Strengthening Operations and Maintenance Practices In State-Sector Coal-Fired Power Generation Plants in India

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Sustainable Development Network
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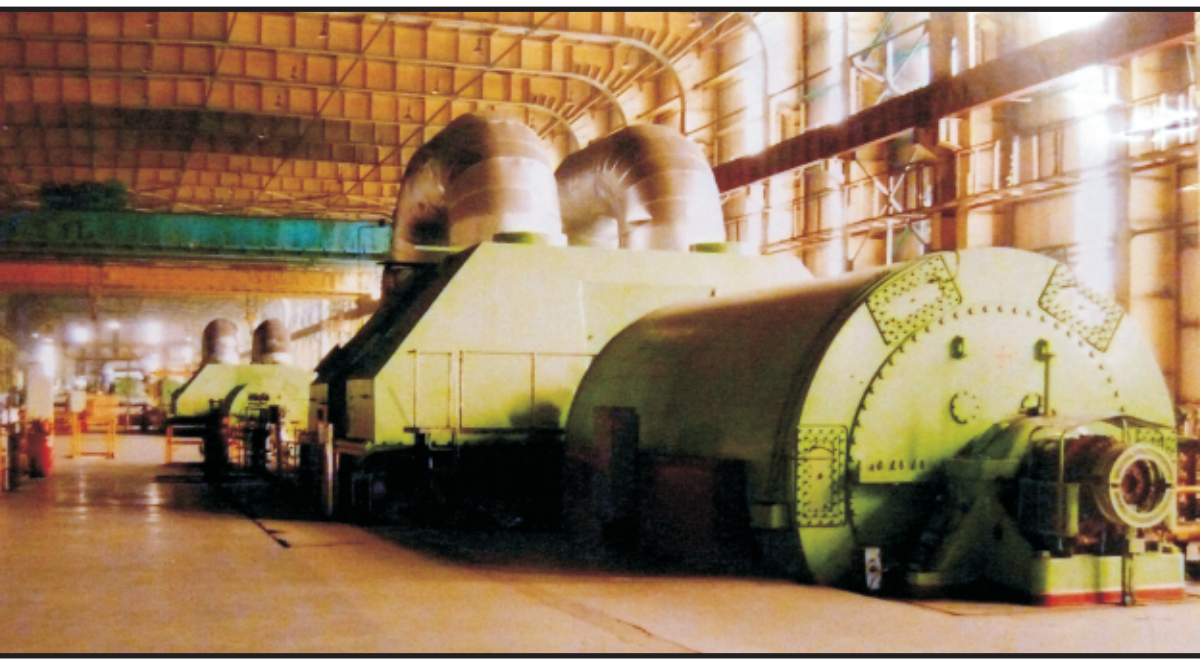
Energy Sector Management Assistance Program (ESMAP)



ESMAP
Energy Sector Management Assistance Program

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This policy note was prepared by a World Bank team led by Mikul Bhatia and Chandrasekeren.Subramaniam (South Asia Sustainable Development - Energy). Masaki Takahashi (Energy Transport and Water Department) and R.K.Jain (Consultant) provided extensive input.

The work for the underlying study was carried out primarily by Pricewaterhouse Coopers and Steag Encotec India (now called Evonik Industries). Extensive inputs were also provided by international consultants Robert Richwine and Don Bennett. Dirk Pauschert (Research Analyst) and Mani Khurana provided support to the effort especially during workshops for stakeholder consultations. The peer reviewers were Natalia Kulichenko and Pedro Antmann (Energy Transport and Water Department).

The underlying study by the consultants examined Operations and Maintenance (O&M) practices at Bandel Thermal Power Station in West Bengal and Koradi Thermal Power Station in Maharashtra. Select power generation units in these two power plants are included in World Bank and GEF funded Energy Efficiency Renovation and Modernization (EE R&M) project in India. The findings of the study on O&M practices at these plants and strategy for strengthening the same were discussed extensively with officials of respective utilities at workshops held at Kolkata and Mumbai. The underlying study has been endorsed by the respective generation utilities – West Bengal Power Development Corporation Limited (WBPDCL) and Maharashtra State Power Generation Company Limited (MSPGCL). Action Plans for improving O&M practices at these power plants are being finalized by the utilities based on the O&M study.

ACRONYMS AND ABBREVIATIONS

ABC	Activity Based Costing
ABT	Availability Based Tariff
APC	Auxiliary Power Consumption
C&I	Control and Instrumentation
CEA	Central Electricity Authority
CHP	Customer Hold Points
CM	Condition Monitoring
CMMS	Computerized Maintenance Management System
DoP	Delegation of Powers
DPIs	Departmental Performance Indicators
EER&M	Energy Efficiency Renovation and Modernization
ERP	Enterprise Resource Planning
ESMAP	Energy Sector Management Assistance Program
F&A	Finance and Accounts
FMEA	Failure Mode and Effect Analysis
FY	Financial Year
GCR	Generation Control Room
GEF	Global Environment Facility
GoI	Government of India
HR	Human Resource
Hr	Hour
ISO	International Standards Organization
IT	Information Technology
Kcal	Kilocalories
KPIs	Key Performance Indicators
KRAs	Key Responsibility Areas
	KwhKilowatt Hour
LAN	Local Area Network
MIS	Management Information System
MPD	Maintenance Planning Department
MSPGCL	Maharashtra State Power Generation Company Limited
MW	Megawatt

O&E	Operations and Efficiency
O&M	Operations & Maintenance
OEM	Original Equipment Manufacturer
ORT	Operation Review Team
MTBF	Mean Time Between Failures
PIE	Partnership In Excellence
PLF	Plant Load Factor
PMS	Performance Management System
PSUs	Public Sector Undertakings
QA	Quality Assurance
QAP	Quality Assurance Plan
R&M	Renovation & Modernization
SCADA	Supervisory Control and Data Acquisition
SERC	State Electricity Regulatory Commission
SWAS	Steam and Water Analysis System
ToR	Terms of Reference
UI	Unscheduled Interchange
VED	Vital Essential Desirable
WAN	Wide Area Network

ABSTRACT

The Plant Load Factor (PLF) of state-sector thermal power plants in India in 2006-07 was on an average 70.84 percent compared with 89.4 percent for central-sector NTPC power plants and 86.35 percent for private-sector power plants. Among the state-sector power plants also, there is a wide performance range with more than 90 percent PLF for some power plants in Punjab, Gujarat, Rajasthan, Andhra Pradesh and Tamil Nadu. It is seen that most of the high performing power plants have adopted modern Operations and Maintenance (O&M) practices and systems. There is a significant scope for improving the performance of the underperforming state-sector power plants just by focusing on the O&M practices / systems.

Improving performance of state-sector power plants through interventions aimed at strengthening O&M practices, coupled with required rehabilitation and life extension interventions is perhaps the quickest and least cost alternative for augmenting availability of power in the Indian context. It is estimated that the availability of power in the country can be enhanced by more than 17 percent (as against energy deficit of 9 percent) if all the available generation units can be utilized at an average PLF similar to NTPC units through rehabilitation combined with better O&M practices. Although such high levels of performance may be difficult to achieve across all state-sector power plants, the potential benefits of focusing on improved power plant performance are clearly immense. Improved O&M practices are also necessary to sustain the performance of rehabilitated power plants as well as new power plants. Government of India initiatives in this regard (Partnership in Excellence – PIE Program) also amply demonstrated the potential benefits.

This note is intended to serve as a concise guide for the utility senior management and other sector agencies on the key steps for strengthening the Operations and Maintenance Practices in state-sector coal-fired power generation plants in India. The note primarily focuses on managerial and organizational aspects of power plant operation and maintenance and brings out possible interventions in these areas for enhancing power plant performance. While the note refers to some technical aspects of plant performance in context of managerial and organizational interventions, it does not purport to be a technical guide on O&M of power plants.

The note is based on a study carried out by independent consultants in two state-sector power plants and highlights the key gaps identified in the O&M practices of these plants with a *clear focus on efficiency management*. Adequacy of management practices in the areas of generation target-setting, plant level budgeting, cost management and inventory management have been assessed especially in context of the current regulatory regime and the Availability Based Tariff (ABT) regime which are the key determinants of the fixed cost recovery through tariff. The maintenance practices have been assessed with a view to identify the gaps vis-à-vis a predictive and condition based maintenance approach that is the hallmark of leading utilities worldwide. Based on the observations at the two select power plants, interventions for strengthening O&M practices in state-sector power plants in India have been proposed.

For enhancing the O&M practices, multiple interventions are required across the various aspects including people, technology, process and facilities/infrastructure. Operational practices improvement will require setting up an *Operations and Efficiency (O&E) cell* at the plant which needs to complement the current corporate performance oversight process. It

would also require setting up a *Trip Committee* at the plant to analyze the root causes of unforeseen outages. There is also a need for designing a framework for assessment of losses on commercial basis.

Maintenance practices enhancement shall require short-term interventions in the form of establishing and strengthening the maintenance planning function through establishment of a *Maintenance Planning Cell* along with preparation of a *Plant Asset Database* and a *Condition Monitoring Plan.* Longer term interventions could be towards investing in a *Computerized Maintenance Management System (CMMS)* and developing a decision support system linking maintenance costs to reliability levels of station.

Generation budgeting process would need to be strengthened through establishment of an in-house *Budget Committee* and the preparation of a comprehensive *Budget Manual* along with conducting training for the utility personnel to operate in a performance based budget regime. In the area of Generation Planning, there is a need to slowly move from the 'Bottom Up' approach (based on what is readily achievable) of generation target setting to the 'Top Down' approach (based on the desired level of performance). Enablers for achieving these targets should be identified and all out efforts be made to achieve them.

There is a need to establish a Quality Assurance function along with introduction of Quality Assurance Plan in tenders and developing strong vendors through long-term contracts for spares and services. The existing inventory levels could be rationalized through classification on Vital-Essential-Desirable (VED) basis for the ease of setting differential procurement strategies for the same. Also spares banks could be established to benefit from reduced inventory holding by pooling spares across plants at close distances.

A deeper appreciation of cost related aspects needs to be inculcated at the utility through development of a costing framework and establishment of *cost codes* and operationalising the same with requisite training to the finance personnel. Over a long term based on the benefit assessment, the utility may migrate to an *Activity Based Costing (ABC)* System.

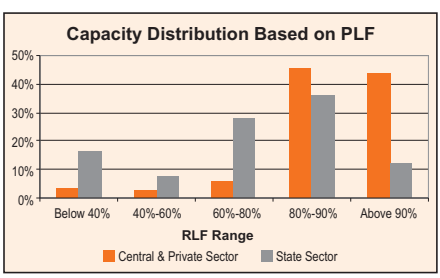
Human resource related aspects are a key concern with most utilities. In particular, there is a need to have robust job descriptions with clearly identified accountabilities to establish *Key Responsibility Areas (KRAs)* and *Key Performance Indicators (KPIs).* The established KRAs and KPIs should feed into an improved Performance Management process. A structured approach towards training has to be developed both for the plant and corporate level staff. Given the increasing complexities of operating the assets in a competitive regime, it is essential that a rigorous skill gap analysis is conducted and suitable measures taken towards training and recruitment of staff.

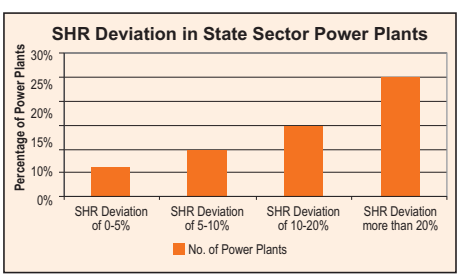
STRENGTHENING OPERATIONS AND MAINTENANCE PRACTICES IN STATE-SECTOR COAL-FIRED GENERATING PLANTS IN INDIA

BACKGROUND

1. Sector Background The Indian power sector suffers from considerable electricity supply shortages (peak deficit of 15.2 percent and energy deficit of 9.0 percent in 2007-08). The Government of India (GoI) is addressing this problem both through a major green field capacity augmentation program and through rehabilitation of existing coal fired generation capacity. Around two-thirds of India's 65,000 MW of coal fired plant capacity is owned by state government utilities, and a significant part of this is reported to be in a poor condition, with plant load factors of about 70 percent (with some plants having lower than 55 percent) and station heat rates of about 3,000 kcal/kWh (in some cases up to 3,500 kcal/kWh).

2. The Plant Load Factor (PLF) of state-sector thermal power plants in India in 2006-07 was on an average 70.84 percent compared with 89.4 percent for NTPC power plants in the central sector and 86.35 percent for private-sector power plants – clearly indicating the significant scope for improving performance of state-sector power plants. However, there is a wide performance range among the state-sector power plants themselves, with PLF of more than 90 percent for some power plants in Punjab, Gujarat, Rajasthan, Andhra Pradesh and Tamil Nadu. It is also seen that almost all power plants which exhibit high PLF also have better energy efficiency performance as well – typically less than 10% deviation from the design heat rate, compared to up to 50% deviation in some cases.





Source: Review of Performance of Thermal Power Stations 2006-07, CEA

3. Improving performance of state-sector power plants through interventions aimed at strengthening operations and maintenance practices is essential to ensure optimum performance of the power plant both from the Availability as well as Efficiency aspects. This holds true for new as well as old power plants. It is estimated that the availability of power

in the country can be enhanced by more than 17 percent (as against energy deficit of 9 percent) if all the available generation units can be utilized at an average PLF similar to NTPC units through rehabilitation combined with better O&M practices.[1] Although such high levels of performance may be difficult to achieve across all state-sector power plants, the potential benefits of focusing on improved power plant performance are clearly immense. Improved O&M practices are also necessary to sustain the benefits from rehabilitation of power plants as well as to sustain good performance of new power plants. Government of India initiatives in this regard (Partnership in Excellence Program) also amply demonstrated the potential benefits as discussed in Section-II of this paper.

4. Context of the Study The World Bank is currently preparing a project aimed at demonstration of energy efficiency focused approaches for Renovation and Modernization (R&M)[2] of coal fired power generation plants owned by state-sector utilities in India. Under the project about 640MW of old coal fired power generation capacity in three select power plants would be rehabilitated through funding from World Bank and Global Environment Facility.

5. As a part of the project preparation efforts, a study was commissioned under funding from *Energy Sector Management Assistance Program (ESMAP)* to examine the Operations and Maintenance practices at two of these three power plants. Independent consultants appointed for the study submitted their findings which included a review of the existing O&M practices (both management and technical aspects), benchmarking against industry practices and development of an Action Plan for improvement of these practices. Implementation of the agreed action plan is seen as essential for improved O&M performance of the power plant to ensure sustained energy efficient generation of power after rehabilitation. The two power plants selected for the study exhibit different levels of O&M practices and broadly represent the existing practices across a wide section of state-sector power generation plants in India. This paper brings out the observations of the consultants and other sector experts in a systematic manner for the benefit of other power plants (including new builds) in India and elsewhere.

6. This note is intended to serve as a concise guide for the utility senior management and other sector agencies on the key steps for strengthening the Operations and Maintenance Practices in state-sector coal-fired power generation plants in India. The note primarily focuses on managerial and organizational aspects of power plant operation and maintenance and brings out possible interventions in these areas for enhancing power plant performance. While the note refers to some technical aspects of plant performance in context of managerial and organizational interventions, it does not purport to be a technical guide on O&M of power plants.

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[1] During 2006-07, average PLF across all state-sector power plants in the country was 70.8 percent (for a capacity of about 70,570 MW), as against 89.4 percent for NTPC power plants. If the state-sector power plants are operated at PLFs similar to NTPC power plants, the addition generation would be 115,000 MUs which is equivalent to adding a capacity of nearly 15,000 MW. Equivalent new capacity addition would require several years and an investment of more than USD 12 billion.

[2] The terms Renovation and Modernization (R&M) and Rehabilitation have been used interchangeably in this paper.

Past Experiences in Improving O & M Practices in India

7. The Government of India launched a program called "Partnership In Excellence (PIE)" in August 2005 with the objective of enhancing the performance of under-performing power stations (with less than 60% Plant Load Factor) in the country. Under the PIE program, some of the well-performing generation utilities (such as NTPC Ltd and Tata Power)[3] partnered with 16 under-performing power stations, while another four power plants implemented O&M improvement steps on their own. The high-performing utility deployed teams of experienced personnel at the under-performing power plants for a period of almost two years. These teams partnered with counterpart teams from the client utility to conduct gap analysis of technical as well as management issues, develop action plans for performance improvement and assisted the client utilities in adopting best practices in operation and maintenance of the plant. O&M systems and procedures were introduced and institutional capacities at the client utility strengthened through hand-holding and training.

8. The key technical problem areas typically identified by NTPC under the PiE program[4] were as follows:

- *Poor condition of boiler pressure parts* with high erosion, overheating, external corrosion, oxide deposits, weak headers and pressurized furnace etc.
- *Poor water chemistry* has affected the condition of boiler and turbine in many cases. The water treatment plant is often in a dilapidated condition.
- *Poor performance of air pre-heaters* due to blocked elements and high seal leakage
- *Poor performance of the milling system* resulting in high unburnt carbon. This was often a result of lack of preventive or scheduled maintenance.
- *Poor condition of Electrostatic Precipitators (ESPs)* resulting in high emissions.
- *Problems of high axial shift, vibrations and differential expansion in Turbine*
- Low vacuum in condenser due to dirty / plugged tubes, air ingress and tube leakages
- High vibrations in Boiler Feed Pumps and Condensate Pumps and passing of recirculation valves, resulting in low discharge
- High pressure heater not in service in most of the units, directly impacting the energy efficiency performance
- Deficiencies in electrical systems including High HT and LT motor failures, poor condition of DC system, non-availability of Unit Auxiliary Transformer etc
- Poor condition of Balance of Plant (BoP) resulting in under-utilization of capacities

NTPC's observations on areas of most frequent forced outages and partial unavailability of power plants are also consistent with the information collated by Central Electricity Authority (CEA) in the "*Review of Performance of Thermal Power Stations 2006-07*".

[3] The program was shouldered primarily by NTPC who partnered 15 of the 20 power stations.
[4] Source: NTPC Report on "Partnership in Excellence – A Year of Success", 2006.

9. The PIE program *addressed the technical problems, while also introducing the management systems necessary for sustained change in O&M practices*. This resulted in improvement in plant load factor of the PIE power plants from an average of 43.9% before implementation of PIE to 52.1% during the year 2007-08. Prior to the PIE intervention, four of the identified power plants had PLF of less than 40%, while only one had a PLF of more than 60%. However, as a result of PIE intervention, during 2007-08 none of the identified power plant operated at PLF of less than 40%, while eight of them had a PLF of more than 60% - some as high as about 80%.

10. The PIE program was focused on improvement of power plant performance – the primary objective being to improve plant load factor (PLF) in PIE stations which were originally operating between 40- 60 percent to more than 60 percent. The program was broadly successful in achieving this objective. Going forward however, state-sector generation utilities would need to target even higher plant performance – not just in terms of plant load factors of 80 percent and above (as seen in central sector and private sector power plants), but also in terms of *improved energy efficiency, strategic deployment of resources and commercial orientation,* considering the prevailing Availability Based Tariff regime and Multi-Year-Tariff regulations.

11. This note builds upon the PIE experience as well as the findings of the O&M study consultants in selected power plants to bring out management interventions aimed at enhancing plant output, energy efficiency and reliability through improved operations and maintenance practices.

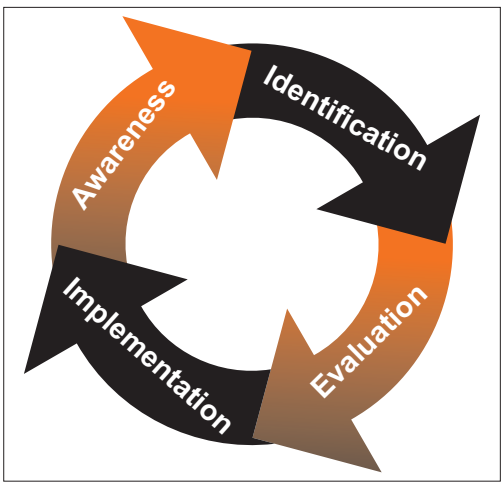
Developing And Implementing A Performance Improvement Program

12. Achieving significant improvements in plant performance over a short period requires a "Performance Improvement Program" (PIP) which would identify the key aspects that hold maximum potential for yielding performance improvements, develop steps towards addressing those aspects and systematically implement the same. The PIP process should start with an assessment of the current operational practices both managerial and technical, including inter-alia an assessment of various technical sub-systems of the plant to bring out the minimum technical interventions needed to sustain regular functioning of the plant. Such an assessment could also tie-in with a Residual Life Assessment of the plant which would indicate the need for rehabilitation (R&M) interventions, including need for upgrading Control and Instrumentation systems. In Parallel, the PIP process requires steps to be initiated for strengthening the managerial and organizational systems as described in the later sections of this note.

13. The PIP serves as the overall change management theme, covering several individual activities which are outlined in the subsequent sections of this note. The overall phases of a PIP are:

- *Awareness Phase,* including unit benchmarking and forecasting worth of unit improvement

- *Identification Phase,* including equipment / component benchmarking, High Impact-Low Probability benchmarking, trend analysis and creating a wide range of solution options using input from many sources
- *Evaluation Phase,* including using advanced methods to justify, select optimal timing and prioritizing among many competing projects as well as day-to-day O&M decisions, both reactive and increasingly proactive decision-making
- *Implementation Phase,* including using the results of the evaluations to select that group of projects offering the best use of the limited resources, goal-setting based on the projects actually chosen for implementation,



It is also essential to track the actual results of implemented projects and compare these results to the expectations used in the evaluations and finally incorporating feedback of these results into the first three phases of the process. The various aspects of change necessary for performance improvement are brought out in the subsequent sections, starting with industry best practices on operations.

Enhancement of Operational Practices

14. *Existing Operational Practices in State Sector Coal Fired Power Plants* 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.

15. Owing to a *legacy of focus on plant load factor,* most utilities still do not pay adequate attention to energy efficiency aspects. Regular energy audits (including efficiency tests for boiler, turbine and other sub-systems) are not carried out in most cases. Heat rate and specific oil consumption targets are fixed and monitored for the station as whole and as a result unit-level energy efficiency related issues do not get identified and addressed. Auxiliary power consumption is often not measured systematically and is generally computed by deducting sent out energy from the total energy generated. In the absence of any trend analysis and benchmarking, opportunities for improvement do not get identified.

16. *Coal accountability issues both external and internal to the plant*, including availability and accurate measurement of quantity as well as quality (calorific value) have a direct bearing on technical and commercial performance of the plant, but continue to receive less than required attention.

17. *Poor Water Chemistry* Water quality and make-up quantity are often not monitored systematically, leading to operational problems in boiler (for example more frequent tube failures) and turbine (for example deposits on blades).

18. In many utilities, *well documented operating procedures are not available* to the relevant staff who execute their functions based on personal experience. As a result, staff response to various situations becomes subjective and may lead to sub-optimal approaches in addressing operational issues. Such responses may sometimes cause avoidable tripping and forced outages, and in some cases even reduce equipment availability, reliability and life. The observations from independent consultants on one such poorly operated power plant are provided in Text Box-1.

19. Operational data is often relegated to records and not systematically utilized to generate information on operational and maintenance requirements through trending and other analysis.

Text Box-1: Consultant's Observations on Use of Procedures, Manuals and Instructions at a Select Power Plant

Independent Consultants have reported that the various operating procedures are not available with the plant shift personnel or shift-in-charge in well-documented form. The original OEM manuals are available in limited quantity for reference on a requirement basis. There is no library or Centralized documentation centre. The originals are therefore difficult to be located at one place. Signature check-lists for equipment lining up and various systems start-up and shut down were also not available which is utilized by most utilities for standardizing such operational processes. Equipment changeover guidelines along with key process diagrams for critical equipments along with checking procedures at local for critical and non-frequented equipment were also observed to be absent at the Power Plant. During the field visit, the consultants noted that the Key process diagrams, Heat balance diagrams and Technical parameters handbook indicating ideal measurement at various plant load factors are not available with Operation Personnel. Also the consultants observed that operation personnel did not have at shifts the Key logic diagrams indicating interlocks, protections and associated C&I details.

20. Housekeeping in general is poor in several power plants with heaps of scrap (including discarded components), coal dust and ash scattered all over the plant, which is not only reflective of the poor O&M culture, but is also a significant deterrent to conducting prudent O&M practices. Similarly, safety aspects are also usually neglected.

21. *Operating Procedures, Manuals and Instructions Proper* documentation of various operating procedures and making such documentation readily available is critical to enhanced operating practices in power plants. Such documentation would typically include:

a. *Operations and Maintenance Manuals* supplied by the Original Equipment Manufacturer (OEM). The O&M manuals and the operating procedures based on them should be made available with the shift-charge engineer at the plant and the respective maintenance heads.

b. *Technical Handbook* for the plant indicating the various equipment specifications, process parameter limits and critical alarm values. The handbook should be made available to all operations and maintenance personnel.

c. *Key Process Diagrams, Key Logic Diagrams and Heat Balance Diagrams* which would assist in better operational decision-making, trouble shooting and enable enhanced operational efficiency.

d. *Signature Check List* for start-up, shut-down and all emergency handling procedures should be available with the Unit in-charges and shift-charge engineer. In addition, Walk-down Checks should be carried out in each shift by the respective operational staff responsible for boiler, turbine, balance of plant etc. to report any abnormalities and take corrective actions. Checklists should be deployed to ensure that all necessary aspects are verified during the walk-down checks.

e. *Equipment Changeover Guidelines and Schedule* to ensure reliability of stand-by equipment and balanced utilization. These should also be made available to the Unit in-charges and shift-charge engineer

22. *Training on Procedures, Manuals and Instructions* Further, in all well-run generation utilities, operating staff are provided exhaustive training to familiarize them with the above procedures, manuals and instructions. Such trainings include trainings on 'Power Plant Simulator'. Refresher courses are also conducted for experienced staff to reinforce awareness of these procedures and reduce complacency in adherence.

23. *A Central Technical Library* needs to be setup preferably under the Head of O&M at the plant. The library should have an archive of all procedures, manuals and instructions, as well as latest technical journals in hard and soft copy so that the same can be accessed on-line by operations and maintenance personnel.

24. *Monitoring of Energy Efficiency Performance* In several state owned coal fired generation plants in India, lack of focus on energy efficiency is reflected by the absence of adequate mechanisms for monitoring energy efficiency performance. The industry best practice in this regard is to have Computer-based systems for On-line Monitoring of Energy Efficiency Performance. Such systems are deployed to monitor, for each unit in real time, the overall unit heat rate (overall unit efficiency), boiler efficiency, turbine efficiency, controllable and non-controllable losses, performance of condensers, regenerative cycle etc. Such a system allows Heat rate to be monitored on a unit-wise basis (rather than for the whole plant) in real-time through on-line measurement of coal consumption and electricity generation. The calorific value of coal however has to be measured off-line and fed manually to the system.

25. *Coal Measurement Systems* In order to bring greater accountability and focus on energy efficiency, it is necessary to have a reliable coal flow measurement device – separate for each generation unit. This needs to be coupled with adequate systems for reliable measurement of coal quality in order to determine the amount of heat being put into the generation unit

vis-à-vis the electricity generated.

26. *Auxiliary Consumption Monitoring System* is deployed to monitor the energy consumption and operating parameters of key systems / auxiliaries such as Boiler Feed Pump (current drawn), Ash Handling System (ash to water ratio), Coal Handling System (idle running of conveyors) etc.

27. *Steam and Water parameters* (conductivity, pH values, PO4) are measured online in real-time through the Steam and Water Analysis System (SWAS). Similarly, on-line condensate conductivity measurement system is deployed to determine condenser tube leakages. Even simple historical trends of such parameters can reveal malfunctions and areas of potential improvement in plant efficiency.

28. *Specialized and Focused Cells / Committees* For effective O&M of power plants, it is necessary to have specialized and focused cells at each power plant as well as centralized cells at the headquarters catering to multiple plants. The division of functions across these plant-level and centralized cells could vary across utilities – some may have a largely plant based approach (with only critical management inputs going to centralized cells) while others may have more centralized approach (with data inputs from plants being provided to specialist experts located at the headquarters), or a blend of these two. The information technology solutions now available facilitate adoption of more centralized systems which better utilize precious technical expertise and enable closer management oversight. However, a minimum level of expertise at the plant is necessary in any case to cater to day-to-day O&M requirements at the plant and take necessary actions in real time, while also feeding information to the centralized cells. The following specialized/focused cells may be recommended:

a. *Operations and Efficiency (O&E) Cell at the Plant* The O&E cell measures and analyses energy efficiency performance of the plant on a regular basis and is responsible for strict monitoring of the unit heat rate and its deviations. It ensures the operation of the plant and auxiliaries at optimum efficiency by identifying and rectifying gaps in efficiency compared to the design parameters. This is achieved by ensuring the operation of the unit at rated parameters and minimizing the consumption of coal, secondary oil, auxiliary power and make-up water. Another aspect specifically monitored by the O&E cell is achievement of optimum water chemistry parameters. Some of the tests routinely carried out by the O&E cell in association with O&M divisions are (i) Boiler Efficiency, (ii) Air Pre-Heater X- Ratio, (iii) Condenser Efficiency, (iv) Turbine Cylinder Efficiency, (v) Dirty Pitot Tube Test for Mills, (vi) Cooling Towers Efficiency, and (vii) Efficiency Tests for Heaters and De-aerators.

b. *Trip Committee at the Plant* Typically, well-run plants have a trip committee which is entrusted with the task of root cause analysis of trips and suggesting corrective actions to prevent recurrence of trips. The suggested corrective actions are typically formulated as an action plan with clearly ear-marked responsibility center and schedule. Compliance with such recommendations is monitored at plant as well as corporate levels and an institutional framework for achieving this is

also put in place. Recommendations of the trip committee also feed into the maintenance plan. In some cases, specialized committees are also in place for analyzing boiler tube leakages – one of the most frequent reasons for forced outages. Other causes of forced outage are also analyzed in detail by what are called as 'Forced Outage Committees'.

c. *Energy Audit Committee at the Plant* The Energy Audit Committee is mandated with preparing the Energy Audit Plan for the plant, conducting in-house energy audits and coordinating third party external audits at the plant. In the Indian context, the Energy Conservation Act, 2001 mandates periodic energy audits for all energy intensive industries (including thermal power plants). It has been observed that Energy Audits lead to significant inexpensive performance improvements by enabling capture of low hanging fruits (energy losses). An efficiency audit should be carried out based on which the Energy Efficiency indicators should be defined for major energy consumption/loss centers. However it is also essential to set up mechanisms and institutional processes for ensuring that the recommendations of the Energy Audit Committee are evaluated through a cost-benefit assessment and implemented in a time bound manner.

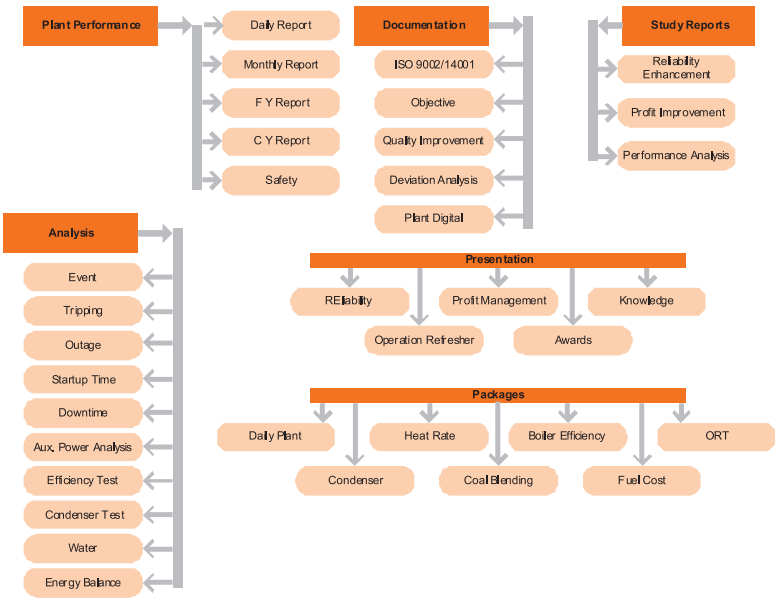
d. *Pool of Technical Experts across the Organization* In order to build-upon the shared expertise across various power plants, a Pool of Technical Experts is developed across the organization, deriving expertise in different areas (such as turbine, boilers, C&I etc) from different locations. From this pool, Knowledge Teams are derived, which bring knowledge and experience in different areas from different power plants and provide in-house consultancy to technical problems at any location.

29. *Daily Operational Review of Plant Performance* Structured Daily Plant Meetings chaired by the head of plant O&M should be held each morning to analyze the previous day's performance and plan the generation target as well as the maintenance activities for the current day. Relevant inputs from the specialized cells/committees mentioned above are also discussed in these meetings. Apart from the daily meetings, a monthly operational review meeting chaired by the head of the plant should be held to follow-up on O&M aspects as well as other plant issues.

30. *Knowledge Management* In any power station a huge amount of operational data is generated on an ongoing basis which needs to be stored properly for future reference, analysis and feedback. Moreover, significant data is also regularly churned out by supporting departments like stores, procurement, finance, environment and human resources etc. A proper knowledge management framework needs to be developed in the power plant for its smooth and efficient functioning. Such a framework would enable the utility to capture, analyze and refer experiences from different situations including unit tripping, specific problems of various plant systems, experience pertaining to plant overhauls etc. Utilities having a portfolio of plants of varying vintage can be expected to have a rich experience across the years of operation that needs to be captured through a

knowledge management initiative.

Figure-1: Content Framework of a Typical Power Plant Knowledge Management Platform



31. The process of developing a robust knowledge management framework can be initiated through implementation of department-level Information Systems (possibly through modular Enterprise Resource Planning – ERP interventions) which will share all relevant data for multiple uses and subsequently these systems can be interlinked to develop a proper knowledge sharing platform.

32. The knowledge platform also provides various standardized reports for management decision making and serves as the Management Information System (MIS) backbone at the plant and corporate levels. Figure-1 provides an indicative content framework for a typical power plant knowledge management platform. A separate discussion on MIS is provided in Section-VII of this note.

Enhancement of Plant Maintenance Practices

33. *Existing Maintenance Practices in State Sector Coal Fired Power Plants* Based on the review of select power plants by independent consultants it is seen that there is wide variation in existing maintenance practices in state sector power generation plants, although even the relatively better utilities do not exhibit practices comparable with the industry best practices. It is seen that often documented maintenance procedures have not been developed and deployed even for critical equipment, especially in case of weaker utilities.

34. *Maintenance Related Operational History* Comprehensive database of performance trends and failure history is often not available even for critical assets such as mills, pumps and balance of plant. Also, where available data is recorded in hard copy maintenance registers and is not used for failure history analysis or for monitoring Mean Time Between Failures (MTBF). *Failure Modes and Effect Analysis* is usually absent as an institutional practice.

35. *Maintenance Planning* Based on the review of select power plants by the consultants, it is seen that typically there is *no dedicated maintenance planning department* – and even when there, it is not effectively contributing to systematic maintenance planning. Mostly, maintenance planning is being carried out by individual maintenance groups (boiler / turbine / electrical etc). Long term planning for overhaul is done 2-3 years in advance, though inadequate planning and preparation often leads to extension of shutdown-schedule. Spares-planning is carried out on the basis of past experience rather than a systematic analysis of spares requirement, leading to imbalance in availability of spares. Spares for planned-maintenance are planned 6-8 months in advance by the individual maintenance groups.

36. There is a *limited appreciation of the commercial linkages* of plant level availability and the reliability of individual equipments. Often the commercial implications of productivity loss (impact on fixed cost recovery) and reduced heat rate due to poor equipment performance (for example underperforming mills) is not objectively assessed in the maintenance decision-making process., Prioritization of maintenance areas based on a pareto analysis of failures is not undertaken.

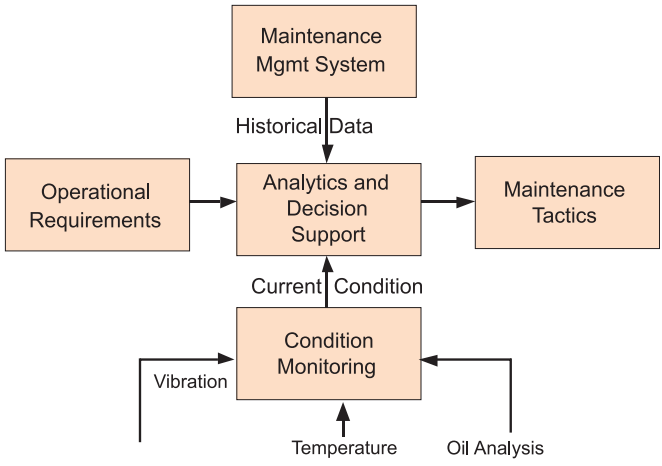
37. *Condition Monitoring* Since most of these plants are relatively old, there is inadequacy of modern measuring equipments and where available, such equipment is often not used on a regular basis. Absence of adequate condition monitoring systems leads to reactive maintenance practices rather than pro-active maintenance practices.

38. *Pro-Active Maintenance* One of the hallmarks of top performing generating companies worldwide is their successful efforts to establish a Pro-active O&M program, one that uses their equipment reliability, cost and efficiency data to supplement the recommendations of the equipment manufacturers and the utility's first hand experience. The key elements of proactive maintenance in power plants are illustrated through Figure-2.

39. *Steps for Strengthening Maintenance Practices and Establishing Pro-Active Maintenance*

a. *Establish a Strong Maintenance Planning Department (MPD) at the Plant* The Maintenance Planning function at the Plant should be strengthened in terms of placing it as the nodal point in both target review and daily decision making process for day-ahead maintenance plan, in association with Operations and Efficiency (O&E) Cell. The MPD would be responsible for the overall planning of the maintenance activities both short-term and long-term. This includes developing preventive maintenance schedules and ensuring compliance, formulation of overhauling strategy (for example preparation of six year maintenance rolling plans), spare parts

Figure-2: Proactive Maintenance Management Systems

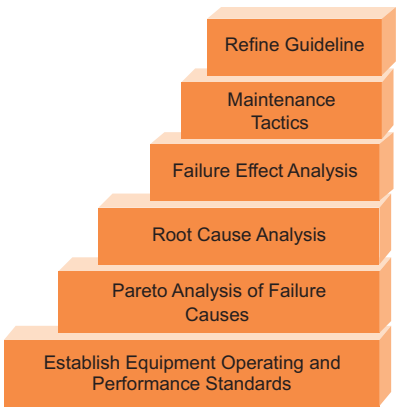


planning, condition monitoring and maintenance of equipment history.

b. *Establish a Condition Monitoring (CM) Cell under the MPD* Setting up of a condition monitoring cell at the plant with priority basis will facilitate the induction of proactive maintenance at the plant. The staffing requirements and role definitions for the CM cell would need to be defined and adequate infrastructure in respect of instrumentation shall need to be made available to make it fully functional.

c. *CM cell should develop a Condition Monitoring* Plan which would include check-lists and frequency for equipment monitoring. Equipment monitoring would require a wide array of techniques including among others Vibration analysis, Shock-pulse analysis, Lubricant oil analysis and Thermo-vision etc.

Figure 3 - Maintenance Process Enhancement Steps



d. *MPD should carry out Maintenance Process Enhancement* Steps in coordination with respective maintenance departments. (See Figure-3)
   i. Creation of a comprehensive asset database at individual departments and MPD.
   ii. Identification of critical equipments in the process train based on past operating history of the assets.
   iii. Failure Modes and Effects Analysis (FMEA), Root Cause Analysis and Pareto Analysis for the critical equipment.
   iv. Updating of Condition Monitoring Plan (including standardized procedures for condition monitoring of critical equipment) and Operating Norms / Signature Checks in light of the above.
   v. Identification of Key Performance Indicators (KPIs) for maintenance.

e. *Establish a Decision Support System to Facilitate Pro-Active Maintenance* Such a system should be aimed at optimization of power plant reliability based on the following approach:

   i. Allocation of the risks of production discontinuity to individual assets and failure modes. This is done through a bottom to top linkage – i.e. probability weighted impact of equipment/part's failure on plant operation and therefore profitability.
   ii. Estimation of returns on reliability enhancement investment for each asset/part.
   iii. Prediction of profit impact of selective maintenance relaxation for each asset/part.
   iv. Comparison of investment costs with risk-reduction returns on both annualized and plant lifetime basis.

f. *Establish a Technical Database* to establish relationship between equipment aging rate and equipment reliability, equipment reliability and generation reliability, and optimal power generation and penalty consequences of failure to generate.

g. *Establishment of a Computerized Maintenance Management System* having modules like-Plant Performance module, Human resource module, Works Planning module, Materials Management Mmodule, Budget and Cash flow module, Work Permit module, Costing System module, Financial accounting system module, Coal Management module, etc. This system will generate various reports on daily, monthly and annual basis which will be used to review and take corrective measures for various facets of plant performance.

Similar to the plant level and centralized approaches discussed for operational aspects in paragraph 28, the maintenance activities could also be organized across plant level and centralized level. In case of utilities favoring a more centralized approach, the above suggestions would need to be implemented at the centralized cells through suitable information technology interventions.

40. The budgeting and financial planning for O&M of the power generation utilities in India typically has a strong linkage to the annual tariff filing and scrutiny by the State Electricity Regulatory Commission (SERC)

by virtue of operating in a regulated environment with the regulator setting the performance norms for operational aspects. Under the prevailing regulatory regime, tariff levels are typically set for individual generating stations based on normative performance parameters under an annual tariff approval process (though some states have introduced multi-year tariffs recently). The normative performance parameters are determined based on performance during the previous periods and a comparison with similar plants elsewhere in the country. The annual tariff process requires the utility to submit the expectations on both fixed and variable costs to the SERC under the tariff filing process. The fixed costs comprise of O&M costs besides other standard elements like depreciation, interest charges, return on working capital (normative basis), return on equity and taxes. With the exception of O&M, the majority of the other fixed cost elements are maintained by the corporate office and hence the budgeting/planning at the plant level is primarily limited to O&M budgeting.

41. *Existing practices in Generation Planning and Plant Level Budgeting*

a. *Weak Framework for Generation Planning* It is seen that generation planning process in state power generation utilities in India is often based on a qualitative input from various operations and maintenance departments. Even in the relatively better utilities, where all key plant personnel (including shift incharges, maintenance incharges and plant head) are involved in the generation target setting process, the system is currently more reliant on their experience and judgment than on hard data analysis. Further, in the select power plants reviewed by the consultants, there is limited participation from the maintenance planning cell, where such a cell exists. Also, the generation planning process does not incorporate any significant inputs from the energy audits.

b. *Trend Based Generation Planning* The generation planning process at state power generation utilities is typically focused on maintaining status quo of plant performance and maintaining historical performance levels. As a result, generation parameters are projected conservatively based on trends from past years.

c. *Partial Loss Occurrences from Previous Year not Analyzed* for setting in place plans for improved generation levels for the year ahead. Further, limited focus on commercial analysis of generation loss or operational constraints during the year results in reduced generation than potentially achievable output.

d. *Inadequate Focus on Monitoring Tariff Parameters during Operation* The consultants have reported that there is inadequate appreciation at plant and enterprise level of the commercial implications of the Tariff plan including Performance targets given by the state electricity regulatory commission. The monthly / daily target is often not revised to reflect shortfall in generation (if any) or other plant parameters on a cumulative basis against the

regulator approved benchmarks.

e. *Limited Focus on Other Aspects during Management Review* Although regulatory targets are included during the periodic management reviews of achievement against generation targets, several other aspects of plant operation such as commercial performance (cost of generation on fixed / variable basis), implications of Availability Tariff, status of maintenance works, inventory position, safety and environmental performance etc. do not find adequate focus.

f. *Departmental Budgets are prepared mostly on Historical Basis* It is seen from the consultant's reports that the departmental budgets are prepared mostly on historical basis using previous experience and are subject to some discretion of senior departmental personnel. It is also seen that the explanation of variance of actual expenditure versus budgetary projections is often inadequate / lacking.

g. *Inadequate Design of Accounting Codes* The Budget compilation exercise typically takes around a month. Part of this can be attributed to the current design of accounting codes where there are single codes for repairs and maintenance items encompassing both supply and labour. This results in the departments furnishing the information under a single accounting code that later requires segregation of the supply and labour components. Additionally often due to non-standardization of reporting template, cost codes are not represented on the utilizing department budget forwarded to Finance and Accounts department.

h. *Budgeting for O&M is typically restricted to Regulatory norms* The approved level of O&M expenses in the Annual Tariff Order by the Regulatory commission is usually set as the Station O&M budget level as a gross whole. The Tariff order levels thus constitute the sole basis of O&M budgets for cost control in the station on an aggregate basis.

42. *Generation Planning and Transition Steps*

a. *Focus on exceeding regulatory targets on a sustained basis* The minimum plant performance for ensuring commercial operations is defined by the targets specified by the regulator in the tariff order. Therefore, the utility has to identify the steps required to achieve / surpass the same on a sustained basis. The steps identified have to be reflected suitably across generation planning as well as plant level budgeting.

b. *Scenario Based Approach to Generation Planning* The regulatory framework provides for incentives linked to higher availability of the unit. In addition, higher generation beyond the Declared Capacity (DC) (within limits set by the regulator to prevent gaming) can potentially yield higher revenues through Unscheduled Interchange (U.I.) charges in the prevailing supply shortage conditions. Therefore,

better performing utilities strive to exceed regulatory targets with respect to availability, while also attempting to generate beyond the declared capacity. Such utilities plan scenarios for maximizing generation and while providing resources for concomitant capital expenditure over a medium term time horizon, especially where regulator has provided multi-year tariffs.

c. *Operation efficiency needs to be attributed greater focus* at both the corporate and plant level. It is essential that elements of detailed shortfall analysis, partial loss analysis and inputs from the energy audit reports be utilized for the preparation of year-ahead plans. However prior to initiating the same, the utility may also require formalizing an energy audit and performance review plan for the asset portfolio.

d. *Day-ahead forecasting* may be important in states where generation utilities stand to be affected by Availability Based Tariff. *Establishment of an ABT Cell* comprising of personnel skilled in analyzing the impact of ABT would be important in such cases. Utilities could also develop internal guidelines on day-ahead generation planning to optimize on commercial implications of ABT regime.

e. *Adopt an availability based approach to generation planning*

   i. The plant should target to progressively move towards *Zero Forced Outages.* With this aim, the benchmark targets should be set for forced outages as well as planned maintenance. This should be utilized to project Availability and derive the PLF projection based on the same.
   ii. Assess individual equipment level reliability and performance levels so that the expected station overall availability can be projected and steps taken to improve the same, with the aim of meeting the targets set in the tariff regulations.

f. *Strengthen the generation target review process through*

   i. Utilization of a commercial basis for evaluation of plant constraints to prioritize maintenance interventions
   ii. Analysis of shortfall at plant on daily basis to develop and implement recovery plans for shortfalls (if any).
   iii. Expansion of topical coverage to address other non technical issues like stores, finance, human resources in the generation target review meetings
   iv. Strengthening of channels of communication for the review meeting outcomes via circulation of formalized Minutes and making the same accessible to plant executive staff at all levels.

43. *Plant Level Budgeting and Transition Steps*

a. *Develop a Suitable Budget Manual* which will act as a guideline for all involved in the budget preparation process in the organization. The budget manual should typically cover the overall framework of the Budgeting System, detailed budgeting process, budgeting responsibility, time schedule for budget preparation, and the system for monitoring adherence to budgetary targets. It also provides the

relevant formats for all the above aspects.

b. *Establish Plant Level Budget Committee* comprising of Plant Head, O&M in-charges and various departmental heads. The committee should review the overall physical targets, examine the budget proposals of the individual cost centers and prioritize the allocation of resources to them.

c. *Technical Vetting of the Budget* is carried out by Operation and Efficiency (O&E) Cell as well as the Maintenance Planning Department (MPD) at the plant for operating parameters and maintenance requirements necessary to meet the proposed budgetary targets. The technically vetted budgetary inputs from the plant level budget committee are subsequently finalized during the review by corporate level budget committee.

d. *Budget System should be aligned* with Finance and Accounts (F&A) for account codes and Costing System for cost codes to ensure that variance against the budgetary targets during the previous years and cost estimates for planned activities can be fed into the budgeting process.

e. *Periodic Review of Budgetary Performance at Plant and Corporate Levels* Typically performance against budgetary targets should be reviewed at the plant on a monthly basis and at the corporate level on a quarterly basis, with the aim of formulating recovery plans, if needed. Review of actual expenditure against budgetary targets and actual plant performance against physical targets should typically feed into a periodic review of the impact on overall profitability.

Management Information Systems

44. *Existing practices in Management Information Systems* Some of the leading state owned power generation utilities have traditionally had reasonably strong (though manual or part computerized) MIS systems and are now in the process of adopting state-of-the-art Enterprise Resource Planning (ERP) systems which would also cater to their MIS requirements. Some utilities (such as MSPGCL) have even initiated steps towards remote monitoring of plant performance in real-time at a centralized facility called the Generation Control Room (GCR) at the corporate office through a SCADA system. However, Information Technology (IT) infrastructure at power plants owned by many other state-sector utilities has significant deficiencies – in some cases virtual absence of any IT infrastructure at the plant is observed. The key aspects of existing MIS systems at some of the lagging utilities are as follows:

a. *IT Infrastructural Constraints* Typically, in poorly performing power plants with weak IT infrastructure, MIS data is collected manually by the relevant plant staff. There is absence of Local Area Network (LAN) connectivity and only limited availability of computers. As a result access to internet and email is also limited. Officials are not habitual to using computers and are dependent on specialized computer operators even for basic applications.

Figure-4: Daily Situation Report from one of the power plant

REPORTED ON : 08/12/07 RECORDS OF : 07/12/07 EVENING FORECAST (MW) : 330 on 08/12/07 SENT OUT (2.95 AM)

	Generation in MW		Generation in MU	Aux Consumption in MU
	At 19:00	At 8:00 of 08/12/07		
Unit # 1	45	55	1.030	0.10000
Unit # 2	0	0	0.000	0.00000
Unit # 3	55	35	1.190	0.10000
Unit # 4	40	40	0.890	0.00000
Unit # 5	185	190	4.263	0.22500
Unit # 6	0	0	0.000	0.00000
Plant	325	320	7.373	0.53500

Condenser Vacuum in MM of HG	Flue Gas Temp. at A/H outlet (oC)		Feed water Temp. at Economiser inlet (o C)
715	166	166	160
0	0	0	0
710	162	161	230
712	176	177	215
715	159	164	232
0	0	0	0

Hour	Availability in (MW)	CLD load sch.(MW)	Generation in MW
01:00	276	238	320
02:00	276	238	320
03:00	276	238	320
04:00	276	238	320
05:00	276	238	320
06:00	276	276	310
07:00	276	276	310
08:00	276	276	310
09:00	276	276	315
10:00	276	276	310
11:00	276	276	310
12:00	276	276	315
13:00	276	276	315
14:00	276	276	315
15:00	276	276	315
16:00	276	276	315
17:00	276	276	315
18:00	276	276	315
19:00	276	276	325
20:00	276	276	325
21:00	276	276	325
22:00	276	276	325
23:00	276	276	330
24:00	276	276	345
MU	7.3730		7.3730

COAL WAGON STATUS	BOBR	BOX	TOTAL
Balance at 00:00 Hrs	0	54	54
Receipt	0	59	59
Unload	0	68	68
Release	0	58	58
Blance at inside yard	0	45	45
Balance at 00:00 hrs of 08/12/07	0	45	45
Unloading between 00 to 06 hrs 08/12/07	0	14	14
Balance at 06:00 hrs of 08/12/07	0	89	89

	COAL (MT)		OIL (KL)	
	DAY	CUMM	DAY	CUMM
OPENING STOCK	8753	0	4664.000	0.000
RECEIPT	3540	27690	0.000	0.000
CONSUMPTION	4424	30639	3.000	30.000
CLOSING STOCK	7869	0	4661.000	0.000

PLANT MAXIMUM GENERATION (MW/TIME)	345	23:45
PLANT MIMIMUM GENERATION (MW/TIME)	310	05:45
MAXIMUM SYSTEM FREQUENCY (HZ/TIME)	49.50	06:00
MINIMUM SYSTEM FREQUENCY (HZ/TIME)	48.80	09:16

IMPORTANT DATA	DAY	CUMM
GROSS GENERATION (MU)	7.373	51.065
AUXILIARY CONSUMPTION (MU)	0.53501	3.96010
BACK DOWN (MU)	0.000	0.162
DM WATER CONSUMPTION (KL)	680	4895

MISCELLANEOUS

1) Unit #2 is under shutdown. 2) 58 Box of Bankola was received at 05-40 hrs. on 08.12.2007. 3) Due to expiry of monsoon period usable stock of 18000 MT has been taken into account as usable stock and hence Book stock & Usable stock are same. 4) From 16.08.2007 onwards the anticipated availability & SLDC demand schedule are given on sent out basis (i.e. excluding aux. consumption) but our backdown is calculated taking into account aux. consumption which is included on availability & SLDC schedule as per our ECR department. *Condenser vacuum, Flue gas temp. & Feed water temp. are taken at maximum load. *Auxiliary energy meter readings are taken from existing meters whose accuracy levels are low.

The Daily Situation Report captures information primarily in terms of physical quantities such as generation in MW and MU, coal consumption in Metric Tons, Flue gas temperature etc. but does not capture financial and commercial aspects such as:

i) Variable Cost achieved in last 24 hr basis
ii) Variance with respect to regulator approved levels for the station
iii) APC performance on % basis
iv) Availability achieved with the shortfall in generation from a 100% availability attributed to various causes (as stated in the monthly report)
v) Deviation from Daily target generation and Target generation for next day.
vi) Losses on account of partial loading of machines
vii) Impact of out–of process limits of equipments on Variable Cost Performance

b. *MIS design and Process Shortcomings* Typically MIS formats being used by generation utilities report on basic operational data (mainly physical parameters), and are not amenable to detailed analysis of key plant issues on commercial terms. This is illustrated in the MIS formats collected by the consultants from one of the power stations (see figure-4 below). Reports typically do not adequately cover other power plant aspects such as maintenance activities, stores, commercial performance, environmental performance and training of personnel

etc. Further, it seen that MIS reports generated by various departments at the plants often contain duplicate data.

45. *Transition Steps for a Strengthening MIS Framework*

a. *Integrated MIS policy for the Organization should be formulated* for implementation across the headquarters and the various plants, covering all aspects of functioning of the plants – viz. operations, maintenance, stores, purchase, human resource, safety, environment etc.

b. *Appropriate IT Organizational Structure should be developed* Separate MIS and IT cells would be required at each location. MIS Cell should look after data collection, compilation, and report preparation while the IT cell will be responsible for taking care of the technology / hardware related issues. There has to be a single departmental interface for reporting and information archival- MIS department preferably in the Technical Secretariat of the Plant In-charge.

b. *Plant-wide and Company-wide IT infrastructure development* All the executives at the plant should be provided with IT infrastructure with Local Area Network (LAN) connectivity in the plant and Wide Area Network (WAN) connectivity across all plants and headquarters.

c. *Development of IT modules* to cater to various functional requirements, such as Computerized Maintenance Management System (CMMS), Materials and Stores Management System (MSMS), Operation Plant Performance Management System (OPPMS), Business Planning Module, Finance and Accounting (F&A) and Human Resource Development modules etc. Alternatively, generation companies can install Enterprise Resource Planning (ERP) packages customized for power plant / generation company requirements encompassing all the above mentioned modules.

d. *MIS interface with Digital Control System (DCS)* of the power plant for automatic generation of management reports. The DCS captures data in real time without much human interference directly from the various instruments installed in the plant. This information can be fed into the ERP / MIS system directly.

Purchase And Stores

46. *Existing practices in Purchase and Stores Management* The existing practices in purchase and stores management differ significantly across different utilities, with some of the better utilities have adopted some of the industry best practices such as rationalized list of inventory items, e-procurement, computerized inventory management systems and evolved vendor management systems.

47. On the other hand, the relatively lagging utilities have under-evolved practices on several fronts. Indents for purchase have to be raised manually by the utilizing department (with no system of automatic flagging of

requirement). The delegation of powers is not adequate considering the current price levels, often implying that all purchases have to be approved by the corporate authorities which may require considerable time causing delays. Absence of suitable quality assurance system and vendor performance management system imply that related issues are not identified systematically and remain unaddressed. In most cases material is inspected only after receipt at the plant.

48. Plants of some of the lagging utilities have a much higher number of inventory items than comparable plants of relatively better utilities due to inadequate item codification and poor inventory management practices. For example, one such lagging plant has about 46,000 inventory items compared with about 3500 items for a similar plant of a better managed utility. In the absence of suitable and effective categorization of store items (with respect to cost, criticality, procurement lead time and fast moving/slow moving), it is difficult to manage stocks availability while strategically keeping the costs low and reducing the procurement effort. It is often difficult to undertake annual physical verification of stocks of all the items in the stores, especially where inventory management processes are manual.

49. *Transition Steps for a Strengthening Purchase and Stores*

a. *Establish a Quality Assurance (QA) System* The better performing generation utilities typically have a stringent quality assurance system which caters to the requirements of regular maintenance, annual overhauls, major rehabilitation works as well as new builds (expansion or green-field projects). Such QA systems extend to both plant *level (Field Quality Assurance Cell)* and corporate level *(Corporate Quality Assurance Department).* They typically have *Quality Assurance Manuals* with detailed process documentation. A Quality Assurance Plan (QAP) is prepared for all major items detailing out the Checks/Tests to be carried out, Customer Hold Points (CHP) and Acceptance Criteria. The QAP also details out the stage, location and agency responsible for testing.

b. *Establish a Vendor Management System* Establishing a strong vendor management system based on enlistment of vendors after due assessment of vendor's manufacturing capabilities (including quality control aspects) and subsequent monitoring of vendor's performance through a *Vendor Performance Appraisal System* is critical for ensuring smooth availability of quality components. Further, utilities could also undertake vendor development activities aimed at developing more vendors and strengthening manufacturing practices of existing vendors. Strategic interventions like pooling of spares requirements across the organization to achieve economies of scale as well as to elicit greater interest from larger (and more capable) vendors could also be undertaken.

c. *Tendering Related Aspects* Since delays in procurement can imperil smooth functioning of the plant and timely completion of overhauls, standardization of tender procedures should be done along with clearly defined *delegation of powers* (DoP), responsibility and timelines.

Bid documents should be strengthened to include appropriate provisions for liquidity damages, price variations (especially for long lead time items) and *Quality Assurance Plans*. Utilities could progressively move towards *e-tendering* which would allow faster and more efficient procurement while ensuring adherence to required procedures. The utility should develop strong procurement skills at both the plant and corporate levels and should conduct suitable trainings in this direction. Having a *materials management manual* which also covers procurement and stores (inventory management) can be useful.

d. *Proper Identification and Codification of Stores Items* to achieve rationalization of inventory levels by bringing out duplication or redundancy of items. Also, the stores should generate monthly report of inventory positions with respect to all materials, and an annual report which should be linked to the *physical verification of assets*.

e. *An ABC analysis or a Vital-Essential-Desirable (VED) analysis* is carried out for all stores items. This helps in classification of spares in accordance with an appropriate inventory management and procurement strategy based on the criticality, cost and lead time of the items. For example, an *Automatic Procurement Process* is devised for all fast moving items and consumables by fixing minimum and maximum reorder levels which are monitored and procured by the stores personnel themselves. Similarly, an *organization-wide pooling of common high value spares* could be organized and systems devised to share this information across plants.

f. *A suitable Computerized Inventory Management Package* linked to the main Enterprise Resource Management (ERP) System is implemented to cater to all requirements of stores management.

g. Finally, a *Materials Preservation Manual* should be developed which will act as a reference for the store employees to ensure proper storage of equipment.

Organizational Climate And Human Resource Development Aspects

50. *Existing Organizational Climate and Human Resource Development Practices* Organizational culture and Human Resource Development are issues that cut across all functions of the plant and have a significant impact on the service delivery of all the departments. While there are several broader aspects of organizational climate and human resource development, the ones which have a direct bearing on operational and maintenance performance of the plant are discussed here.

51. *A large but Aging Workforce with Significant Skill Gaps* Almost all state-sector generation utilities have an aging workforce, which affects the utility's ability to change-over to new systems and approaches – especially when new technologies (such as state-of-the-art Control and Instrumentation) are introduced. The skill-base in these utilities is likely to shrink further in the coming years as old employees retire and it remains

difficult to attract and retain good younger employees. Also, although most utilities have more employees than necessary for plant operations; some key skills are not adequately available. Further, most utilities do not have well-defined job descriptions and a clear delineation of authorities and accountabilities for different roles (designations) in the organization.

52. *Inadequate Skill Development Initiatives* Many utilities do not have a practice of systematically mapping skills to organizational requirements and do not have appropriate skill development plans based on training needs assessment.

53. *Performance Monitoring* There is not enough emphasis on developing departmental level Key Performance Indicators (KPIs) by cascading the station performance requirements to the departmental level performance requirements. In some state utilities the KPIs are used only primarily to measure unit wise operational performance. This performance measurement is linked to the selection of best performing unit and finally group incentive is given to the best performing unit. There is no incentive at the departmental and at the individual level.

54. *Inadequate Performance Accountability and Weak Incentive Structures* In almost all state owned power generation utilities there is no incentive scheme for employees to motivate performance beyond benchmark levels. In some utilities there are schemes like giving a cash award to the group responsible for the best performing unit – the cash award amount being used for welfare schemes. Considering the compensation differentials with the private sector, an incentive plan may prove to be an effective tool not only in stemming the attrition but also help in improving the performance as is the case with many public and private sector Utilities.

55. A quick summary of the key issues at various facets of employee life cycle in the organization is highlighted in Table-1 .

Table-1: Human Resource Issues in State-sector Power Generation Utilities in India

Recruitment	Training	Performance Management	Compensation
• Long recruitment cycle with the time taken from requisition to government approval sometimes taking years to fill in the positions. • Mandatory requirement of recruiting from employment exchanges. • Inability to attract the best talent pool due to lack of professional culture, poor branding and efforts towards creating awareness amongst possible target group	• HRD function is inadequate and has failed to bring in the desired change • Lack of mechanism that captures training needs; There is no linkage between developmental needs & training imparted • Post training evaluation is not done and as such, there is limited scope for up-gradation of training methods, faculty and curriculum	• Annual Confidential Reports are subjective in nature. • Annual Confidential Reports are utilized only for Promotion purposes • Annual Confidential Reports are not used as an effective performance appraisal tool • Inadequate mapping of skills to roles and absence of career development plans	• Governed by Government prescribed pay-scales • Limited variable pay factor • Nominal linkage of compensation and performance • Differential level in terms pay-scales with central sector PSUs

56. *Steps for Improving Organizational Culture and Human Resources Development*

a. *Revise the Organization Structure to Meet the Requirements of Various Functions* The Organizational setup both at the Power Plant and Headquarter (HQ) levels would have to be restructured with clearly defined Roles and Responsibilities.

An indicative Organization Structure at the Power Plant Level could typically have four main functions each with a senior executive in-charge, who would report directly to the Head of the Plant who would be the overall in charge of the Power Plant. These functions are (i) Operations and Maintenance (O&M), (ii) Materials, (iii) Finance, and (iv) Human Resources. Such a set-up would ensure adequate attention to each of these functions, which is often lacking in the present set-up.

The functions reporting to senior executive for O&M could typically include: a) Operations; b) Efficiency /Commercial/Energy Conservation; c) Chemistry; d) Boiler Maintenance; e) Turbine Maintenance; f) Balance of Plant Maintenance; g) Electrical Maintenance; h) Ash Handling Plant Maintenance; i) Control & Instrumentation Maintenance; j) Maintenance Planning; k) Coal Handling Plant Maintenance; l) Civil (O&M) and where required, m) Renovation And Modernization (R&M). Each of these functions should be headed by a separate experienced executive reporting to the incharge for O&M.

Table-2: Indicative Responsibilities of Some Important O&M Departments at the Power Plant

Department	Responsibilities
Operations	• Day to day operation of the plant at the optimum level • Review operating instructions and tailor them to site specific requirements • Identify factors resulting in low availability, high partial loading and deviation of critical performance parameters from standard norms and take corrective actions
Operations and Efficiency (O&E)	• Assessment of critical performance parameters and performance optimization • Root cause analysis of tripping, failures, outages, low availability, and partial loading • Review of operational strategy and philosophy • Energy audit and cost optimization at plant level • Convener for Tripping Analysis Committee • Convener for Forced Outage Analysis Committee • Co-ordinate conduction of Operations Review Team Meetings
Maintenance Planning	• Conduct daily maintenance planning meetings • Condition Monitoring of equipment (through *Condition Monitoring Cell)* • Short term planning of maintenance schedules (including preventive maintenance) and shut down maintenance schedules based on defect list from Operation, Condition Monitoring data and feedback from O&E • Formulation of overhauling strategy - Preparation of six-years maintenance rolling plan • Preparation of Scope of works and Engineering declaration for overhauls • Spare part planning for preventive and shut down maintenance & overhauls. • Assessment and optimization of receipt, consumption pattern,

Department	Responsibilities
	inventory and reclamation of resources – spares, manpower & consumables • Development of equipment history and information card with standardized detailing of associated maintenance jobs
Maintenance (including Boiler, Turbine, BoP, C&I, Electrical, Civil, Coal Handling and Ash Handling)	• Day to day maintenance • Standardization of maintenance practices • Detailing scope of work for preventive maintenance, short shut down, restoration and overhaul for individual equipments • Standardize resource utilization for different works. • Formulation of QP for different works and spares procurement. • Maintenance cost optimization.
Station Chemistry	• Implementation of standard norms for water and steam into day to day practice • Monitoring of Environmental Parameters such as Particulate Matter (PM) and other effluents as per relevant guidelines

b. *At the HQ Level, there should be an organization structure to oversee the O&M of all Power Plants in the company. Its main functions would typically be: (a) Set performance targets for the Power Plant and monitor the same periodically (say monthly); (b) Identification of O&M performance gaps and drawing up of action plans for removal of the same; (c) Provide specialist services for study of chronic problems (trouble shooting) and their resolution; (d) Develop and implement performance improvement initiatives across all power plants; (e) Develop, document and update O&M systems and procedures and ensure compliance across all Power Plants; (f) O&M budgeting and compliance monitoring; (g) Preparation and compliance monitoring of Maintenance Rolling Plans for the organization as a whole (based on inputs from individual power plants); (h) Draw up quality plans for maintenance / overhauls and ensure compliance; (i) Carry out Energy Audits across the Organization and draw up action plans to remove the gaps and ensure compliance; (j) Provide support for equipment selection, commissioning, stabilization, PG Test; (k) Plan and Monitor R&M activities; and (l) Serve as a repository of knowledge pertaining to O&M and ensure its dissemination across power plants (Web-based knowledge portal). This organization should mirror the departments at the Power Plants and should be staffed with senior executives who have considerable field experience.*

   Utilities having multiple power stations could also consider the feasibility of establishing centralized utility wide organizational unit responsible for some of the above mentioned activities such as Maintenance Planning, O&E, Trip Analysis, CM Cell, etc.

c. *Well defined job descriptions for all employees at the plant* It is essential that existing job descriptions are comprehensively reworked with clear delineation of authorities and accountabilities for each position which will bring in transparent work environment with higher efficiency level. Key Responsibility Areas (KRAs) and Key Performance Indicators (KPIs) should be assigned to each unique and critical role.

d. *Structured Performance Assessment and Incentivization Program* A structured incentive program should be put in place like other well-functioning utilities. They should develop a robust incentive scheme in place to address productivity aspects and alignment of employee efforts with plant / corporate goals. The organization should formulate a comprehensive performance assessment mechanism to ensure that accountability and authority are fully aligned in the system.

This mechanism should have adequately designed HR indicators which is more based on a balanced mix of qualitative and quantitative aspects and has a greater manager-subordinate participation and discussion aspect compared to an annual review mechanism.

e. *Strategic Human Resource Planning and Skills Enhancement* There should be more importance on training needs identification procedure for the employees. This exercise should be properly followed up through skill mapping process and arrangement for substantial amount of training for the employees across different levels in the plant. There should be a well designed succession plan in place and with the war for talent on in terms of attracting and retaining talent, it is essential that due attention is also laid on strategic human resource planning by the utilities.

Indicative Action Plan For Strengthening O&M Practices

57. An indicative action plan for strengthening O&M practices is provided at Annexure 1 to this Guidance Note.

Conclusions and Way Forward

58. Although there has been significant progress in strengthening the operational and maintenance practice of several power plants under the Partnership in Excellence (PIE) program, most state-level generation utilities are yet to institutionalize the above mentioned industry-best practices for sustained good performance. Initiatives in this direction are also critical for ensuring that the large new generation capacities being added at present do not suffer from poor performance due to weak O&M practices. However, strengthening of O&M practices is a challenge that requires strong management and employee commitment for achieving the change. It would be a long drawn process requiring sustained engagement by the change agents – internal or external to the company.

59. This paper could serve as a concise guide for the utility owners (state government), senior management team, plant heads and other change agents for understanding the steps required for affecting this transformational change. However, detailed plans of action would have to be drawn for each of identified areas based on the specific requirements of each power plant and each utility.

Underlying Consultancy Study

Pricewaterhouse Coopers India and Evonik Industries, *Assessment of Operations and Maintenance Practices in Select Thermal Power Stations in India,* Draft Final Report, December 2008.

INDICATIVE ACTION PLAN FOR STRENGTHENING O&M PRACTICES

The O&M strengthening Plan at the utilities will need to be based on ensuring not only business process turnaround but also instilling in place an improved organizational culture and climate. The Strengthening plan aimed at transforming the existing plant practices and creating an agile generation utility shall need to be overseen and supported by the Utility Management as a Change management exercise. The improvement activities shall need to be kick-started with a *Performance Improvement Program* aimed at disseminating the program benefits and ensuring readiness within the organization to adapt to the necessary changes that shall be set out in the individual modules.

A modular approach could be adopted for the entire change management exercise. Each module shall a number of tasks both technical and management related with a specific time line as tabulated below:

MODULE	TASKS
Operating Practices Enhancement	Redesign of existing O&M Manuals post review of existing ones along with development of equipment procedures and conducting training for O&M personnel
	Establishing efficiency management as a thrust area through setting up the Efficiency Monitoring Cell and institutionalizing procedures for performance testing, auxiliary energy management, root cause analysis of trips. The efficiency management is expected to be complemented by a commercial loss evaluation and efficiency benchmarking tool which will facilitate analysis and identification of controllable losses and identify assets for refurbishment/ replacement.
	Initiation of Knowledge Management through establishing a Central Technical library at the Plants and subsequently creating of a web based system for capturing plant information, best practices, technical, operational details for dissemination across the entire utility.
Proactive Maintenance	Creating an asset database to be populated with failure history, performance characteristics, design data which shall enable analysis of failure mode and effects. This will lead to development of a proactive maintenance plan along with the condition monitoring schedules and reliability assessment matrix.

MODULE	TASKS
	Designing and setting up a Decision support system linking the costs to reliability along with equipment level operating limits and checklists which shall enable the utility to pre-empt failures and also utilize cost / reliability information to substantiate refurbishment / replacement decisions.
	Setting up a Computerized Maintenance Management System (CMMS) at the Plant.
Cost Information System	The costing system shall entail setting up a costing framework at the plant along with relevant cost codes and centres. The implementation arrangement shall consist of creating a cost database, populating it with one time cost data and conducting training for utility personnel on the same. Depending upon the current maturity level of the utility, this can be extended towards designing an Activity Based Costing system at the Plants.
Generation Planning & Budgeting	Realignment of existing practices with the future market scenario.
	Establishing a Techno-commercial cell at the plant along with integration with CMMS based planning.
	Setting up of procedures for Equivalent Availability Factor, Year ahead planning integrated with Energy Audit and Partial Loss analysis
	Developing a Budget Manual along with introduction of a Performance Based Budget System at the utilities.
Management Information System	The MIS system at the utilities shall require varying levels of intervention based on the existing systems with the utility and shall range from improving existing system through additional functionalities to developing an IT policy, establishing a full fledged IT and MIS system along with procuring an MIS system via bid route.
Purchasing & Stores	Review and Redesign of existing procurement procedures
	Institutionalizing Quality Assurance (QA) systems in the Procurement cycle by setting up QA cell at the Plants, developing a QAP and setting up checks and controls within the Procurement Contracts. This will also require training for Plant Personnel in QA related aspects

MODULE	TASKS
	Optimization of Inventory levels releasing idle working capital through review of inventory holding, reorder levels, creation of a high value spares bank by inventory pooling, standardization of stores items, automatic procurement protocols on reorder level basis for fast moving consumption items.
Organizational Culture & Climate	Performance Management System by designing the job description for all positions along with formulating Key Performance Indicators and Key Result Areas for the positions. This shall need to be complemented through a KPI monitoring mechanism through a base line study and establishing targets and review principles. Improving the existing system of Training & Development through conducting a Training Needs Analysis exercise , formulating the training scope and strategy along with developing training course materials and conducting Training for the Plant Personnel.

Depending on the institutional bandwidth and capabilities of each Utility the above tasks could be carried out in-house or with the help of consultant, spread over a period of around two years. The exact time-line for each activity would depend on the resources available with the Utility and whether it is being done in-house or with the help of consultant.

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank and assists low- and middle-income countries to increase know-how and institutional capability to achieve environmentally sustainable energy solutions for poverty reduction and economic growth.