Good Practices Manual

Green House Gases Emission Reduction

Thermal Power Plant

Prepared by
National Productivity Council, India

Supported by
Department of Industrial Policy and Promotion
Ministry of Commerce and Industry
Government of India

TABLE OF CONTENTS

ACKNOWLEDGEMENT

Auraiya Gas Power Station (AuGPS) (NTPC), Auraiya, Uttar Pradesh	Shri R.K.Pal, General Manager
Muzaffarpur Thermal Power Station (MTPS), Muzaffarpur, Bihar	Shri C.S. Gupta, Chief Executive Officer, and Shri R.K. Singh, AGM (O&M), MTPS
Anpara Thermal Power Station, (UPRVUNL), Anpara, Uttar Pradesh	Shri Anand Kumar, Chief General Manager
Patratu Thermal Power Station (PTPS), Patratu, Jharkhand	Shri Sudhanshu Kumar, General Manager
Barauni Thermal Power Station (BTPS), Barauni, Bihar	Shri Abinash Kumar, General Manager-cum-Chief Engineer
Tanda Thermal Power Station, (TTPS) Tanda, Uttar Pradesh	Sh A.K. Sinha, General Manager
Dadri Gas Power Station (DGPS), Dadri, Uttar Pradesh	Shri. P. R. Dhake, General Manager
Harduaganj Thermal Power Station (HTPS), Kasimpur, Uttar Pradesh	Shri Nand Lal, General Manager
Dadri Thermal Power Station (Coal), Dadri, Uttar Pradesh	Shri. P. R. Dhake, General Manager
National Thermal Power Corporation (NTPC), Singrauli, Uttar Pradesh	Shri Jay Narayan Singh, General Manager
National Thermal Power Corporation (NTPC), Kahalgaon, Bihar	Shri S.Ghosh, General Manager
Obra Thermal Power Station (OTPS), Obra, Uttar Pradesh	Shri D.N.Bajpai, Chief General Manager
Feroz Gandhi Unchahar Thermal Power Station, Unchahar, Uttar Pradesh	Sh Prakash Tiwari, General Manager
Panki Thermal Power Station (PTPS), Kanpur, Uttar Pradesh	Shri M.D. Bhagchandani, General Manager
Parichha Thermal Power Station (PTPS), Parichha, Uttar Pradesh	Shri Rajendra Singh, General Manager
Rihand Super Thermal Power Station, (RhSTPS) Rihand, Uttar Pradesh	Sh P. Ramesh, General Manager (I/C)

PREFACE

It is widely accepted we have to limit the temperature rise to $2^{o}C$ to mitigate effects of climate change. This requires changing the portfolio of energy basket from fossils to non-renewables, reduce energy use through energy efficiency and conservation and reduce GHG emissions.

The broad intent and its goals can only be achieved by coordinated actions at ground level by society, business, industry and government. As part of its endeavour the Government of India is formulating policies, action plans to support and guide industry and entrusted National Productivity Council to prepare of Best Practices Manual for Reducing GHG Emissions in various sectors namely, **Thermal Power Plant, Chlor Alkali, Cement, Pulp and Paper and Iron and Steel**.

This manual is expected to serve as reference manual for

- Identifying sources of GHG emissions
- Assess and quantify emissions.
- Evaluate and assess potential to improve energy efficiency and reduce GHG emissions.
- Propose a menu of options which industry can consider for assessment and implementation.

The scope of this manual covers GHG emissions in the plant boundary and does not include transportation of raw materials, products and wastes to secured landfills, emissions from domestic waste treatment and emissions from sales and other offices.

It is hoped the manual will be useful as a handy reference for all levels of engineers and managers working in the sector.

STUDY TEAM

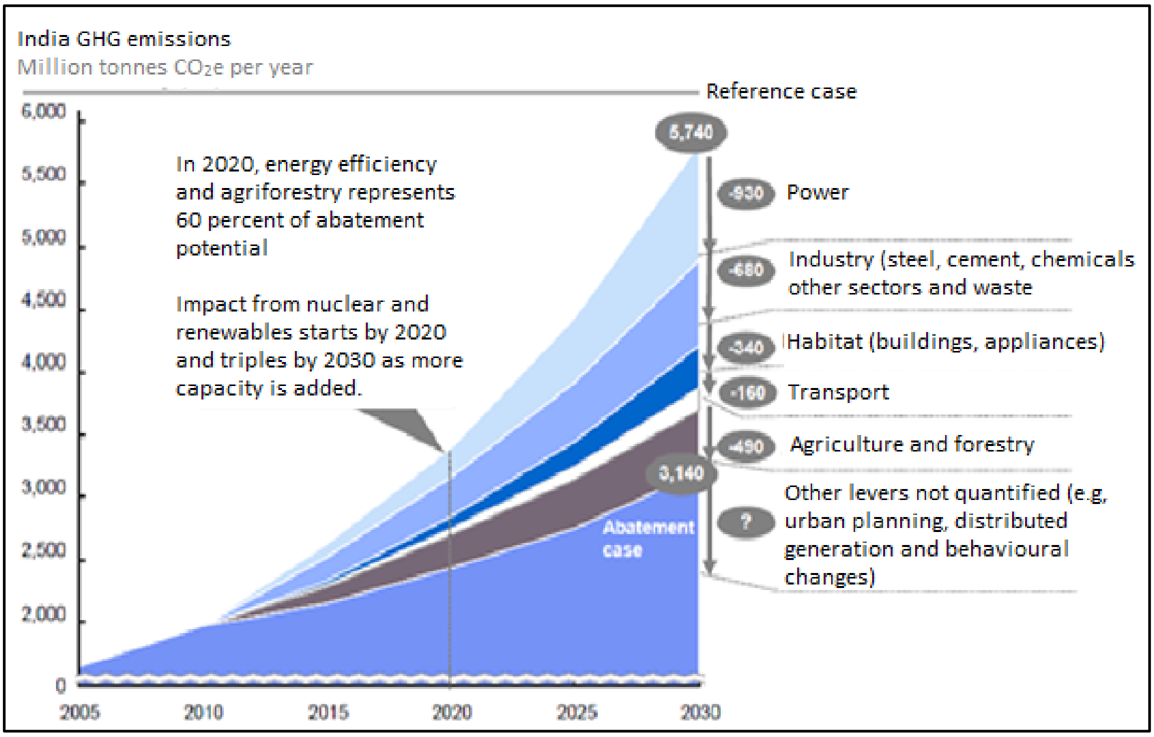
Project Coordinator	Mr. R Virendra, Dy. Director General, National Productivity Council
Team Coordinator	Mr. B. P. Bhandary, Director, National Productivity Council Mr. Alok Kumar Mittal, Dy. Director, National Productivity Council
Team Members	Mr. Amitava Ray, Dy. Director National Productivity Council Mr. Anand Verma, Dy. Director National Productivity Council Mr. Vipin Rohilla, Dy. Director National Productivity Council
Associates	Shri S.K. Gautam, Field Engineer National Productivity Council Miss Khyati Agarwal, Project Associate National Productivity Council Miss Sneha Singh, Project Associate National Productivity Council

1. INTRODUCTION

1.1 BACKGROUND

Energy is a major driver of economy and the per capita consumption of energy is a lead indicator of its development. The fossil fuels, comprising about 72% of the energy basket as of 2013[1], is the major contributor of GHG emissions and consequently global warming. The wider consensus that the temperature rise is to be limited to 2°C requires reducing these emissions by changing the portfolio of energy mix from fossil fuels to non-renewable sources, and reducing energy use through energy efficiency and conservation.

India is a net energy importing country and its GDP growth is expected to be highest among the world. To maintain its growth rate as well as to ensure energy security and meet its committed GHG emission target reduction (30-35%) by 2030 from 2005 levels, increase non-renewable power generation capacity to 40% of total generation, create carbon sink of 2.5–3 $GtCO_2e$), India needs to shift its energy consumption towards renewable energy, besides adopting energy conservation and management measures. Studies indicate potential to reduce GHG emissions as shown in Figure 1.1.



[1] http://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS

Figure 1.1 Indian GHG Emission Scenario (Past, Current & Projected)
Source: Pathways to lowcarbon_economy_Version2

As can be seen, industrial sector's GHG reduction potential is about 680 million tonnes CO_2e per year. In line with these projections provided by various studies, Government of India evolved policies, action plans and mission oriented programs to address the following objectives and issues.

- Energy security – to meet present and future needs
- Environmental impact-to address local emissions & global climate change
- Economic development – to create a sustainable development
- Ease of implementation

1.2 ABOUT THE PROJECT

To ensure effective translation of policy and implementation of action plans, Department of Industrial Policy & Promotion (DIPP), under Ministry of Commerce & Industry, Government of India has entrusted National Productivity Council of India (NPC) with the project entitled "Preparation of Good Practices Manuals for Green House Gas Emission Reduction in Five Energy Intensive Industry Sectors in India" under the 12th Plan period (2012-2017).

The scope of the project is to conduct field and questionnaire survey in five selected energy intensive sectors (Thermal Power Plant, Chlor Alkali, Cement, Pulp and Paper and Iron and Steel) of Indian economy, and bringing out manuals on Good Practices for GHG Emission reduction in the selected energy intensive sectors. Out of these five energy intensive sectors, this manual highlights the best practices involved for reducing Green House Gases Emission Reduction in Thermal Power Plant sector.

This manual brings out sources and trends driving India's greenhouse gas emissions in the Thermal Power Plant sector, outlining present situation and technologies that offer potential for significant emission reductions through enhanced energy efficiency that will put India on a sustained low-carbon path without sacrificing economic growth. It also highlights the Government of India policies and interventions that spur energy efficiency and GHG reduction activities in the sector eventually leading to improving energy security.

1.3 METHODOLOGY

For preparing this manual, following methodology was adopted:

- Sector reports were prepared with inputs from questionnaire survey, detailed field visits and audits, workshops and guidance from steering committee.
- The synopses of the reports were extracted to prepare this manual for comprehensive presentation of information and provide guidelines for implementation of GHG emission reduction options.
- Feedback on the manual contents and the material was sought and received from industries, sector association, and other stakeholders and the same was incorporated in the final manual

1.4 GREENHOUSE GASES AND ITS IMPACT

Over the last 100 years, it was found out that the earth is getting warmer and warmer, unlike previous 8000 years when temperatures have been relatively constant. The present temperature is 0.3–0.6 $^{\circ}$C warmer than it was 100 years ago. The key greenhouse gas (GHG) causing global warming through human enhanced GHG effect is carbon dioxide.

The natural greenhouse effect is the process by which radiation from the earth's atmosphere warms its surface to a temperature above what it would be without its greenhouse gases naturally present in the atmosphere. The greenhouse gases naturally present in the atmosphere include water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Certain human activities add to the levels of most of the naturally occurring gases. For example, carbon dioxide is released to the atmosphere when fossil fuels such as oil, natural gas, coal, wood etc are burned. The enhanced greenhouse gas effect is the further rise in average earth’s temperature due to increase in the amount of carbon dioxide and other greenhouse gases in the earth's atmosphere due to human activities. Both these effects are depicted in Figure 1.2.

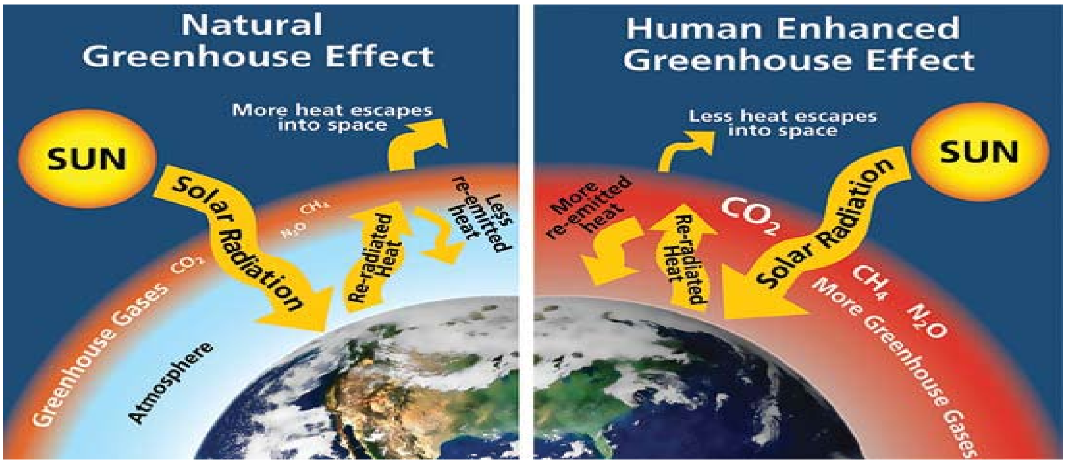


Figure 1.2 Natural and Human Enhanced Greenhouse Effect

Green House Gases (GHG) is of two types namely direct and indirect. Direct GHG contribute directly to the greenhouse effect in the atmosphere by trapping the infrared radiation near the earth's surface. The major GHG gases identified by Intergovernmental Panel on Climatic Change (IPCC) are carbon dioxide, methane, nitrous oxide, hydrogen fluorocarbons, per fluorocarbons, sulphur hexafluoride.

Indirect GHG control the oxidising capacity of the troposphere by reducing the hydroxyl radicals distribution thereby increasing the residence time of some direct greenhouse gases, such as methane and ozone. Although there are a number of ways of measuring the strength of different greenhouse gases in the atmosphere, the Global Warming Potential (GWP) is the most useful indicator. The GWP for different GHG is shown in Table 1.1.

GWP depends upon the greenhouse gas ability to absorb heat in the atmosphere. HFCs and PFCs are the most heat-absorbent. Methane traps over 21 times more heat per molecule than carbon dioxide, and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide.

Table 1.1 Direct and Indirect Green House Gases and its GWP

Symbol	Name	Common Sources	Atmospheric Lifetime (years)*	Global Warming Potential
CO_2	Carbon Dioxide	Fossil fuel combustion, forest clearing, cement production, etc.	50-200	1
CH_4	Methane	Landfills, production and distribution of natural gas and petroleum, fermentation from the digestive system of livestock, rice cultivation, fossil fuel combustion, etc.	12	21
N_2O	Nitrous Oxide	Fossil fuel combustion, fertilizers, nylon production, manure, etc.	150	310
HFC's	Hydro fluorocarbons	Refrigeration gases, aluminum smelting, semiconductor manufacturing, etc.	264	Up to 11,700
PFC's	Per fluorocarbons	Aluminum production, semiconductor industry, etc.	10,000	Up to 9200

H_2	Hydrogen	Chlor alkali production etc	100	5.8

The Figure 1.3 shows comparison of per capita CO_2 emission for the top five GHG emitting countries of the world and EU. India, owing to higher population, per capita CO_2 emission is the least. However, in terms of absolute emissions India is the third largest CO_2 emitting country, behind the US and China (2015) and contributing about 6 % (2.3 Gt CO_2) of global emissions (WEO 2015).

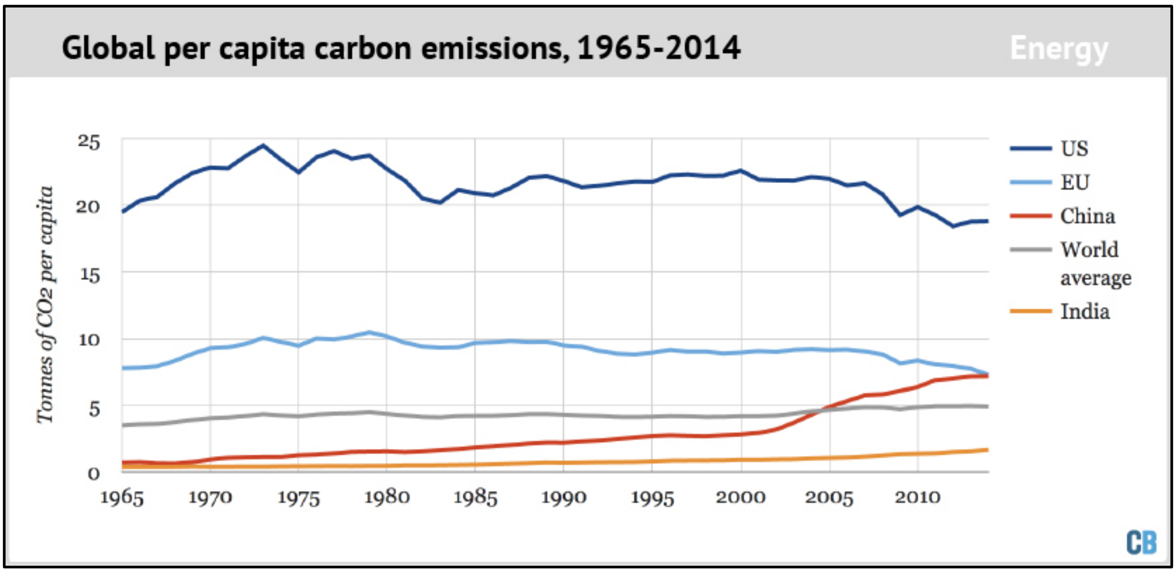


Figure 1.3 Per capita CO_2 Emissions

Impacts of Global Warming

Rise in Global Temperature

Observations show that global temperatures have risen by about 0.6 °C over the 20th century. There is strong evidence now that most of the observed warming over the last 50 years is caused by human activities. Various climate models predict that the global temperature will rise by about 6 °C by the year 2100.

Rise in Sea Level

In general, the faster the climatic change, the greater will be the risk of damage. The mean sea level is expected to rise 9 - 88 cm by the year 2100, causing flooding of low lying areas and other damages.

Food Shortages and Hunger

Water resources will be affected as precipitation and evaporation patterns change around the world. This will affect agricultural output. Food security is likely to be threatened and some regions are likely to experience food shortages and hunger.

Models predict an average increase in temperature in India of 2.3 to 4.8°C for the benchmark doubling of carbon dioxide scenario. It is estimated that 7 million people would be displaced, 5700 km^2 of land and 4200 km of road would be lost, and wheat yields could decrease significantly.

Due to rising energy demand, India's CO_2 emissions is expected to grow at the rate of 7% and surpass the present EU-28 emissions by 2020. As a part of mitigation effort, India is committed to increase its share of non-fossil energy sources from current 19% to 40% by 2030. Combustion of fossil fuel will continue to be the single major contributor to the global warming and hence the focus world-wide is on efforts to opt for renewable energy and enhance energy efficiency.

1.5 OUTLINE OF ENERGY SCENARIO IN INDIA

The energy mix of India for 2013 presented in the pie chart (Figure 1.4) indicates fossil fuel is the main stay of India's energy mix.

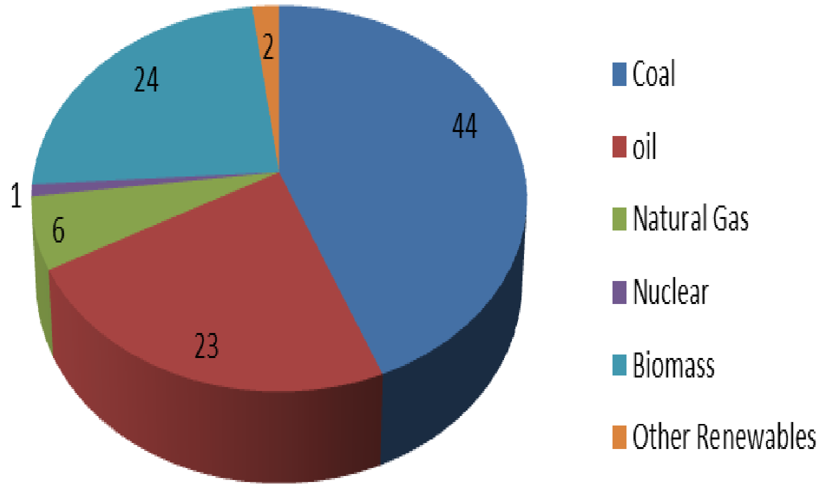


Figure 2.4 Primary Energy Demand in India for 775 MTOE
(Source : IEA, 2015)

Industrial energy demand has almost doubled over the 2000-2013 period, with strong growth from coal and electricity. Large expansion in the energy-intensive sectors is anticipated in the future. The present energy consumption in these energy intensive sectors in the country is high compared to the developed world. The major energy consuming sectors in the country are Iron & Steel, Chemicals, Textiles, Aluminium, Fertilizers, Cement & Paper. These sectors account for about 60% of the total energy consumption in industry. The energy consumption in manufacturing is relatively high in India which is reflected in the Specific Energy Consumption (SEC). This, therefore, provides an opportunity to reduce energy consumption and thereby GHG emissions. The typical SECs in different manufacturing sectors is presented in Table 1.2.

Table 1.2 Specific Energy consumption in Energy Intensive Industries

Sl. No.	Industrial Sector	Specific Energy Consumption (SEC)	
		India	World
1	Iron and Steel	6.5–7.0 GCal/Ton	4.5–5.5 GCal/Ton
2	Cement	80 kWh/T	110 kWh/T
3	Aluminium	4300 kWh/T (Refinery) 16500 kWh/T (Smelter)	3850 kWh/T (Refinery) 15250 kWh/T (Smelter)
4	Fertilizer	7.7 GCal/T of Urea	6.5 GCal/T of Urea
5	Paper and Pulp	8.4 Steam consumption/Ton	4.5 Steam consumption/Ton
6	Textile	7.1 GCal/Ton	3.1 GCal/Ton
7	Chlor Alkali	3.1 GCal/T (Soda ash) 2.1 GCal/T (Caustic Soda)	2.6 GCal/T (Soda ash) 1.8 GCal/T (Caustic Soda)

Source: BEE PAT Document

Energy Conservation and GHG Emission Reduction Initiatives by Government

The major policies that are currently promulgated and being implemented to meet the energy and climate challenge are summarized in Table 1.3.

Table 1.3: Government Policies and Initiatives for Energy Conservation

Policy /Initiative Statement	Key Features of the Policy
Energy Policies	
1. National Electricity Policy 2. National Rural Electrification Policy	• Access to Electricity - Available for all households in next five years • Availability of Power - Demand to be fully met by 2012. Energy and peaking shortages to be overcome and adequate spinning reserve to be available. • Supply of Reliable and Quality Power of specified standards in an efficient manner and at reasonable rates. • Per capita availability of electricity to be increased to over 1000 units by 2012.
3. National Tariff Policy 2006	• Minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012. • Financial Turnaround and Commercial Viability of Electricity Sector.

Policy /Initiative Statement	Key Features of the Policy
	• Protection of consumers' interests.
Industrial Energy Efficiency Programs	
1. National Mission for Enhanced Energy Efficiency (NMEEE) (a) Market Transformation for Energy Efficiency (MTEE) (b) Energy Efficiency Financing Platform (EEFP) (c) Perform, Achieve, and Trade (PAT) Mechanism for Energy Efficiency	• Market-based approaches to unlock energy efficiency opportunities, estimated to be about Rs. 74,000 crores By 2014-15: • Annual fuel savings in excess of 23 million toe • Cumulative avoided electricity capacity addition of 19,000 MW • CO_2 emission mitigation of 98 million tons per year
2. National Mission on Sustainable Habitat (NMSH)	Works on MSW, urban storm water & water mgmt. & energy efficiency
3. Energy efficiency Standards and Labelling Program	• BIS: formulations and implementations of national standards/production, quality and EMS certifications BEE : key thrust of EC Act,2001
1. Capacity Building for Industrial Pollution Management	• Build capacity at the state and central level, and develop a framework to address these issues in a comprehensive and systemic manner under an area-wide management approach. • The proposed project is aligned with the endeavour of the GoI to establish a National Program for Rehabilitation of Polluted Sites (NPRPS) as a framework for scaling up the clean-up and rehabilitation of polluted sites and facilitate the reduction of environmental and health risks associated with legacy polluted sites.
Capping, Trading and Taxing	
1. Tax on Coal to Fund Clean Energy	A means to instil price signals to spur energy efficiency and using cleaner fuels

<table>
<tr><th>Policy /Initiative Statement</th><th>Key Features of the Policy</th></tr>
<tr><td>2. Renewable portfolio standards/obligation
• Renewable Purchase Obligation (RPO) under the Electricity Act 2003 is mandated at the state level (discussed below in “National Policies Implemented at the State Level”)</td><td>• States often design them to drive a particular technology by providing "carve out" provisions that mandate a certain percentage of electricity generated comes from a particular technology
• States can choose to apply the RPS requirement to all its utilities or only the investor owned utilities.
• States can also define what technologies are eligible to count towards the RPS requirements.</td></tr>
<tr><td>3. RECS (Renewable Energy certificate System)</td><td>• Aimed at addressing the mismatch between availability of RE resources in state and the requirement of the obligated entities to meet the renewable purchase obligation (RPO)
• Cost of electricity generation from renewable energy sources is classified as cost of electricity generation equivalent to conventional energy sources and the cost for environmental attributes.
• Two categories of certificates, viz., solar certificates issued to eligible entities for generation of electricity based on solar as renewable Cost of Electricity Generation by Renewable Sources Cost Equivalent to Conventional Source Cost for Environmental Attributes energy source, and non-solar certificates issued to eligible entities for generation of electricity based on renewable energy sources other than solar</td></tr>
<tr><td colspan="2">Subsidies for Energy Conservation</td></tr>
<tr><td>1. Financial incentives through the Jawaharlal Nehru National Solar Mission</td><td rowspan="2">• Creating capacity in the area of solar, wind, bio-mass and other forms of renewal energy generation
• Supports financially as well as technically to promote solar heater other solar applications widely in the country and particularly in the areas where conventional energy is not possible to supply
• Long term energy security
• Ecologically sustainable growth
• Set target-20,000MW</td></tr>
<tr><td>2. Financial incentives by the Ministry of New and Renewable Energy through the Indian Renewable Energy Development Agency</td></tr>
<tr><td colspan="2">Energy Conservation in Buildings and Municipalities</td></tr>
<tr><td>Energy Conservation Building Code</td><td>• Provide technical support to BEE to implement the ECBC in a rigorous manner
• Develop reference material and documentation to support the Code</td></tr>
</table>

Policy /Initiative Statement	Key Features of the Policy
	• Develop ECBC Training material for workshops and training programs • Develop a road map for ECBC implementation
1. Municipal Demand-Side Management 2. State Energy Conservation Fund	Municipal Demand Side Management (MuDSM) is devised to take care of the most common and other issues which are seen as a hurdle by the Municipality to shift itself towards the Energy efficient zone from the existing situation of high amount of energy consumption.
Energy Conservation in Agriculture and Forestry Activities	
Agriculture, forestry, and other land use policies 1. Agricultural Demand - Side Management 2. National Mission for Sustainable Agriculture 3. National Mission for a Green India	• Consists of those activities, methodologies, awareness, policy and technologies that influence consumer (farmers) behaviour and Changes their (farmers) consumption patterns. • The objective of the AgDSM programme is to reduce peak demand, shift the time during which electricity is consumed to off-peak hours and to reduce the total quantum of consumption.

1.6 GHG EMISSION FACTORS

The emission factors considered for calculations in this manual are tabulated in Table 1.4 (CEA, 2014).

Table 1.4 GHG Emission Factors

No.	Parameter	Units	Factor
1	Grid Electricity	T CO_2/MWh	0.82
2	CPP Electricity		
a)	Coal Fired	T CO_2/MWh	1.03
b)	Diesel Fired	T CO_2/MWh	0.62
c)	Gas Fired	T CO_2/MWh	0.49
3	Coal (Sub-bituminous)	kg CO_2/TJ	96100
4	Gas/ Diesel	kg CO_2/TJ	74100

Source :CO_2 database, CEA, Ver. 10, 2014, IPCC Guidelines, 2006

2. THERMAL POWER PLANT PROFILE

2.1 INTRODUCTION

The thermal power plants can be classified on the basis of the fuel used for power generation. On the basis of fuel used, thermal power plants may be classified as

- Coal based thermal power plants
- Gas based thermal power plants
- Oil based thermal power plants

Coal Based Thermal Power Plants

A coal fired power station produces heat by burning coal in a steam boiler. The steam drives a steam turbine, this steam turbine is coupled with a generator which in turn produces electricity. The waste products of combustion include ash, sulphur dioxide, nitrogen oxides and carbon dioxide.

Gas Based Thermal Power Plants

In this case, natural gas is fired in a gas turbine which acts as the prime mover. The gas turbine is coupled with a generator to produce electricity. The exhaust gases from gas turbine are at very high temperature which can further be utilised for process heating or electricity production through a Heat Recovery Steam Generator (HRSG) and a steam turbine.

It may however be noted that gas being a cleaner fuel produces less GHG emissions compared to Coal Based Power Plants. Further with less availability of natural gas and higher cost of generation being a cause of concern, the gas based power plants operate intermittently and at low capacities, depending on the requirements. Under such circumstances, it would be inappropriate to consider any productivity or performance improvement options. Hence, the gas based power plants are not covered in this report.

Oil Based Power plants

In case of oil-based power plants, oil is combusted in a steam generator to generate steam and this steam is used to drive a steam turbine to produce electricity. In some other type of oil based power plants, oil is used as fuel to run turbines or engines which act as prime movers and coupled with generators, produce electricity.

Oil based power plants are very few in numbers and at remote locations, which are operated only in emergency. Hence, the oil based power plants are also not included in this report.

2.2 PRODUCTIVITY AND PERFORMANCE INDICATORS

The assessment of productivity and performance of a thermal power plant could be carried out by monitoring various parameters. The major parameters that highlight the actual performance of thermal power plants are listed below.

- Heat Rate (Indicator of Fuel Consumption per unit of Power Generation)
- Plant Load Factor (PLF)
- Auxiliary Power Consumption (Internal Consumption)
- Generation Efficiency
- GHG Emissions

Heat Rate

Heat rate is the measure of performance of a power plant which signifies the amount of thermal energy consumed for production of one unit of electricity. Heat rate is expressed in kCals per KWh. Lower the heat rate of a thermal power plant, better is the performance.

Plant Load Factor (PLF)

Plant Load Factor (PLF) is the ratio between the actual energy generated by the plant to the maximum possible energy that can be generated with the plant working at its rated power for a particular duration of time. Higher plant load factor (PLF) signifies better utilisation of capacity and hence, better performance of a thermal power plant.

Auxiliary Power Consumption (Internal Consumption)

APC is the amount of energy consumed within the plant for normal operation of a power plant. For production of electricity, power plants operate various auxiliaries and consume electricity which is a part of the gross energy produced by the plant. The net energy exported by a plant is the energy available after accounting for APC. Lower the APC, signifies better the performance of a power plant.

Generation Efficiency

Generation Efficiency of a thermal power plant signifies its performance in terms of energy supplied that got converted into useful work (electricity). It is the ratio of the energy produced by the plant to energy supplied to the plant. The remaining energy is usually lost to the environment as heat. This is expressed in percentage and higher the efficiency of a power plant, better is the performance.

GHG Emissions

Every thermal power plant consumes fossil fuel for generation of electricity in form of coal or natural gas. As the combustion of these fuels take place it results in generation of CO_2, Sulphur Oxides (SOx) and Nitrogen Oxides (NOx) which are GHG gases and contribute to global warming.

The amount of GHGs emitted for production of every unit of electricity differs from plant to plant and is dependent on its performance. High GHG emission for generation of a unit of electricity shows poor performance of a plant as compared to the plant that is generating same amount of electricity with lesser amount of GHG emissions, for a given fuel.

Coal power plant Performance indicators and Benchmarks

The coal based thermal power plants may be classified on the basis of their generation capacity and for this report purpose we are categorising the units in the following four capacity ranges.

- Upto 150 MW
- 150 MW to 240 MW
- 250 MW to below 500 MW
- 500 MW and above

Table: 2.1 Heat Rate

Category	National Average (kCals/KWh)	Indian Benchmark (Best Operating) (kCals/KWh) (2013-14)	International Benchmark (kCals/KWh) (2013-14)
150 MW and below	2755	2528	
150 MW to 240 MW	2592	2314	
250 MW to below 500 MW	2430	2216	

500 MW and Above	2358	2358	

Table 2.1: Plant Load Factor (PLF)

Category	**National Average (%)**	**Indian Benchmark (Best Operating) (%) (2013-14)**	**International Benchmark (%) (2013-14)**
150 MW and below	54.66	92.8	
150 MW to 240 MW	70.37	89.48	
250 MW to below 500 MW	61.62	93.9	
500 MW and above	56.12	83.8	

Table 2.3: Auxiliary Power Consumption (Internal Consumption)

Category	National Average (%) (2013-14)	Indian Benchmark (Best Operating) (%) (2013-14)	International Benchmark (%) (2013-14)
150 MW and below	12.10	6.91	
150 MW to 240 MW	8.30	7.02	
250 MW to below 500 MW	8.78	6.41	
500 MW and above	6.79	5.48	

Table 2.4: Efficiency

Category	**National Average (%)**	**Indian Benchmark (Best Operating) (%) (2013-14)**	**International Benchmark (%) (2013-14)**
150 MW and below	31.22	34.02	
150 MW to 240 MW	33.17	37.16	
250 MW to below 500 MW	35.39	38.81	
500 MW and above	36.46	36.46	

Table 2.5: GHG Emissions

Category	National Average (Tonnes CO_2/Million KWh)	Indian Benchmark (Best Operating) (Tonnes CO_2/Million KWh) (2013-14)	International Benchmark (Tonnes CO_2/Million KWh) (2013-14)
150 MW and below	885	712	
150 MW to 240 MW	865	768	
250 MW to below 500 MW	757	678	
500 MW and above	768	678	

3. THERMAL POWER PLANT PRACTICES / TECHNOLOGIES

3.1 COAL-BASED THERMAL POWER PLANT

The Figure 3.1 shows the schematic diagram of thermal power plant. In coal thermal power plant, the steam is produced in high pressure in the steam boiler due to burning of fuel (pulverized coal) in boiler furnaces. This steam is further superheated in a super heater. This supper heated steam then enters into the turbine and rotates the turbine blades. The turbine is mechanically so coupled with alternator that its rotor will rotate with the rotation of turbine blades to produce electricity.

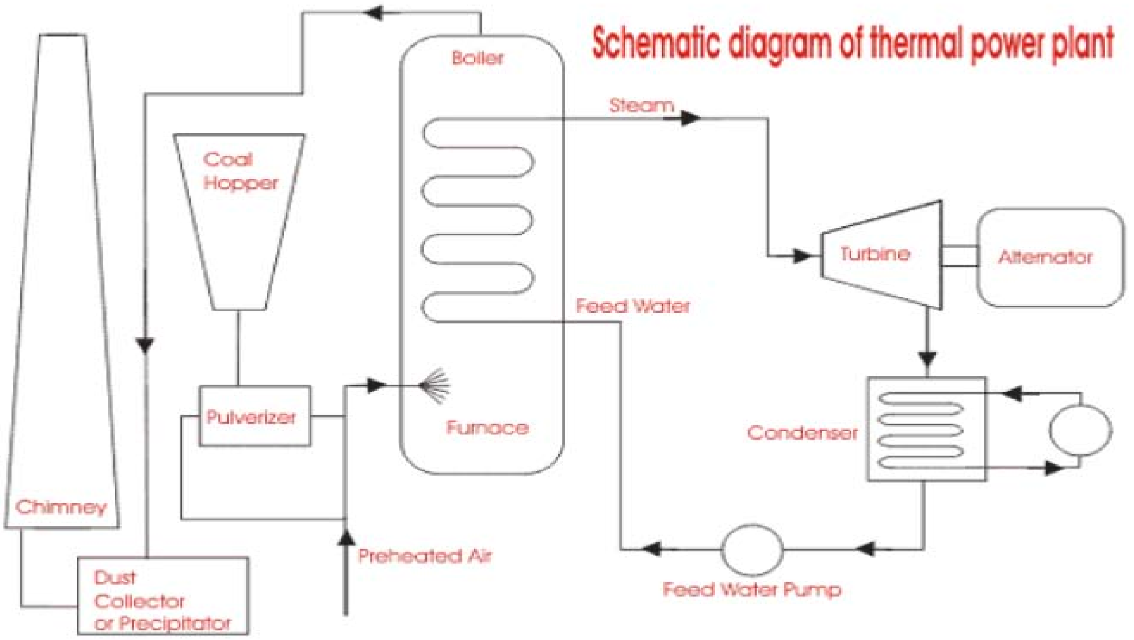


Figure 3.1 Schematic Diagram of Thermal Power Plant

The basic components of the thermal power station are:

- Coal Handling Plant
- Boiler
- Steam turbine
- Generator/Alternator
- Condenser
- Boiler feed pump

- Forced or induced draft fan system
- Ash Handling Plant

Coal Handling Plant

A pulverizer or grinder is a mechanical device for the grinding of many different types of materials. The coal pulverizer (Figure 3.2) is used to pulverize coal for combustion in the steam-generating furnaces of coal based power plant.

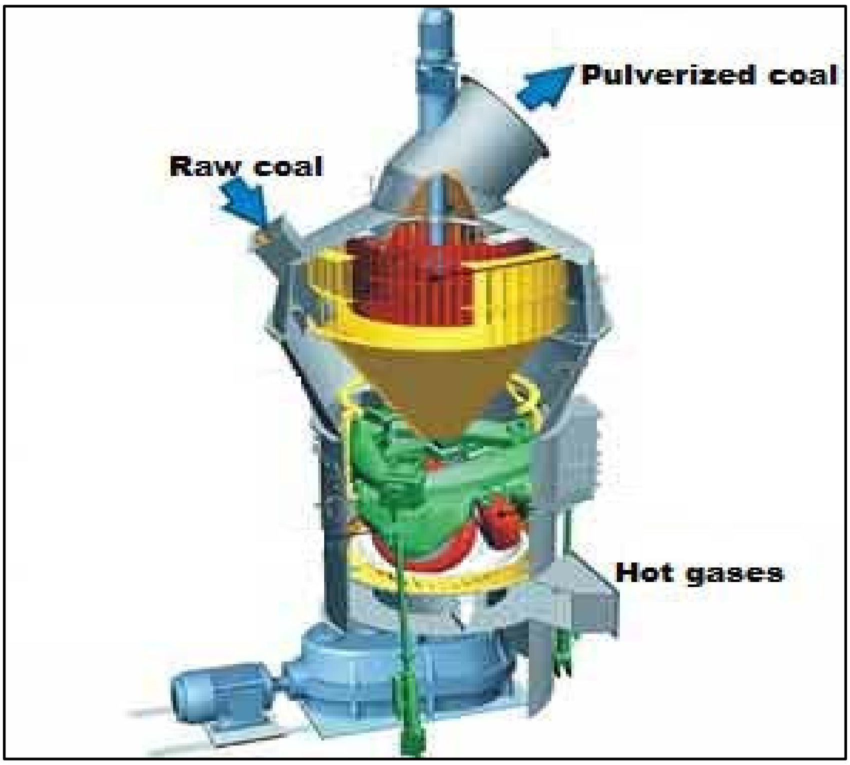


Figure 3.2 Coal Pulverizer

Boiler

A boiler or steam generator essentially is a container into which water can be fed and steam can be taken out at desired pressure, temperature and flow (refer Figure 3.3). This calls for application of heat on the container. For that the boiler should have a facility to burn a fuel and release the heat. The functions of a boiler thus can be stated as:

1. To convert chemical energy of the fuel into heat energy
2. To transfer this heat energy to water for evaporation as well to steam for superheating

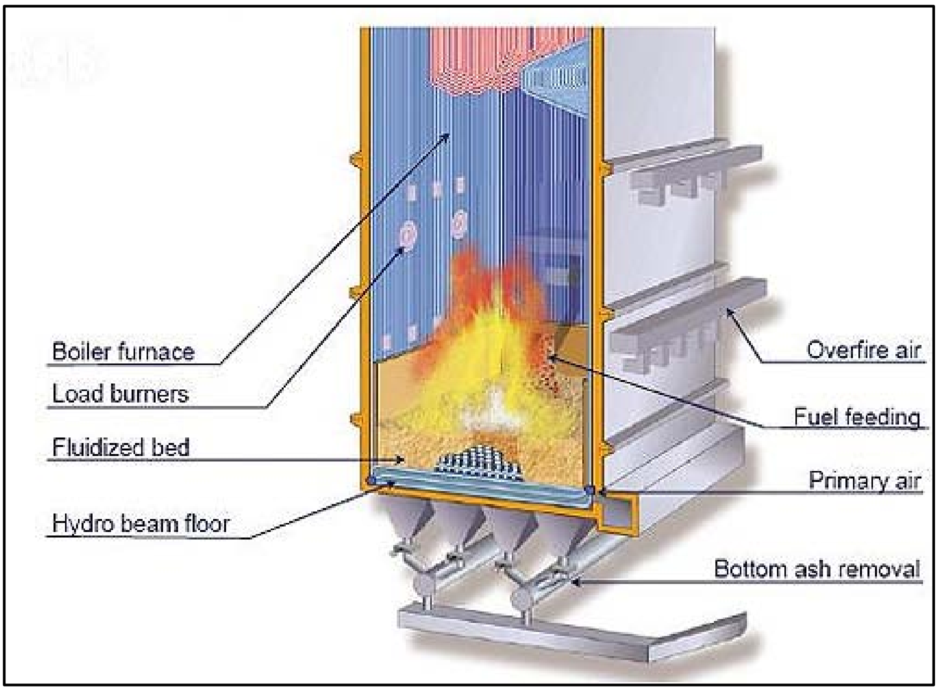


Figure 3.2 Boiler

Steam Turbine

A steam turbine is a device which extracts thermal energy from the pressurized steam (refer Figure 3.3). The energy must be used to organize mechanical work on a rotating output shaft.

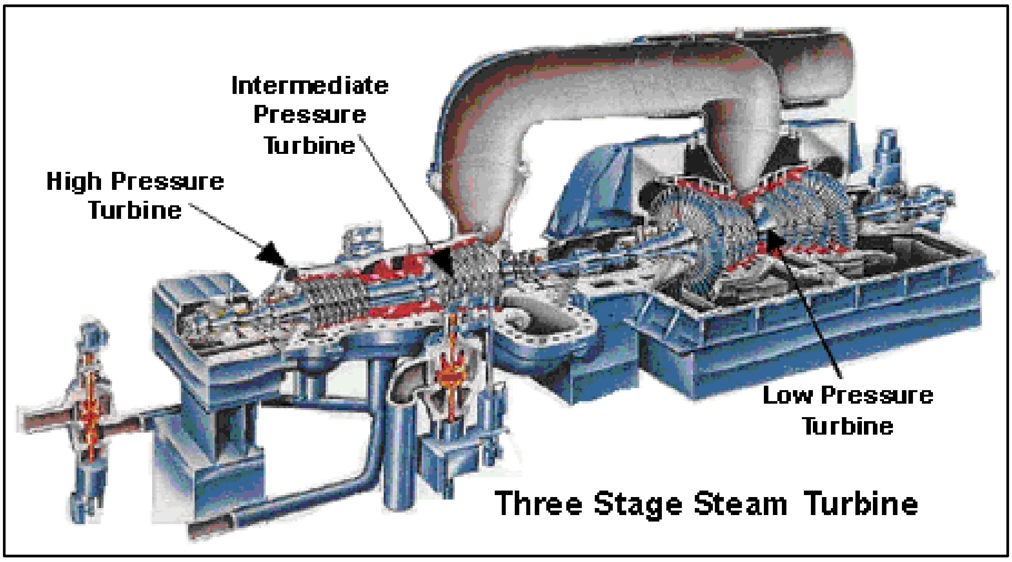


Figure 3.3 Steam Turbine

Generator

A generator is a device which is used to convert the mechanical form of energy into the electrical energy (Figure 3.4).

Figure 3.4 Turbine

Condenser

A condenser is a device used to converts the gaseous substance (Consumed steam in this case) into the liquid state substance with the help of cooling.

Boiler Feed Pump

A boiler feed pump is a specific type of pump which is used to feed the water into the steam boiler (Figure 3.5).

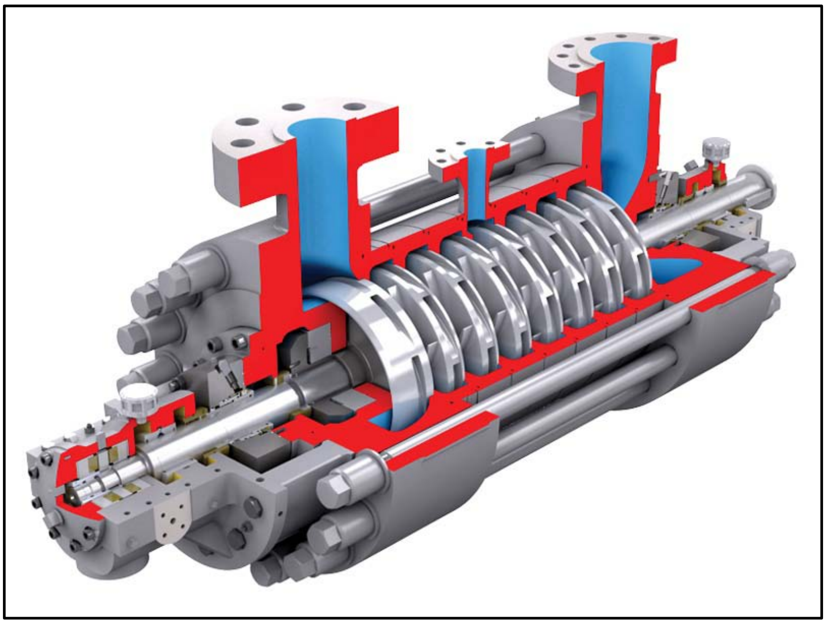


Figure 3.5 Boiler Feed Pump

Forced and Induced Draft Fan System

Fans system provides the boiler with air that is required for combustion of coal. The Forced Draft fan sends the air into the 'heating system' of the power plant which comprises of air preheater, furnace, superheater, economiser etc. and Induced Draft fan works at almost second last stage of the system, sucking out flue gases and finally sending them to chimney.

Ash Handling System

The disposal of ash from a power station is important as ash is produced in large quantities. For ash handling, two type of systems are generally employed that are dry ash handling and wet ash handling depending upon suitability.

- Dry Ash Handling: Ash is collected by electro static precipitator (ESP) and bag filters and collected in ash collection silo. This ash is used in manufacturing of cement and bricks.
- Wet Ash Handling system: The collected ash is mixed with water and is pumped to ash pond where it gets settled.

4. BEST PRACTICES

4.1 COAL-BASED THERMAL POWER PLANT

Table 4.1: Short Term options for Productivity Improvement and GHG Emission Reduction

Sl. No.	Recommendations	Time for Implementation	Payback period
1.	Improvement in condenser pressure	Less than 3 Months	Less Than 1 Year
2.	Reduction in excess air ratio		
3.	Reduction in the stack gas exit temperature		
4.	Optimisation of Condenser		
5.	Optimisation of feedwater heaters		
6.	Flue gas heat recovery		
7.	Soot blower optimisation		
8.	Steam leaks reduction		
9.	Improvement In Hot Re-Heat Temperature		
10.	Modification In Auto Furnace Draft Control Logic Of Id Fan Vane- Scoop Combination Control		
11.	Reducing Slag formation in Boiler		
12.	Normalizing Economizer Feed Water inlet temperature		
13.	Minimizing Auxiliary Steam Consumption & Makeup Water		
14.	Fuel oil tank heating steam optimization		
15.	Application of 415 V VFD for 6.6KV motors		
16.	Blinding one stage of High Pressure Boiler Feed Pump (HPBFP)		
17.	Improvements in process monitoring and control, Auto starts / stops logics for various drives		
18.	Providing solenoid valves for seal flushing requirement		
19.	Substituting glass wool insulation for chilled water lines by PUF insulation		
20.	providing purging system for Fuel nozzles for overcoming Fuel nozzles choking problems		

Table 4.2: Medium Term Productivity Improvement and GHG Emission Reduction Options

Sl. No.	Recommendations	Time for Implementation	Payback period
1.	Optimising Air Preheaters	Less than 6 Months	1 to 3 years
2.	Optimisation of Combustion system		
3.	Cooling system performance Upgrade		
4.	Flue gas moisture recovery		
5.	Reduction of slag and furnace fouling		
6.	Steam turbine refurbishment		
7.	Install Smart Wall Blowing System For Optimising Wall Blowing And Improving Heat Rate		
8.	HP Turbine Module Replacement		
9.	Boiler Maintenance For Minimising Boiler Tube Failure		
10.	DeNox water management		
11.	Load rejection scheme implementation to avoid trips during gird disturbances		
12.	Improvements and modifications to overcome plant recurring trips		
13.	Chillers performance improvement		
14.	Fire hydrant system improvement		
15.	Plant online performance monitoring system development and implementation for better monitoring and control		
16.	Optimizing power consumption for plant extended shutdown preservation activities		

Table 4.3: Long Term Productivity Improvement and GHG Emission Reduction Options

Sl. No.	Recommendations	Time for Implementation	Payback period
1.	Inclusion of a second reheat stage on the steam turbine	Less than 1 year	More than 3 years
2.	Replace Ash removal System with efficient system		
3.	Increase in Air heater Surface		
4.	Installation of coal drying system		
5.	Installation/Improvement of Process controls		
6.	Introduction Of Super Cleaning Of Turbine Oil		
7.	Life Extension Of Coal Mill Gear-Box Lube Oil By Electrostatic Liquid Cleaning Method		
8.	High Concentration Slurry System for Ash Handling		

9.	Improvement of atmospheric condensate collections from all gas turbines inlet air chilling system		
	Gas Turbine output improvement		

Improvement in Condenser Pressure

Condenser vacuum plays a very important role in the performance of a turbine and in ensuring maximum output. The desirable vacuum in condenser of a thermal power plant is 0.08(Kg/CM^2 (Abs)). Several factors impact the condenser vacuum such as

- air ingress due to leakages
- fouling in condenser tubes
- Ejector performance
- Higher cooling water temperature
- Inadequate cooling water flow etc

An improvement in condenser vacuum by 0.01 Kg/cm^2 is estimated to reduce fuel consumption by 1% for same power output. Corresponding GHG emission reduction for production of 1 million units of electricity would be 7.57 tonnes of CO_2.

Reduction in Excess Air Ratio

For combustion of any fuel, oxygen is required which is supplied by air. Every fuel has its theoretical air requirement for complete combustion. In practice however, the theoretical air alone is not sufficient to ensure proper and complete combustion and invariably there is a need to supply some excess air. The optimum excess air level for maximum boiler efficiency occurs when the sum of the losses due to incomplete combustion and loss due to heat in flue gas is minimised. This level varies with furnace design, type of burner, fuel and operational variables which can be determined by conducting tests with different air fuel ratio at different loads.

Excess air can be optimised by effective control of air-fuel ratio. For general operation of thermal power plant boiler the accepted excess air percentage is around 20%, but it can still be further reduced to 14-15% for reducing dry flue gas losses. Controlling excess air to an optimum level always results in reduction in flue gas loses. For every one percent reduction in excess air, there is approximately 0.6% rise in boiler efficiency. The corresponding reduction in GHG emission will be 4.5 tCO_2/Million Units.

Reduction in the Stack Gas Exit Temperature

The products of combustion after transferring heat to water for steam generation are let into atmosphere through stack. The temperature of this flue gas is normally in range of 160-200^{o}C. Higher the stack temperature, greater would be the heat loss from the boiler. By effective heat recovery and draft control can reduce fuel consumption in the boiler. However, the flue gas temperature should not be reduced so much that it results in condensation on the stack walls.

Every 22^{o}C reduction in stack temperature would result in 1% improvement in boiler efficiency. The corresponding reduction in GHG emission would be 7.57 tCO_2/Million units.

Soot Blower Optimisation

The soot produced during burning fuel (coal) in the boiler, sticks to the superheater tubes impeding heat transfer. As the soot deposition increases, the heat transfer effectiveness decreases. This soot is therefore removed periodically through soot blowers. The operation of the soot blowers is normally predetermined and is operated once every shift.

A proactive approach to soot blowing where in, soot blowing is done as per requirement could reduce steam consumption (in soot blowing) without affecting the boiler performance. The control use of soot blowing is expected to reduce steam consumption by about 2 Tonnes per day.

This can also be achieved by installing smart wall blowing systems for automatic control and avoiding manual interventions.

Steam Leaks Reduction

Steam leakages are common scenario in thermal power plants. While it may not be possible to completely eliminate the leakage of steam but it can be largely arrested. Steam leaks have multiple negative effects on steam-based plant operations, including energy losses, increased emissions, loss of reliability, production issues, and safety issues. Estimating the leakage is difficult to do because the orifice is not perfectly round. Measuring the diameter only can be done by visual inspection because physical measurements will cause burns. The plume length is highly dependent on the pressure of the leak, and volume is dependent on the diameter and pressure.

It is estimate that in existing power plants, checking and reducing the steam leakages can improve the efficiency by upto 1% The corresponding GHG emission reduction would be 7.5 TCO_2/MU.

Improvement in Hot Re-Heat Temperature

The steam from HP turbine is reheated before being sent to Intermediate Pressure Turbine. Maintaining the desired reheat temperature helps in improving the performance of a power plant. Possible reasons for reduce reheat temperature may be

- fouling in reheat tubes
- reheat attemperation control valve leakage
- incorrect amount of reheater heat transfer area etc.

Every 10^oC increase in reheat temperature is expected to improve the heat rate by 5 Kcals/kWh. The impact on GHG emission reduction would be 3 TCO_2/MU.

Modification in Auto Furnace Draft Control Logic Of Id Fan Vane- Scoop Combination Control

Background

The furnace draft control is kept in 'auto' with a set point of –5.0 to –8.0mmwc. The 'vane-scoop combination controls' of the running ID Fan/Fans are also placed in 'auto'. Furnace draft controller measures Furnace draft & compares with set point. Output signal is generated & fed to ID Fan 'Vane scoop control'.

Intel guide vane control is quicker compared to speed control using the variable fluid coupling. However, throttling the inlet guide vane leads to reduction in operating efficiency of the fan.

Flow control by controlling the speed (like fluid coupling scoop control) is more energy efficient than inlet vane control though the later is quicker in response. The purpose of the modification of ID Fan operation control logic was to ensure efficient and stable furnace draft control with combination response of vane & scoop.

Previous status

As per the original design philosophy, the vanes would modulate first from 35% (lower limit) to 55% (upper limit) as per demand signal. Once it reached limits, the vane remained fixed & demand signal went to operate Scoop. Scoop would take a position and desired furnace draft was achieved.

Area of concern: the main drawback of the previous control logic was that during high load (full load) the vane opening was limited to 55% whereas the scoop was nearly at

100% position. It was an energy inefficient control resulting in very high ID Fan power Consumption.

Project implemented

Vane control upper and lower limits were made dynamic and compatible with scoop control position feedback. Initially due to the priority set in the process logic, the demand signal modulates the vane. Once it reaches upper / lower limit, scoop starts changing position. When scoop reaches a certain position, the vane upper set point becomes dynamic & increases to higher value (governed by a calculation dependent on scoop position feedback).

Next on receiving further demand signal, scoop remains constant and vane modulates till it reaches changed upper limit. Subsequently the demand signal increases the scoop further. Again, the vane upper limit becomes dynamic and after incremental rise it freezes at a higher value.

Benefits

After modification of the control logic, each ID Fan energy consumption reduced by 7-9 % depending on the coal quality. Resulting in GHG emission reduction of around 0.45 TCO_2/MU.

Reducing Slag Formation in Boiler

Normally, the original design of units in India is for Indian coal having ash fusion temperature of 1400 ^{O}C. However as a common practice, to maintain the GCV of coal, a small amount of Indonesian coal having ash fusion temperature in the range of 1170 to 1230 ^{O}C is mixed in calculated proportions. Slagging index for such coal being higher, it is prone for slagging causing lower heat absorption mainly in Super heater panels.

Trials of injecting special slag reduction chemicals (a mixture of Magnesium oxides and phosphate salts) on fire side may be carried out to minimize impact of slagging. Dosing quantity & frequency may be optimized. Gain in terms of increased heat absorption & decrease in flue gas exit temperature may be limited to maximum 4^{O}C. resulting into efficiency improvement of around 0.18% and corresponding reduction in GHG Emission of around 1.3 TCO_2/MU of generation.

Normalizing Economizer Feed Water Inlet Temperature

In some cases it may be observed that feed water temperature at economizer inlet is being maintained lower than design. The performance of feed water heaters may be inspected during the outage. The heaters may be checked for holes due to erosion in the diaphragms that separated the feed water inlet and outlet water boxes, causing partial bypassing of water in the heater in HP heater, leading to lower feed water temperature. Corrective action may be taken and the heater performance restored back to design conditions. The online availability of the relevant data as well as the facility of historising the data can make the analysis of the problem easier.

Ensuring proper feedwater heating by minimising leakages in feedwater heater is expected to reduce the plant heat rate by 6 kCals/kWh. The corresponding GHG emission reduction would be around 3.5 TCO_2/MU.

Application of LT VFD for HT Motors

Some relatively small power plants auxiliary equipment such as CEP, Drip water pump etc are operated with HT Motors. It is observed that the actual output requirement in most cases under normal operating condition is lower than the designed. This necessitates regulating the capacity which is normally accomplished through throttle valve. Being HT dries, Installing HT VFD becomes a costly preposition. It is possible to regulate the capacities of such equipments using LT VFD drives with provision of stepping down and stepping up the voltages across the VFD.

Energy saving of the tune of 20-40% can be achieved by such an arrangement, at a considerably lower cost of installation of HT VFD.

Assuming a minimum 20% saving due to such an arrangement on CEP, the GHG Emission reduction potential is around 0.2 TCO_2/MU.

Blinding One Stage of High Pressure Boiler Feed Pump (HPBFP)

In thermal power plants it is necessary that the BFPs are designed for pressure higher than the drum pressure to pump water into the boiler drums. There will be no flow from BFP if drum pressure exceeds the pressure generated by BFP.

In many cases it is observed that pressure generated by BFP is much higher than the boiler drum pressure. In such cases the BFPs pump water at much higher pressure than the required pressure thus consume extra energy which can be avoided by pressure reduction. One good option for BFP pressure reduction is to blind one or more stages of BFP so that the pressure thus generated is just higher than the drum pressure, flow remaining the same. Depending on the difference in actual pressure generated and the oprerating pressure, the number of stages to be removed/blinded would vary. Every stage removal in BFP is ecpectes to reduce energy consumption be about 8% (Assuming total 12 stages). The impact on GHG emission reduction would be 1.5 TCO_2/MU.

Optimising Air Preheaters

In air-preheater as the pressure of fresh air being heated is higher than the pressure of hot flue gas duct, there is a possibility of air leaking into the flue gas path, due to improper sealing in the air heater or puncture in the tubes. This air leakage which is lost to the atmosphere not only effects heat recovery but also increases load on ID and FD Fans. He input is therefore two fold, i.e. increase in losses in the boiler and increasing power consumption in auxiliaries (ID and FD Fans).
Every 5% increase in air leakage would result in additional GHG emission of 0.57 TCO_2/MU.

Optimisation of Combustion system

Unburnts in fly ash contributes to heat loss in boilers. Regulating the combustion air supplied, depending upon the coal quality could reduce this loss. Every one percent reduction of unburnts in bottom ash would lead to 0.1 TCO_2 GHG emission reduction for every one million units of power generation.

It should however be ensured that the losses in flue gas does not get compromised as a result of this measure. Adoption of coal quality management system can also help in reduction of such losses.

Cooling System Performance Improvement

Cooling tower performance has an impact on the cooling water going to the condenser. This in turn affects the vacuum maintained in condenser. The cooling the cooling tower performance is affected due to the following factors.

- Insufficient/excess cooling water flow.
- Nozzle choking in the cooling tower basin resulting in uneven distribution of water.
- Algae formation in Cooling tower.

Any impact on cooling tower performance results in higher cooling water temperature going to the condenser. Every $3^{O}C$ increase in the cooling water temperature would impact the condenser vacuum by 1 KPa (0.01Kg/CM_2). This in turn will lead to GHG emission of 7.5 TCO^2/MU.

Steam Turbine Refurbishment

With passage of time, performance of the steam turbine drops, leading to higher steam consumption for maintaining the same power output. A turbine which is operated for 15 years, even after regular overhauls, would still end up operating at a slightly lower efficiency. Every 1% drop in turbine efficiency would result in additional coal consumption of 1.2% causing additional GHG emission of 9 TCO_2/MU.

Thus, it is advisable to go for steam turbine refurbishment if a considerable drop in turbine efficiency is observed.

Other General Recommendations

Boiler Maintenance for Minimising Boiler Tube Failure

Boiler tube leakage one of the major reasons for forced outage. Over stressing, Starvation, Overheating of tubes, Creep life exhaustion, Stress corrosion, Waterside Corrosion, Fireside Erosion, Hydrogen embrittlement, Age embrittlement, Thermal shocks, Improper operating practices, Poor maintenance, Welding defects etc are the major causes for boiler tube failure. The following are the general measures adopted in thermal power station to minimize the boiler tube failures:

- Thorough visual inspection of heating surfaces to identify eroded tube , deformation, swelling, bulging of tubes, etc.
- Shielding of tubes / bends in some identified, highly erosion prone areas to reduce erosion due to gas velocity in second pass.
- Tube thickness survey and thickness mapping in all identified areas. The general practice is to replace the eroded tubes with thickness reduced more than 25% of normal thickness.
- 100% welding inspection to ensure quality weld joints. Involvement of experience IBR welders for pressure parts welding works.
- Emphasis to prevent flue gas / ash erosion. Erosion prone areas are extensively inspected and protected by providing shield / baffles, refractory etc.

Chillers performance improvement
Fire hydrant system improvement
Online performance monitoring system development and implementation

Super Cleaning Of Turbine Oil/Coal mill gear box oil with Electrostatic Liquid cleaner (ELC)
High Concentration Slurry System for Ash Handling
Substituting glass wool insulation for chilled water lines by PUF insulation

Long term Recommendations for Productivity and Performance improvement

Increase in air heater surface
Gas turbine output improvement
High concentration slurry system for ash handling
Coal mill gear-box lube oil electrostatic liquid cleaning
Introduction of super cleaning of turbine oil
Installation/improvement of process controls
Installation of coal drying system
Improvement of atmospheric condensate collections from all gas turbine inlet.
Replace ash removal system with efficient system
Inclusion of second re-heats stage on the steam turbine

5. SELF-ASSESSMENT CHECKLIST

For self-assessment of plant performance, the power plants may compare the parameters in the format below on year to year basis and even with the historic data. The comparison of present data to previous data may bring out the improvement in plant performance. The format below is used by Bureau of Energy Efficiency (BEE) for assessment of plant performance for National Energy Conservation Awards every year.

Table 5.1: (Thermal Power Stations)
"Award Questionnaire"

<table>
<tr><td>1</td><td colspan="2">Name of the Thermal Power Station with complete postal address.</td><td></td></tr>
<tr><td>2</td><td colspan="2">Name of the State/ UT</td><td></td></tr>
<tr><td>3</td><td colspan="2">Type of Thermal Power Station (Please mark ☑)</td><td>☐ Coal / ☐ Lignite / ☐ Liquid Fuel / ☐ Mixed Fuel /
☐ Gas/ ☐ Biomass Fuel Fired/ ☐ Diesel
☐ Combined Cycle Gas Turbines (CCGT)
☐ Open Cycle Gas Turbine (OCGT)
☐ Cogeneration Plants
☐ Diesel Generating Sets
☐ Others (Please specify)</td></tr>
<tr><td>4.</td><td colspan="2">Chief Executive's name & designation with mobile, telephone, fax nos. & e-mail.</td><td></td></tr>
<tr><td>5</td><td colspan="2">Name, designation, address, mobile, telephone, fax nos. & e-mail of Certified Energy Manager appointed or designated under EC Act</td><td></td></tr>
<tr><td>6 (a)</td><td colspan="2">Energy consumption in metric ton of oil equivalent (MTOE) in the current financial year</td><td></td></tr>
<tr><td>6(b)</td><td colspan="2">Whether IS0 50001 Energy Management System Certified (Yes/No) ?
If yes, please attach a copy</td><td></td></tr>
<tr><td rowspan="3">7</td><td colspan="3">Thermal Power Station Design (Coal / Lignite / Liquid Fuel / Mixed Fuel / Gas/ Biomass Fuel / Diesel Fired) Details
(TPS of above type to submit Station Design Details information in this table)</td></tr>
<tr><td>Particulars</td><td rowspan="2">Current completed financial year</td><td rowspan="2">Previous completed financial year</td></tr>
<tr><td>Design details</td></tr>
<tr><td>(a)</td><td>Capacity of the station (MW)</td><td></td><td></td></tr>
</table>

(b)	Average Station Gross Heat Rate on GCV basis of the fuel used, (kcal/kWh)		
(c)	Station Net Heat Rate on GCV basis of the fuel used, (kcal/ kWh)		
(d)	Station Auxiliary Power Consumption (%)		
(e)	Station Secondary Fuel Oil Consumption (ml/kWh)		

8	**Annual Operating Parameters**	**Current completed financial year**	**Previous completed financial year**
8 (a)	Overall Station Generation (Million kWh/year)		
8 (b)	Overall Station PLF (%)		
8 (c)	**Coal/ Lignite/ Biomass Consumption (Million Metric Tonne) (Please specify the name of Fuel used)**		
	Overall Station fuel consumption (Coal/ Lignite/Biomass Consumption) (Million Metric Tonne/ year)		
	Average Gross Calorific Value (GCV)of fuel (kcal/kg)		
	Overall Thermal energy used in the station due to the use of above fuel (Billion kcal/ year)		
8 (d)	**Oil Consumption (kL)(mention FO/ LSHS/ Naptha/HSHS/HSD/other liquid fuel as applicabl**		
	Overall Station Oil Consumption (kL/ year)		
	Average Gross Calorific Value (kcal/Litre or kcal/kg, please specify)		
	Overall Thermal energy used in the station due to the use of above fuel (Billion kcal/ year)		
8 (e)	**Gas Consumption at STP (Million Cubic Meter)**		
	Overall Station Gas Consumption at STP (Million Cubic Meter)		
	Average Gross Calorific Value at STP (kcal/Cubic Meter)		

	Overall Thermal energy used in the station due to the use of above fuel (Billion kcal/ year)		
8 (f)	**<u>Other fuels used (Please specify- Solid Waste/ Liquid Effluent/ Waste gas/ By product gas/ etc.)</u> – Provide data on similar lines of coal / oil / gas, as applicable**.		
	Overall Station fuel Consumption (please specify units______________________)		
	Average Gross Calorific Value (please specify units__________________________)		
	Overall Thermal energy used in the station due to the use of above fuel (Billion kcal/ year)		
8 (g)	**<u>Gross Heat Rate on GCV basis (kcal/ kWh)</u>**		
	Overall Station Gross Heat Rate on GCV basis (kcal/ kWh)		
*** Note: Cogeneration Plants to mention Fuel Quantity used only for power generation**			
8 (h)	**<u>Net Heat Rate on GCV basis (kcal/ kWh)</u>**		
	Overall Station Net Heat Rate on GCV basis (kcal/ kWh)		
8 (i)	**<u>Auxiliary Power Consumption of Gross Energy Generated (%)</u>**		
	Overall Station Auxiliary Power Consumption (%)		

9. Annual Energy savings achieved and investment made due to implementation of Energy Efficiency improvement measures

9	****Annual Energy savings achieved and investment made due to implementation of Energy Efficiency improvement measures**	**Current completed financial year**	**Previous completed financial year**
9 (a)	Electrical Energy Savings (Million kWh/ year)		
9 (b)	Electrical Energy Savings (Lakh Rs/ year)		
9 (c)	Coal / Lignite Savings (Million Tonnes/ year)		
9 (d)	Oil Savings (KL/ year)		
9 (e)	Gas Savings (Million M^3 at STP/year)		

9 (f)	Other fuel savings (Please specify and also mention units)		
9 (g)	Total fuel savings (Million kCal/ year)		
9 (h)	**Total fuel savings (Lakhs Rs/ year)		
9 (i)	Total annual energy savings (Lakhs Rs/ year) 9(b) + 9(h)		
9 (j)	Investment made on energy conservation measures (Lakhs Rs/ year)		

General Parameters for Self-assessment

Apart from improvement in energy performance of a plant, some general parameters also influence the effectiveness of operations and productivity of a plant. The other important parameters that effect the performance and reveal the productivity of power generation are summarized in the format given below. This format would help assess and compare productivity of individual thermal power plant

The data may be compared year to year or any defined interval to assess the improvements made toward better productivity of a plant. The data may also be compared with other plants as it may bring out a clear indication of shortcomings and areas for improvement.

Manpower Assessment	Plant Capacity (MW)	Number of employees		Regular Manpower/ MW	Non Regular Manpower/MW
		Regular	Non-Regular		
	Generation (Million kWh)	Number of employees		Regular Manpower/ Million kWh	Non Regular Manpower/ Million kWh
		Regular	Non-Regular		

Manpower Cost (Executive)	Plant Capacity (MW)	Expenditure on Employees		Regular Expenditure/MW	Non Regular Expenditure/MW
		Regular	Non-Regular		

Manpower Cost (Labour)	Plant Capacity (MW)	Expenditure labour		Regular Expenditure/MW	Non Regular Expenditure/MW
		Regular	Non-Regular		

Assess Your Plant Checklist					
	Yes	**No**			
5S Implemented					
Proper Housekeeping Instructions and Facilities available					
Visual Controls Available					
Work Instructions Available					
Standard Operating Practices (SOPs) designed and available					
Just in Time (JIT) Implemented					
Mistake proofing techniques adopted					
Value stream mapping done (best Layout Options)					
Total Productive Maintenance (TPM) Implemented					
KAIZEN Implemented			No. of KAIZENS Implemented per Month		
Breakdown Maintenance SOPs available			Loss of production due to Breakdown (Hrs/Month)		

Inventory Management Adopted			Loss of production due to non availability of inventory (Hrs/Month)		Inventory carrying cost per MWH of production
Manpower Training need assessment done			No. of such training scheduled per month		
Waste management system available			Ash Disposal system type (wet/dry)	Treated/Un treated	Standard Compliant (YES/NO)
			Waste water disposal system type	Treated/Un treated	Standard Compliant (YES/NO)
Waste Utilisation			Industry Type	Amount Utilised (Tonnes)	

Loss Assessment	No. of possible/apparent points or events	Amount per day/month	Monetary Losses (RS.)
Electrical Wasteful/avoidable Consumption (kWh)			
Steam Leakages (KGs)			
Compressed air Leakages (CFM)			
Machine Breakdown (Numbers)			
Coal (Tonnes)			
Water Leakages (Tonnes or Litres)			
Oil Leakages (Litres)			

6. INTERNET OF THINGS (IOT)

As the world's expendable energy resources deplete and the industrial sector is being asked to deliver more to a growing population, energy efficiency has taken center stage to ensure the longevity of these energy resources, and the Internet of Things can play a crucial role. The emergence of the Internet of Things (IoT) almost certainly is the most important single development in the long evolution of energy management. The insight derived from data collected from new Internet-connected devices can be used to develop new services, enhance productivity and efficiency, improve real-time decision making, solve critical problems, and create new and innovative experiences.

Traditionally, many plants do not have the technology in place to track and measure energy use. On top of that, information on a plant's energy production and consumption is not consolidated into a single place. Energy production and consumption data is often not visible in real time and is not presented at a level granular enough to reflect how changes in behaviour affect energy use. With limited information at their disposal, energy managers can have a difficult time finding the places where energy use could improve. To develop a clear energy-saving strategy and drive energy-saving behaviour, managers need to boost monitoring capabilities and this data needs to be coordinated into a single system.

The Internet of Things (IoT) captures information seamlessly from the sensors and machines that monitor all aspects of the manufacturing process. The information it returns offer greater visibility into actionable data that can result in significant energy savings. Network sensors track energy performance, monitor for leaks and flag any subpar operating situations. Adding Internet of Things sensor technology to a plant allows for real-time alerts that notify energy managers about wasteful situations. Energy managers can then take timely action before their operation loses large amounts of money. Further, the Internet of Things gets the right information to the right expert– whether that person is an onsite manager, an off-site facility specialist, or a third party expert—when they need it, so they can make the best decisions to improve energy performance.

ACRONYMS & ABBREVIATIONS

GHG – Green House Gases

GDP – Gross Domestic Product

IPCC – Intergovernmental Panel on Climate Change

GWP – Global Warming Potential

Gt.CO_2 – Giga Tonne Carbon dioxide

MTOE – Metric Tonne Oil Equivalent

RPS – Renewable Portfolio Standards

TPD – Tonnes per Day

AOX – Absorbable Organic Demand

BOD –Biological Oxygen Demand

COD – Chemical Oxygen Demand

ADT – Air Dried Tonne

GCV – Gross Calorific Value

NCV – Net Calorific Value

TOE – Tonne Oil Equivalent

Mkcals- Million Kilo calories

PLF – Plant Load Factor

TPP – Thermal Power Plant

KWh – Kilo Watt Hour

CFM – Cubic Feet Per Minute

CEP – Condensate Extraction Pump

VFD – Variable Frequency Drive

ESP – Electro Static Precipitator

APC – Auxiliary Power Consumption

HRSG – Heat Recovery Steam Generator

BIBLIOGRAPHY

1. Report 2015 – 16, DIPP, Ministry of Commerce and Industries, GOI
2. BP Statistical Review of World Energy 2016
3. Energy Statistics 2016 by Central Statistics Office, Ministry Of Statistics and Programme Implementation, GOI
4. INCCA GHG Emissions 2007, MoE&F
5. CERC - All India Electricity Statistics, General Review 2014
6. CERC - Review of Performance of Thermal Power Stations 2013-14
7. World Energy Council – World Energy Scenario
8. National Action Plan for Climate Control – GoI
9. http://www.economywatch.com
10. National best practice manual for Thermal Power Plants by CII.
11. Energy audit report of Power Plant Industries by NPC.
12. Base line audit report of Thermal Power Plants by NPC