inadequate assessment

RLA and other tests are conducted for main plant and equipments only whereas in case of rest of areas like BoP the scope is generally derived, without any actual condition assessment for BoP items. Lack of planning/assessment of BoP were found to be the one of the most common issues faced by the utilities. Lack of well chalked out path for cranes to reach the sites, space constraints etc. are some of the important issues generally overlooked during the planning stages. Further, proxy assessment is undertaken in case of multiple units. It is sometimes assumed that since both units are operating under same condition, assessment of one of the units would suffice the purpose and thus scope of work is prepared for both the units based on such limited assessment. This although results in saving of time and cost for the utility in the initial stages, leads to occurrence of technical surprises at the later stages due to non-exhaustive scope of work.

7.4 Weak/inadequate scope of work

Inadequate/weak scope of work is also one of the factors leading to technical surprises. This is primarily due to inadequate assessment/technical studies wherein the exact requirement for R&M is not established. Another reason for weak/inadequate scope of work is the financial constraints of the utility. In order to keep the financial budget under control, the utility may not include certain important works as part of R&M exercise and plans to cover that under O&M head at the later stage. However, this may lead to compatibility issue of old system with the new one leading to surprises at later stages or may impact the overall quality of works.

7.5 Huge time lag between the technical studies (RLA, DPR preparation) and actual award of contract (and commencement of R&M work)

This entire process normally takes ~3-4 years. The units identified for R&M in the interim period get low maintenance priority leading to rapid deterioration in the plant condition not captured in the studies and the scope of work leading to surprises at the execution stage. In case of units that are already shutdown, cannibalization of the material/spares to other unit has also been observed as a common practice.

7.6 Mismatch in plant shutdown period and supply of critical equipments

The schedule of supply of critical equipment has to be synchronized with the shutdown period to ensure completion of work in the minimum possible time. However, this mismatch can be on account of both suppliers and utility. There could be a delay in supply of key components and equipments by the supplier on account of absence of original vendors for such items; non-availability of original equipment details, specifications etc.; obsolete design and inadequate information available about modification done/spares used earlier. This leads to delay in supply of material on a timely basis. Further, due to energy shortages in the state and the prevailing grid conditions, utility may not be able to provide timely shutdown of the plant. Larger the mismatch or gap higher are the chances of occurrence of technical surprises.

7.7 Technological obsolescence

Refurbishment of old equipment or spares may not be possible due to technological obsolescence. This is true especially in case of old units of 110/120 MW units wherein the manufacturers have stopped manufacturing the spares (especially electrical) due to technological obsolescence.

7.8 Genuine uncertainty in R&M

Even with careful planning and implementation, some unforeseen situations are likely to arise. Most of the units being very old and functioning beyond their operating life coupled with poor O&M practices of the utility, it is common to find few technical surprises which cannot be anticipated at early stages.

8. Impact of Occurrence of Technical Surprises

The impact of the occurrence of technical surprises is as follows:

8.1 Scope Creep

The primary impact of occurrence of technical surprises is the additional scope of work which needs to be addressed by the supplier. This additional scope of work leads to cost escalation, time delay and sometimes contractual disputes between the utility and suppliers. The effectiveness with which utility decides the fair allocation of additional work to the supplier, minimises the contractual dispute and time taken by the supplier in delivering to this additional work are the key factors which govern the magnitude of the impact of the scope creep due to technical surprises.

8.2 Cost Escalation

Any additional work discovered in the form of surprise has a cost associated with it. This could be both direct as well as indirect. Direct costs include the cost of additional work and increase in IDC cost of the utility. Indirect cost include the loss in potential generation and hence revenue of the utility due to additional time required to address these surprises. Lack of ownership/active participation by the utility in acknowledging such additional work and deciding an acceptable course of action are key issues faced during implementing R&M. Both suppliers and utility are bearers of this risk. While the loss of supplier is limited to the cost of addressing the surprise, utility suffers/bears a large proportion of the cost in form of both direct as well as significant indirect cost caused due to loss in potential generation. Moreover utility might also face regulatory risk wherein recovery of these costs may not be allowed by the state electricity regulatory commission while determining generation tariffs.

8.3 Non-adherence to the project schedule timelines

Another related impact of technical surprise is the delay in the project schedule due to additional time required to address the technical surprise. The reasons for delay from the project schedule includes the following: a) situation of indecisiveness, b) non-availability of slots for repair, testing at various production/manufacturing units of the supplier, c) non-existence of original vendors for such items, d) customized manufacturing of a particular component/spare due to obsolete design, e) practical time required in transportation of material for repair from the utility place to the workshop of the supplier and back at the utility place etc. All these factors may have adverse impact on the utility revenues as it can lead to months of shutdown of the unit.

8.4 Quality Deviation

Technical surprise may also impact the quality of R&M works and non-achievement of overall R&M benefits. One of the most concurring technical surprises seen is non-availability of spares or incompatibility of older system with the new system envisaged in R&M project. Due to such surprises, the expected outcome of the scope cannot be met and the utility has to look for other alternatives which affect the quality of the system. This situation arises due to improper assessment of the relationship and interaction between different components/equipments in a thermal plant. Further, to minimise the delays/shutdown period certain non-priority items are not given due importance during the R&M process which may affect the overall quality of work.

8.5 Contractual Dispute

Disagreement between supplier and utility regarding additional scope on account of technical surprise and incomplete interfacing between components and instruments may lead to contractual dispute causing delay or slow execution of the work.

9. Strategies for early identification of Technical Surprises and ways to address them

In order to address technical surprises, different actions/strategies need to be undertaken/ executed during different stages of R&M process cycle i.e. from the identification stage/start of R&M project until the closure stage/end of R&M project. These strategies/actions for addressing technical surprises can be categorised into the following categories:

9.1 Preventive Strategy

This involves undertaking actions/strategies by the utilities that either aim at reducing or eliminating the likelihood of the occurrence of such surprises. Preventive actions in generally should be preferred as they aim to address the issue when the magnitude of the problem is small/controllable.

9.2 Managing Strategy

This strategy is adopted because it is seldom possible to eliminate all the surprises and the utilities are bound to face certain surprises. The only possible way is to identify potential surprises, accept it and undertake immediate actions to minimise its impact or consequences.

In order to effectively handle the surprises combination of the strategies mentioned above needs to be adopted. These are explained below.

9.3 Identification Stage

The identification stage includes execution of preventive strategies by the utility to handle technical surprises. This includes strengthening of O&M practices in the plant and strengthening of internal data maintenance, acquisition and reporting in the plant. These are explained below:

9.3.1 Strengthening of O&M practises in the plant (Preventive)

Development of preventive maintenance manuals and adherence to the annual maintenance/overhaul schedule and timely/periodic capital overhaul schedule are pre-requisite for preventing occurrence of technical surprises during R&M of the project. By undertaking regular O&M, utility is constantly updated about the actual condition of the plant and wear and tear of different components of the plant is addressed on regular intervals minimising the probability of occurrence of technical surprises.

9.3.2 Strengthening of internal data maintenance, acquisition and reporting in the plant (Preventive)

Internal data maintenance includes regular monitoring and data collection of key operating and performance parameters such as heat rate, specific coal and oil consumption, auxiliary consumption at the unit level. It is required that utility should undertake the following steps:-

i. The utilities must properly maintain documents related to Operating Procedures, Manuals, Technical Handbooks and Instructions supplied by Original Equipment Manufacturers (OEMs).

ii. Documentation of key engineering diagrams/drawings and other critical plant diagrams in centralised technical library in both hard and soft format. This is one of the most critical requirements for designing the components/equipments that are to be replaced and made compatible with the existing system.

iii. Operation Engineers should maintain day to day parameter data of the units and generate monthly performance report.

iv. Overhaul records along with complete details of repair/replacement of plant equipments/components.

It is important that plants/units that are expected to undertake R&M in near future should try to start compiling and collecting the above mentioned data. Also, for the recently commissioned units, it is important that utility should implement above suggestions in its day to day operation of the unit so that such problem does not arise in future.

Further, compilation of data mentioned above (especially performance data) is also important from the viewpoint of estimation and monetization of GHG emissions reduction through implementation of energy efficient R&M.

9.4 Assessment Stage

The assessment stage includes execution of both preventive strategies and strategies for managing surprises. These are explained below:

9.4.1 Undertaking comprehensive assessment through technical studies with clearly defined scope of work (Preventive)

In order to minimize technical surprises, the utility should undertake comprehensive assessment of both main plant equipment and the BoPs through technical studies for each unit planned for R&M. In this regard

CEA has prepared standard documents for carrying out RLA/CA/EA studies which may be used by the utilities.

9.4.2 Creation of technical surprise plan (Managing Surprises)

A well-defined technical surprise plan should be prepared for effectively handling technical surprises, as and when they occur[35]. The design consultant involved in undertaking comprehensive assessment, DPR and subsequent scope of work should also prepare a technical surprise plan. This should be prepared in consultation with the plant level officials involved in operation, repair and maintenance of the plant to understand the potential surprises as they have the experience of the actual condition of the plant. This includes a list of possible surprises, ensuring availability of spare parts to minimize delays, addressing upfront the likely contractual aspects of additional supplies and works etc. Further, this should also include the unit rates for equipment/parts and total financial implications of the same. In this regard CEA has prepared standard documents for Detailed Project Report (DPR) which may be used by the utilities.

9.4.3 Creation of Dispute Resolution Mechanism (Managing Surprises)

Due to the occurrence of technical surprise there may be disagreement between the utility and vendor on certain aspects which may translate into disputes and affect overall execution of work. Therefore, in order to resolve disputes between the contractor, sub-contractor and utility, it is important to create a Dispute Resolution Mechanism. Under this mechanism a Dispute Resolution Committee (DRC) should be formed at the start of the project with fair participation from both utility and contractor. In this regard, CEA has prepared standard bid documents which may be used by the utilities.

9.4.4 Creation of dedicated R&M Cell and Engaging Specialised Consultants (Preventive)

In order to effectively deliver a successful R&M project, the following steps are required:

i. **Creation of dedicated R&M cell by the utility at the headquarter and at the plant**

   In order to effectively deliver on the R&M project it is important to create a separate R&M cell with adequate and dedicated manpower for the project. This team should involve plant level officials dealing with the different departments like Boiler, Turbine, Electrical, C&I, CHP, Milling system and AHP etc. Further, officials having prior R&M experience should also be included in the team.

   To ensure timely decisions and approvals within the organization it is important that a dedicated R&M cell should also be formed

[35] The first aim in all earnest should be to minimize the occurrence of technical surprises.

at the headquarters level.

ii. **Engaging of design and implementation support consultants**

Specialized agencies should be engaged by the utility (on the basis of competitive bidding) covering assistance on all works from design to implementation. This could be either one agency or multiple agencies.

The role of design consultants is to assist the utility in tasks related to conduct of different studies, identification and selection of best feasible option for R&M, preparation of DPR including technical surprise plan, scope finalization, preparation of tender documents, bid evaluation and selection of vendor etc.

The role of implementation consultant includes review and approval of drawings, coordination between the vendors and the utility, monitoring the progress of work as per approved schedule, assistance to Owner in dealing with statutory authorities such as Boiler Inspectorate Directorate, Pollution Control Board etc., monitoring of day to day progress of the work, review of PG Test Report etc.

Further, to build the requisite capacity of the utility officials, scope of work of consultants should also include training of utility/R&M cell officials on each of these components/fields.

9.4.5 Establishing a clear decision making framework (Managing Surprises)

Once the technical surprises occur, the indecisiveness on the part of the utility can result in significant delay in the execution of work. It is important to specify the decision making process with clearly defined roles and responsibilities, and requisite authority of different officials to enable timely resolution of the issues encountered during the R&M. This includes internal reporting structures and decision making authority for its timely addressal.

9.4.6 Pre-approved contingency fund (Managing Surprises)

Contingency fund should be provided for handling technical surprises and should be incorporated in the final budget of the project.

9.4.7 In principle approval from the regulatory commission for additional capital requirement for handling technical surprises (Managing Surprises)

Appropriate regulatory commission should be apprised well in advance about the technical surprise plan and contingency fund for provisioning of additional costs for dealing with surprises. It is thus suggested that the technical surprise plan and contingency fund be incorporated in the DPR.

9.5 Planning stage

The planning stage includes execution of both preventive strategies and strategies for managing surprises. These are explained below:

9.5.1 Minimising time gap between assessment and award of contract and preparation of interim O&M action plan by the utilities (Preventive)

Time gap between assessment and award of contract should be minimised by the utilities. Also, an interim O&M action plan should be prepared by the utility which identifies the key urgent requirements or actions that must be undertaken by the utility during this interim time period.

9.5.2 Provision for access of potential suppliers to the site (Preventive)

Access to the site should be provided to the bidders for carrying out due diligence. The access to the site may be provided by the utility either at the pre-bid stage or before the submission of financial bid by the supplier. This is important as this would enable the suppliers to acclimatise to the actual condition of the plant and enable them to bid accordingly. The access to the plant site along with providing results of past studies undertaken by the utilities would not only minimise surprises but would also lead to more realistic price discovery for the utility.

9.5.3 Bid documents should seek unit price of various components (Managing Surprises)

In the bid documents the utility should seek unit rates for such components/works which are expected or anticipated based on the prepared technical surprise plan. This should also be incorporated in the contract.

9.5.4 Understanding supplier strategy to deal with technical surprise as an important evaluation criteria (Managing Surprises)

At the tendering stage, suppliers must be asked to provide their understanding of potential surprises based on their past experience, results of the plant studies provided by the utility, their own assessment and the potential technical surprise plan prepared by the utility.

Submission of strategy for technical surprises from the suppliers end would provide some certainty and commitment from the supplier to deal with such surprises.

9.6 Execution Stage

Actual technical surprises are observed at the time of opening up of the machine for R&M. The strategy at this stage includes the following:

9.6.1 Timely identification and reporting of surprises (Managing Surprises)

In order to timely identify surprises it is important that robust communication and periodic review of R&M project be undertaken by the utility.

9.7 Closure stage

The occurrence of technical surprises has an adverse impact on the overall cost of the project. It is therefore important for the utility to obtain approval from the regulatory commission to capitalise the additional cost of the project in order to safeguard its financial interest. This includes the following:

9.7.1 Submission of details to the regulatory commission detailing out the occurrence of technical surprises and strategies adopted to minimise the impact (Managing Surprises)

Utility should undertake a detailed mapping of the potential surprises envisaged at the start of the project, technical surprises actually encountered along with reasons for its occurrence and the mitigation steps undertaken by the utility. This is important as it would enable the utility to justify to the regulatory commission that the cost incurred was in the best interest of the project and the additional expenditure was beyond the control of the utility.

9.7.2 Ex-Post evaluation of surprises and lessons learnt for future R&M projects (Managing Surprises)

Ex-post evaluation of surprises encountered during execution of R&M works and the actions undertaken is essential to understand the impact/effectiveness of the entire plan. Generating company must undertake ex-post evaluation of the R&M works and should document its experiences. This is important especially in case company is undertaking R&M works on multiple units. The learning/experiences gained from the first unit must be incorporated in the implementation plan of the subsequent units even if it requires modification in the scope of work of other units. CEA may provide a methodology/standard template for ex-post evaluation. Further, the learning from different projects should be disseminated through a common platform such as the CEA official website. The CEA may initiate action in this regard.

10. Implementation of the Guidelines

10.1 The utilities should evaluate the type/root causes of potential surprises identified in these guidelines before implementing R&M projects and formulate appropriate strategies in line with that suggested in these guidelines to minimize and manage such surprises.

10.2 It is expected that the guidelines would provide direction to the utilities to improve the planning and execution of R&M projects by preventing and managing the occurrence of surprises.

Annexure 3

List of R&M/LE Plants for Estimating GHG Reduction Potential

A. State Sector (R&M/ LE in 12th Plan)

#	Plant Name	State	Capacity
1	Bhusawal TPS, Unit - 2	Maharashtra	210
2	Bhusawal TPS, Unit - 3	Maharashtra	210
3	Chandrapur TPS Maha, Stage - 1, Unit - 1	Maharashtra	210
4	Chandrapur TPS Maha, Stage - 1, Unit - 2	Maharashtra	210
5	Chandrapur TPS Maha, Stage - 1, Unit - 3	Maharashtra	210
6	Chandrapur TPS Maha, Stage - 1, Unit - 4	Maharashtra	210
7	Chandrapur TPS Maha, Stage - 2, Unit - 5	Maharashtra	500
8	Chandrapur TPS Maha, Stage - 2, Unit - 6	Maharashtra	500
9	Gandhinagar TPS, Unit - 3	Gujarat	210
10	Gandhinagar TPS, Unit - 4	Gujarat	210
11	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 1	Chhattisgarh	210
12	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 2	Chhattisgarh	210
13	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 3	Chhattisgarh	210
14	Hasdeo Thermal Power Station(HTPS), Korba West, Unit - 4	Chhattisgarh	210
15	KHAPERKHEDA TPS, Unit - 1	Maharashtra	210
16	KHAPERKHEDA TPS, Unit - 2	Maharashtra	210
17	Kolaghat TPS, Unit - 1	West Bengal	210
18	Kolaghat TPS, Unit - 2	West Bengal	210
19	Kolaghat TPS, Unit - 3	West Bengal	210
20	Kolaghat TPS, Unit - 4	West Bengal	210
21	Kolaghat TPS, Unit - 5	West Bengal	210

#	Plant Name	State	Capacity
22	Kolaghat TPS, Unit - 6	West Bengal	210
23	Koradi TPS, Unit - 5	Maharashtra	200
24	Koradi TPS, Unit - 7	Maharashtra	210
25	Kota TPS, Unit - 3	Rajasthan	210
26	Kota TPS, Unit - 4	Rajasthan	210
27	Kota TPS, Unit - 5	Rajasthan	210
28	Nasik TPS, Unit - 3	Maharashtra	210
29	Nasik TPS, Unit - 4	Maharashtra	210
30	Nasik TPS, Unit - 5	Maharashtra	210
31	Panipat Thermal Power Station, Unit - 5	Haryana	210
32	Parli TPS, Unit - 3	Maharashtra	210
33	Parli TPS, Unit - 4	Maharashtra	210
34	Parli TPS, Unit - 5	Maharashtra	210
35	Raichur TPS, Unit - 1	Karnataka	210
36	Raichur TPS, Unit - 2	Karnataka	210
37	Raichur TPS, Unit - 3	Karnataka	210
38	Raichur TPS, Unit - 4	Karnataka	210
39	Ropar TPS, Unit - 1	Punjab	210
40	Ropar TPS, Unit - 2	Punjab	210
41	Ropar TPS, Unit - 3	Punjab	210
42	Ropar TPS, Unit - 4	Punjab	210
43	Ropar TPS, Unit - 5	Punjab	210
44	Ropar TPS, Unit - 6	Punjab	210
45	Sanjay Gandhi (Birsinghpur), Stage 1, Unit - 1	Madhya Pradesh	210
46	Sanjay Gandhi (Birsinghpur), Stage 1, Unit - 2	Madhya Pradesh	210
47	Satpura, Stage - 2, Unit - 6	Madhya Pradesh	200
48	Satpura, Stage - 2, Unit - 7	Madhya Pradesh	210
49	Satpura, Stage - 3, Unit - 8	Madhya Pradesh	210

#	Plant Name	State	Capacity
50	Satpura, Stage - 3, Unit - 9	Madhya Pradesh	210
51	TENUGHAT TPS, Unit - 1	Jharkhand	210
52	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 1	Tamil Nadu	210
53	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 2	Tamil Nadu	210
54	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 3	Tamil Nadu	210
55	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 4	Tamil Nadu	210
56	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 5	Tamil Nadu	210
57	Ukai Thermal Power Station, Stage 1, Unit - 3	Gujarat	200
58	Ukai Thermal Power Station, Stage 1, Unit - 4	Gujarat	200
59	Ukai Thermal Power Station, Stage 1, Unit - 5	Gujarat	210
60	Wanakbori Thermal Power Station, Unit - 1	Gujarat	210
61	Wanakbori Thermal Power Station, Unit - 2	Gujarat	210
62	Wanakbori Thermal Power Station, Unit - 3	Gujarat	210
63	Wanakbori Thermal Power Station, Unit - 4	Gujarat	210
64	Wanakbori Thermal Power Station, Unit - 5	Gujarat	210
65	Wanakbori Thermal Power Station, Unit - 6	Gujarat	210
66	Anpara TPS, Stage - B, Unit - 4	Uttar Pradesh	500
67	Anpara TPS, Stage - B, Unit - 5	Uttar Pradesh	500
68	Bandel TPS, Unit - 5	West Bengal	210
69	Barauni TPS, Unit - 6	Bihar	110
70	Barauni TPS, Unit - 7	Bihar	110
71	Guru Nanak Dev TPS, Unit - 4	Punjab	110
72	Harduaganj TPS, Unit - 7	Uttar Pradesh	110
73	Koradi TPS, Unit - 6	Maharashtra	210
74	Kota TPS, Unit - 1	Rajasthan	110
75	Kota TPS, Unit - 2	Rajasthan	110
76	Muzaffarpur TPS, Unit - 1	Bihar	110
77	Muzaffarpur TPS, Unit - 2	Bihar	110

#	Plant Name	State	Capacity
78	Obra TPS, Unit - 10	Uttar Pradesh	200
79	Obra TPS, Unit - 11	Uttar Pradesh	200
80	Obra TPS, Unit - 12	Uttar Pradesh	200
81	Obra TPS, Unit - 13	Uttar Pradesh	200
82	Obra TPS, Unit - 7	Uttar Pradesh	100
83	Panipat Thermal Power Station, Unit - 3	Haryana	110
84	Panipat Thermal Power Station, Unit - 4	Haryana	110
85	PARICHA TPS, Unit - 1	Uttar Pradesh	110
86	PARICHA TPS, Unit - 2	Uttar Pradesh	110
87	Patratu Thermal Power Station, Unit - 9	Jharkhand	110
88	Vijayawada TPS, Stage 1, Unit - 1	Andhra Pradesh	210
89	Vijayawada TPS, Stage 1, Unit - 2	Andhra Pradesh	210
	Grand total		**18360**

B. State Sector (R&M/ LE in 13th Plan)

#	Plant Name	State	Capacity
1	Chandrapur TPS Maha, Stage - 2, Unit - 5	Maharashtra	500
2	Gandhinagar TPS, Unit - 3	Gujarat	210
3	Gandhinagar TPS, Unit - 4	Gujarat	210
4	KHAPERKHEDA TPS, Unit - 1	Maharashtra	210
5	KHAPERKHEDA TPS, Unit - 2	Maharashtra	210
6	Kolaghat TPS, Unit - 1	West Bengal	210
7	Kolaghat TPS, Unit - 5	West Bengal	210
8	Kota TPS, Unit - 3	Rajasthan	210
9	Kota TPS, Unit - 4	Rajasthan	210
10	Mettur TPS, Unit - 1	Tamil Nadu	210
11	Mettur TPS, Unit - 2	Tamil Nadu	210
12	Mettur TPS, Unit - 3	Tamil Nadu	210

#	Plant Name	State	Capacity
13	Mettur TPS, Unit - 4	Tamil Nadu	210
14	Panipat Thermal Power Station, Unit - 5	Haryana	210
15	Parli TPS, Unit - 5	Maharashtra	210
16	Raichur TPS, Unit - 3	Karnataka	210
17	Ropar TPS, Unit - 3	Punjab	210
18	Ropar TPS, Unit - 4	Punjab	210
19	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 4	Tamil Nadu	210
20	Tuticorin TPS/Thoothukudi TPS (TTPS), Unit - 5	Tamil Nadu	210
21	Vijayawada TPS, Stage 2, Unit - 3	Andhra Pradesh	210
22	Vijayawada TPS, Stage 2, Unit - 4	Andhra Pradesh	210
23	Wanakbori Thermal Power Station, Unit - 6	Gujarat	210
24	Gandhinagar TPS, Unit - 5	Gujarat	210
25	Panipat Thermal Power Station, Unit - 6	Haryana	210
26	TENUGHAT TPS, Unit - 2	Jharkhand	210
27	Raichur TPS, Unit - 5	Karnataka	210
28	Raichur TPS, Unit - 6	Karnataka	210
29	Sanjay Gandhi (Birsinghpur), Stage 2, Unit - 3	Madhya Pradesh	210
30	Sanjay Gandhi (Birsinghpur), Stage 2, Unit - 4	Madhya Pradesh	210
31	KHAPERKHEDA TPS, Unit - 4	Maharashtra	210
32	KHAPERKHEDA TPS, Unit - 3	Maharashtra	210
33	Chandrapur TPS Maha, Stage - 2, Unit - 7	Maharashtra	500
34	Suratgarh TPS, Unit - 3	Rajasthan	250
35	Suratgarh TPS, Unit - 2	Rajasthan	250
36	Suratgarh TPS, Unit - 1	Rajasthan	250
37	Bakreshwar TPS, Unit - 3	West Bengal	210
38	Bakreshwar TPS, Unit - 2	West Bengal	210
39	Bakreshwar TPS, Unit - 1	West Bengal	210
	Grand total		**8890**

C. Central Sector (R&M/ LE in 12th Plan)

#	Plant Name	State	Capacity
1	Bokaro TPS B, Unit - 1	Jharkhand	210
2	Durgapur TPS, Unit- 4	DVC	210
3	FARAKKA STAGE-1, Unit - 1	West Bengal	200
4	FARAKKA STAGE-1, Unit - 2	West Bengal	200
5	FARAKKA STAGE-2, Unit - 4	West Bengal	500
6	Korba STPP, Stage - 1, Unit - 2	Chhattisgarh	200
7	Korba STPP, Stage - 1, Unit - 3	Chhattisgarh	200
8	Neyveli TPS - 2, Stage 1, Unit - 3	Tamil Nadu	210
9	Ramagundam, Stage - 1, Unit - 2	Andhra Pradesh	200
10	Ramagundam, Stage - 1, Unit - 3	Andhra Pradesh	200
11	Singrauli Thermal Power Station, Unit - 3	Uttar Pradesh	200
12	Singrauli Thermal Power Station, Unit - 4	Uttar Pradesh	200
13	Singrauli Thermal Power Station, Unit - 5	Uttar Pradesh	200
14	Singrauli Thermal Power Station, Unit - 6	Uttar Pradesh	500
15	Vindhyachal Thermal Power Station, Stage - 1, Unit - 1	Madhya Pradesh	210
16	Singrauli Thermal Power Station, Unit - 7	Uttar Pradesh	500
17	Korba STPP, Stage - 2, Unit - 4	Chhattisgarh	500
18	Korba STPP, Stage - 2, Unit - 5	Chhattisgarh	500
19	Korba STPP, Stage - 2, Unit - 6	Chhattisgarh	500
20	Ramagundam, Stage - 2, Unit - 4	Andhra Pradesh	500
21	Ramagundam, Stage - 2, Unit - 5	Andhra Pradesh	500
22	Ramagundam, Stage - 2, Unit - 6	Andhra Pradesh	500
23	Unchahar TPS, Stage 1, Unit - 1	Uttar Pradesh	210
24	Unchahar TPS, Stage 1, Unit - 2	Uttar Pradesh	210
25	Unchahar TPS, Stage 2, Unit - 3	Uttar Pradesh	210
26	Unchahar TPS, Stage 2, Unit - 4	Uttar Pradesh	210

#	Plant Name	State	Capacity
27	Vindhyachal Thermal Power Station, Stage - 1, Unit - 2	Madhya Pradesh	210
28	Vindhyachal Thermal Power Station, Stage - 1, Unit - 3	Madhya Pradesh	210
29	Vindhyachal Thermal Power Station, Stage - 1, Unit - 4	Madhya Pradesh	210
30	Vindhyachal Thermal Power Station, Stage - 1, Unit - 5	Madhya Pradesh	210
31	Vindhyachal Thermal Power Station, Stage - 1, Unit - 6	Madhya Pradesh	210
32	Vindhyachal Thermal Power Station, Stage - 2, Unit - 7	Madhya Pradesh	500
33	Vindhyachal Thermal Power Station, Stage - 2, Unit - 8	Madhya Pradesh	500
34	Simhadri TPS, Stage - 1, Unit - 1	Andhra Pradesh	500
35	Simhadri TPS, Stage - 1, Unit - 2	Andhra Pradesh	500
36	Talcher STPS, Stage - 1 for ER, Unit - 1	Orissa	500
37	Talcher STPS, Stage - 1 for ER, Unit - 2	Orissa	500
38	Dadri Thermal (NCTPP) - Stage 1, Unit- 1	Uttar Pradesh	210
39	Dadri Thermal (NCTPP) - Stage 1, Unit- 2	Uttar Pradesh	210
40	Dadri Thermal (NCTPP) - Stage 1, Unit- 3	Uttar Pradesh	210
41	Dadri Thermal (NCTPP) - Stage 1, Unit- 4	Uttar Pradesh	210
42	Rihand STPS, Stage - 1, Unit - 1	Uttar Pradesh	500
43	Rihand STPS, Stage - 1, Unit - 2	Uttar Pradesh	500
44	Kahalgaon Thermal Power Station Stage 1, Unit - 1	Bihar	210
45	Kahalgaon Thermal Power Station Stage 1, Unit - 2	Bihar	210
46	Kahalgaon Thermal Power Station Stage 1, Unit - 3	Bihar	210
47	Kahalgaon Thermal Power Station Stage 1, Unit - 4	Bihar	210
48	Bokaro TPS B, Unit - 2	Jharkhand	210

#	Plant Name	State	Capacity
49	Bokaro TPS B, Unit - 3	Jharkhand	210
50	Badarpur Thermal Power Station, Unit - 4	Delhi	210
51	Badarpur Thermal Power Station, Unit - 5	Delhi	210
52	Singrauli Thermal Power Station, Unit - 1	Uttar Pradesh	200
53	Singrauli Thermal Power Station, Unit - 2	Uttar Pradesh	200
54	Korba STPP, Stage - 1, Unit - 1	Chhattisgarh	200
55	Ramagundam, Stage - 1, Unit - 1	Andhra Pradesh	200
	Grand total		**16350**

D. Central Sector (R&M/ LE in 13th Plan)

#	Plant Name	State	Capacity
1	Mejia TPS, Unit - 1, (MTPS - A)	Jharkhand	210
2	Mejia TPS, Unit - 2, (MTPS - A)	West Bengal	210
3	Mejia TPS, Unit - 3, (MTPS - A)	Tamil Nadu	210
4	Bokaro TPS B, Unit - 3	Tamil Nadu	210
5	Talcher STPS, Stage - 2 for SR, Unit - 4	Tamil Nadu	500
6	Talcher STPS, Stage - 2 for SR, Unit - 3	Tamil Nadu	500
7	Neyveli TPS - 1, Expn (Stage - 3), Unit - 2	Tamil Nadu	210
8	Neyveli TPS - 1, Expn (Stage - 3), Unit - 1	Tamil Nadu	210
9	Neyveli TPS - 2, Expn, Unit - 1	Tamil Nadu	250
10	Neyveli TPS - 2, Stage 2, Unit - 7	Tamil Nadu	210
11	Neyveli TPS - 2, Stage 2, Unit - 6	Tamil Nadu	210
12	Rihand STPS, Stage - 2, Unit - 3	Uttar Pradesh	500
13	Rihand STPS, Stage - 2, Unit - 4	Uttar Pradesh	500
14	FARAKKA STAGE-2, Unit - 5	West Bengal	500
	Grand total		**4430**

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