Reducing Air Pollution in India's Industrial Cluster through Smart Energy Management

Report: **Jharsuguda, Odisha** | Reference number: **M1-32SLP-000047**

Prepared for

Climate and Clean Air Coalition (CCAC)

By

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Table of Contents

List of Annexures

List of Abbreviations

AAQ	Ambient Air Quality
AAS	Atomic Absorption Spectrometry
AERMOD	Atmospheric Dispersion Modeling System (Software)
APEC	Asia Pacific Economic Cooperation
APGENCO	Andhra Pradesh Power Generation Corporation
ASU	Air Separation Unit
AQ-SEMP	Air Quality and Smart Energy Management
BAT	Best Available Technology
BAU	Business as Usual
BHEL	Bharat Heavy Electrical Limited
Ca (OH)2	Calcium Hydroxide
CaCO3	Calcium Carbonate
CaO	Calcium Oxide
CaSO3	Calcium Sulphite
CCS	Carbon Capture and Sequestration
CEA	Central Electricity Authority
CEPI	Comprehensive Environmental Pollution Index
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
CPP	Captive Power Plant
DISCOM	Distribution Company
DVC	Damodar Valley Corporation
EDXRF	Energy Dispersive X-ray Fluorescence
EE	Energy Efficiency
ENCON	Energy Conservation
EP Act	Environmental protection Act
FBC	Fluidized Bed Combustion Boilers
FGD	Flue Gas Desulfurization
GHG	Green House Gas
GLC	Ground Level Concentrations
GRP	Gross Rating Point
GW	Giga Watt
HCL	Hydrochloric Acid
HF	Hydrogen Fluoride
HHV	Higher Heating Value
HPLC/GC Analysis	High Performance Liquid Chromatography and Gas Chromatography
ICP-ES	Inductively Coupled Plasma Emission Spectrometry
IGCC	Integrated Coal Gasification Combined Cycle
IMD	India Meteorological Department
Kg/hr	Kilogram per Hour
kWh	Kilowatt Hour
LP	Low Pressure
MOD	Merit Order Dispatch
MoEFCC	Ministry of Environment Forest and Climate Change

M/S	Meter per Second
MPa	Megapascals
Mtoe	Million Tonnes of carbon Equivalent
MW	Mega Watt
MWh	Mega Watt Hour
NAAQs	National Ambient Air Quality standards
NOx	Nitrogen Oxides
NTPC	National Thermal Power Corporation
OSPCB	Odisha State Pollution Control Board
PAT	Perform, Achieve and Trade
PC boiler	Pulverized Coal Boiler
PCBs	Pollution Control Boards
PM	Particulate Matter
RE	Renewable Energy
SC-FBC	Super Critical Fluidized Bed Combustion Boilers
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
SOx	Sulphur Oxides
SPCB	State Pollution Control Board
Sq.Km	Square Kilometers
tCO2	Tonnes of Carbon Dioxide
TOEM	Technology for Particulate Measurement
T/hr	Tonne per hour
TPP	Thermal Power Plant
USC	Ultra-Supercritical
USC-FBC	Ultra-Super Critical Fluidized Bed Combustion Boilers
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
µg/m3	Microgram per Cubic Meter

1 Executive Summary

In India, there is an urgent need to address rapidly worsening effects of air pollution—on the climate as well as on human health. The situation is serious as out of the 20 most polluted cities in the world, 12 are in India. In response to reduce the worsening effects of air quality, the International Institute for Energy Conservation (IIEC) with funding support from Climate and Clean Air Coalition (CCAC) is working in India to build air quality monitoring and tracking capacity among government, industry, and utility partners, and to demonstrate and deliver cost-effective air pollution reduction strategies in two industrial Indian states—Gujarat and Odisha—through smart management of industrial energy use. These states were selected based on a need assessment as well as the demonstrated interest and commitment of their Pollution Control Boards. The project responded to a large body of evidence that points to industrial and power plant emissions as two of the major sources of air pollution in industrial areas. It also builds on an increasing number of studies demonstrating the effectiveness of smart energy management as a strategy for reducing air pollution in industrialized urban areas.

The project selected Jharsuguda and Ankleshwar Industrial Areas in Odisha and Gujarat States to develop the framework to transform the efforts to mitigate air pollution from industrial areas. The project addressed two key barriers to the adoption of energy management as a solution to the deteriorating air quality in industrial areas: 1) Lack of a demonstrated link between smart energy management and air quality improvement; and 2) the difficulty of financing smart energy solutions, that could help address air pollution in industrialized urban areas. The project established a clear connection between industrial energy use and air quality and showing how highly polluted areas can address air pollution through adoption of energy efficiency measures and through deploying clean energy solutions. This report presents the outcomes of the study conducted in Jharsuguda Industrial Area of Odisha.

Adopted Methodology for the Study

The project focused on improving understanding among government, industrial, and utility partners of the linkages between air quality and utility/industrial energy management, demonstrating the potential for reducing air pollution levels to achieve multiple health-related and economic benefits through smart management of industrial energy use and developing a methodology for clean energy solutions. To demonstrate the Air Quality and Smart Energy Management (AQ-SEMP) Framework, the following methodology has been adopted in Jharsuguda Industrial Area.

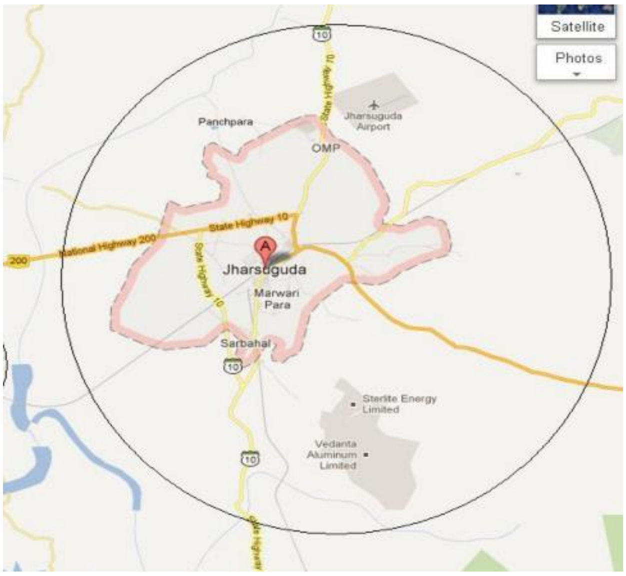


Figure 1: Study Area in Jharsuguda, Odisha

- **Step 1: Defining the Study Area:** The study area in Jharsuguda covers an area of 1961 Sq.Km (25 Kms radius of study area) **(Figure 1)**. The area falls under "North Western Plateau" agro-climatic zone having hot and moist sub-humid environmental conditions **(Figure 2)**. The area experiences extremely high temperatures and moderate humidity conditions during summer conditions and low temperature and normal humidity conditions during winter season. Moderate to high wind speeds in the region enable effective dispersion of pollutants during summer season and due to lower mixing heights, the ventilation coefficient during winter season is generally lower than that of other seasons.

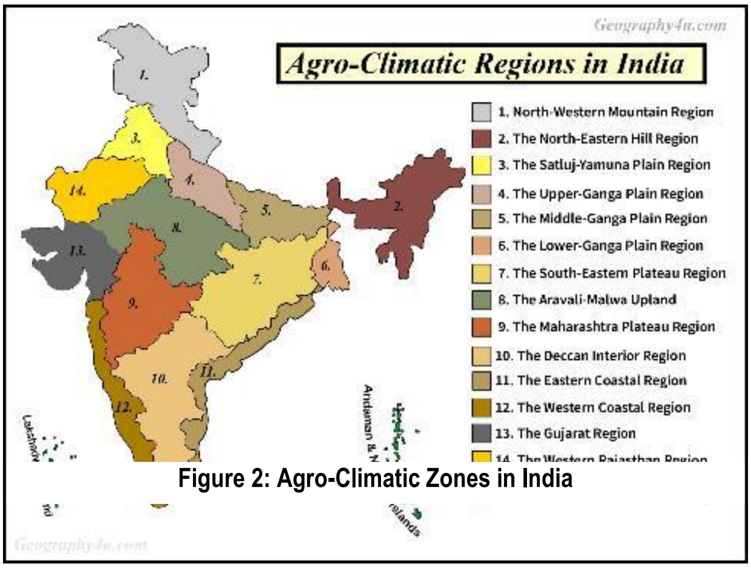


Figure 2: Agro-Climatic Zones in India

- **Step 2: Review of Published Baseline Air Quality in the Study Area** – As a part of the study, published secondary air quality data has been collected from online ambient air quality stations installed by Odisha State Pollution Control Board (OSPCB) at the Brajrajnagar location, and from published EIA reports at following locations such as Lapanga, Bomaloi, Gumkarama, Sripura, Brundamal, Tarikela and Thelkoloi villages. Continuous air quality monitoring data of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 levels are considered for the study.
- **Step 3: Developing Emission Inventories**: An attempt was made to develop baseline emission inventory for all the large to medium scale industrial facilities in the study area based on the data presented in the consent to operate issued for the respective industries, continuous emission monitoring data available with OSPCB, published emission factors data for respective industrial clusters wherever primary data is not available. Various industries such as integrated steel plants, aluminum smelter, steel re-rolling mills, sponge iron units, thermal power plants and captive power plants are covered under this emission inventory study. Since the energy conservation measures (ENCON) are proposed for industries, the emissions from vehicular traffic, fugitive emission from material handling facilities and natural dust emissions during the summer windy conditions are considered under this study. While the industries are required to meet emission standards for particulate matter, emission levels from the industrial source is less significant compared with SO_2 and NOx. Although thermal power plants are required to meet the new thermal power plant emission norms notified by MoEF&CC under EP Act 1986 in 2015, all the CPPs and power plants in the study area are in the process of implementing the SO_2 and NO_X control technologies as per the directions of CPCB and OSPCB. It is assumed that respective industries are meeting the industry specific emission norms issued by CPCB/OSPB as per the consent conditions. Details of the emission inventory in the study area is discussed in the subsequent sections of this report.
- **Step 4: Predicting Ground Level Concentrations (GLCs) for the Baseline Emission Scenario Case**: To establish the possible Ground level Concentration (GLCs) due to release of emissions from current industries, the baseline emission inventory data is adopted. The modelled GLCs are plotted as isopleths to establish the spread and distribution of possible GLC in the study area. The 2nd height GLC's represent the worst-case emission release scenario in the study. Since all the stacks in the study area buoyant dominant plumes, unstable conditions (Stability Class A and B as per Pasqual classification) represent the worst-case meteorological scenario. Since highest mixing heights with

maximum number of unstable meteorological conditions will be experienced in hot and dry climatic conditions, summer season has been considered as a worst-case scenario for air quality modelling.

- **Step 5: Evaluating the Reduction of Emissions due to Proposed Energy Conservation (ENCON) Measures**: Based on the discussion with technical experts revised inventory levels in the study area has been estimated to depict the reduced emission levels due to proposed ENCON measures and cleaner production opportunities. These inputs formed the basis for predicting the post project GLCs.
- **Step 6: Predicting Post ENCON GLCs in the Study Area and Evaluating the Benefits:** The revised estimated emission inventories are adopted to model the GLC to depict the possible reduction in the pollutant GLCs in the study area. Based on the results, an attempt was made to assess the possible benefits due to reduced ambient air pollutant concentration in the study area.

The flow diagram of the model depicting the methodology is presented in Figure-3.

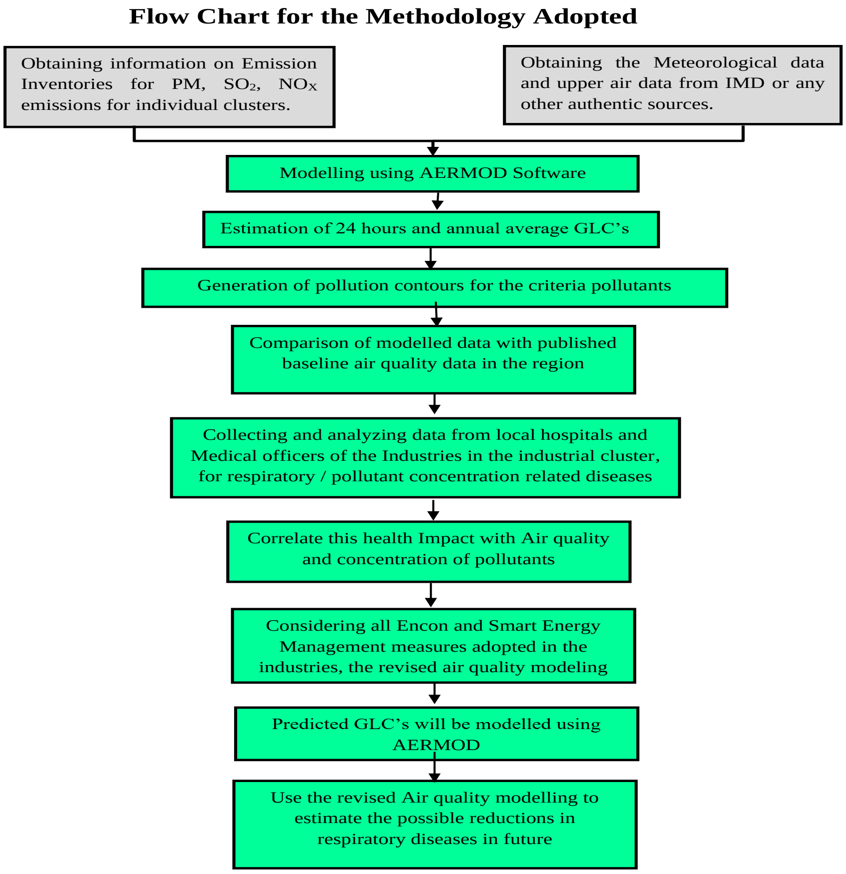


Figure 3: AQ-SEMP Framework Model and Methodology

Summary of Results

Based on the envisaged reduced emission loads, the air quality modelling exercise was undertaken to compare the GLC's of PM_{10}, NOx and SO_2 due to reduced emission levels as against the uncontrolled emission scenario in Jharsuguda Industrial Area. The summary of model results before and after implementation of ENCON measures and clean technology options are presented in **Table 1**. The model output files are presented in **Annexure IV**.

Table 1: Predicted GLC for Baseline Emission Scenario Vs. Post ENCON Scenario

Pollutant	Uncontrolled Emission Scenario		Envisaged Reduced Emission Scenario (Post ENCON Measures & Clean Technology Options)		Maximum Reported Baseline Air Quality Data
	Pollutant load (T/hr)	2nd Height Predicted 24Hrs Avg GLC (µg/m³)	Revised pollutant load (T/hr)	2nd Height Predicted 24Hrs Avg GLC (µg/m³)	
SO_2	50.3	254	4.4	20.2	24
NOx	24.5	123	4.3	26.9	31
PM_{10}	6.1	22.9	2.7	14.1	81.4

Predicted GLC of SO_2: Predicted 2nd height GLC is reported to be in the order of 20.2 µg/m³ as against the uncontrolled emission scenario of 254 µg/m³. A significant reduction in GLCs can be achieved due to implementing various ENCON measures and clean technology options in thermal power plants, integrated iron and steel plants, aluminium smelters, and steel rolling industries. The predicted SO_2 concentrations were compared with that of the authentic published data and presented in **Table 2.**

Predicted GLC of NOx: Predicted 2nd height GLC is reported to be in the order of 26.9 µg/m³ as against the uncontrolled emission scenario of 123 µg/m³. A significant reduction in GLCs can be achieved due to implementing various ENCON measures and clean technology options. The predicted NOx concentrations were compared with that of the authentic published data and presented in **Table 3.**

Predicted GLCs of PM: Predicted 2nd height GLC is reported to be in the order of 14.1 µg/m³ as against the uncontrolled emission scenario of 22.9 µg/m³. The predicted GLC's is compared with reported baseline concentration which is presented in below **Table 4.**

Table 2: Predicted GLCs of SO_2 – Post ENCON Measures and Clean Technology Options

Location	Coordinates	Predicted concentration of SO_2 (µg/m³)		Published Baseline Concentration of SO_2 (µg/m³)
		Uncontrolled Scenario	Reduction Emission Scenario	
Brajrajnagar	182079.74 m E 2416375.25 m N	62.3	2.3	7.2
Lapanga Village	191233.77 m E 2405217.10 m N	52.6	2.0	8.2
Bomaloi Village	192953.47 m E 2402128.17 m N	43.4	1.6	8.0
Gumkarama Village	195297.80 m E 2408625.96 m N	67.1	2.9	8.5
Sripura Village	193955.96 m E 2410889.85 m N	74.4	3.9	8.0
Brundamal village	192154.54 m E 2414605.36 m N	248.7	6.2	8.0
Tarikela village	189041.00 m E 2410328.63 m N	72.8	3.1	7.5
Thelkoloi village	190844.32 m E 409845.99 m N	78.6	3.6	8.2

Table 3: Predicted GLCs of NO_x– Post ENCON Measures and Clean Technology Options

Location	Coordinates	Predicted concentration of NOx (µg/m³)		Published baseline concentration of NOx (µg/m³)
		Uncontrolled Scenario	Reduction emission scenario	
Brajrajnagar	182079.74 m E 2416375.25 m N	35.7	2.3	24.1
Lapanga Village	191233.77 m E 2405217.10 m N	24.8	2.0	29.8
Bomaloi Village	192953.47 m E 2402128.17 m N	23.1	1.8	29.1
Gumkarama Village	195297.80 m E 2408625.96 m N	34.9	2.7	25.2
Sripura Village	193955.96 m E 2410889.85 m N	38.4	3.4	28.8
Brundamal village	192154.54 m E 2414605.36 m N	122.5	4.4	26.3
Tarikela village	189041.00 m E 2410328.63 m N	41.7	3.1	24.9
Thelkoloi village	190844.32 m E 2409845.99 m N	44.5	3.3	29.8

Table 4: Predicted GLCs of PM. – Post ENCON Measures and Clean Technology Option

Location	Coordinates	Predicted Concentration of PM (µg/m³)		Published Baseline Concentration of PM (µg/m³)
		Uncontrolled Scenario	Reduction Emission Scenario	
Brajrajnagar	182079.74 m E 2416375.25 m N	3.1	1.4	141
Lapanga Village	191233.77 m E 2405217.10 m N	2.4	1.5	86.6
Bomaloi Village	192953.47 m E 2402128.17 m N	2.0	0.8	81.7
Gumkarama Village	195297.80 m E 2408625.96 m N	3.6	1.8	80.4
Sripura Village	193955.96 m E 2410889.85 m N	4.5	2.0	84
Brundamal village	192154.54 m E 2414605.36 m N	6.5	3.5	83.4
Tarikela village	189041.00 m E 2410328.63 m N	4.7	2.2	75.4
Thelkoloi village	190844.32 m E 2409845.99 m N	4.6	2.7	78.8

The detailed analysis and the design of the framework are presented in the sections below.

2 INTRODUCTION

Rapid economic growth has brought many benefits to India, but at a cost to human health and the environment. Growth in industrial production, construction of buildings, roads and highways and urban transport has led to poor air quality in many Indian cities and industrial clusters. There is an urgent need to address the rapidly worsening effects of air pollution—on both human health and the global climate—by implementing measures to improve air quality and reduce greenhouse gas (GHG) emissions in India's industrial clusters.

Smart energy management, which has proven to be an effective strategy for reducing air pollution in both developed and transitioning economies, holds significant potential to reduce emissions from industries and power plants—two of the major sources of air pollution in many of India's urban areas. The project provides a critical proof of concept: That developing country cities can achieve significant, measurable reductions in air pollution and greenhouse gas emissions through investing in smart energy management. Achieving this goal, however, requires addressing two key challenges: 1) Lack of a demonstrated link between smart energy management and air quality improvements in India; and 2) the need to scale up development, financing, and implementation of smart energy solutions, including renewable energy (RE) and energy efficiency (EE), that can help address air pollution in industrialized urban areas by offsetting fossil fuel use for diesel and coal-fired electricity generation.

Project Objectives

The project tends to transform efforts to mitigate air pollution from India's industrial and power sectors by: 1) improving understanding among government, industry, and utility partners of the linkages between air quality and utility/industrial energy management; 2) demonstrating the potential for reducing air pollution levels to achieve multiple health-related and economic benefits through smart management; and 3) developing and testing an approach for providing clean energy solutions. The project activities have been implemented in industrialized areas of Gujarat and Odisha States, where air pollution is a critical concern. The project has support from both State Governments, indicating their strong interest in the project.

In view of the implementation of various energy conservation (ENCON) strategies and cleaner production initiatives, IIEC intended to develop a technical report to demonstrate the advantages of implementing ENCON measures and cleaner production initiatives to reduce the targeted emissions from the respective industrial clusters. For the study, two such industrial clusters located at Jharsuguda in Odisha and Ankleshwar in Gujarat were selected. These are among 44 critically polluted industrial clusters as identified by the Central Pollution Control Board (CPCB) based on Comprehensive Environment Pollution (CEPI) Index. The implementation of ENCON measures and clean technology options in industrial clusters will exhibit multiple advantages and benefits such as reduced fossil fuel consumption and thereby conservation of natural resources for future generations. Reduction in greenhouse gas and criteria pollutant emissions such as PM, SO_2 and NOx will help to improve the regional air quality and reduced the health effect due to air pollution in the region.

The project tends to predict possible reduction in ground level concentration of above-mentioned criteria pollutants due to adoption of ENCON measures and cleaner production initiatives in various sectors in the Jharsuguda Region. This report presents the air quality modelling results for current baseline emissions scenario and post project implementation scenario.

3 Project Approach and Summary of Activities

The project started in February 2019 with gathering the understanding from the concerned stakeholders on the subject matter identifying linkages between the industrial air pollution and its mitigation through introduction of smart energy management techniques, was completed. Several meetings with the Odisha and Gujarat State Pollution Control Board were organized. The meetings focused on presenting the project objectives and seeking acceptance from the State Pollution Control Board in helping the project team in implementation of project activities. Jharsuguda Industrial Area in Odisha and Ankaleshwar Industrial Area in Gujarat were mutually selected to conduct project activities.

Consecutive to the same a desk-based literature review was carried out understanding the critical important industries present in the identified industrial areas and developing questionnaire to collect air pollution relevant data from the industries. Majorly it was identified that Thermal power Plants, Iron and Steel Industry, Aluminum industry and Mining Industries are present in the Jharsuguda Industrial areas and Chemical Industries mainly Pharmaceutical, Pesticide and Dye Intermediate Industries in Ankaieshwar industrial areas. The questionnaires were peer reviewed by the state pollution control board.

Followed by this outreach activities were conducted to mobilize the support of industries, utilities, experts, industry associations, donor agencies, financing institutions and the staff at Pollution Control Boards in both Odisha and Gujarat States.

Launch workshops were also organized in both the states wherein stakeholders such as industry representatives, health department representatives and government stakeholders were present. The main objective of the launch workshops was to generate awareness amongst the local stakeholder on the project activities, request the information required from them and discuss the issues in implementation.

After the launch workshops, surveys of select industries were conducted to understand the critical areas responsible for emissions and developed the methodology to performs emission load analysis for the two selected industrial areas. The emission data was analysed and the current emission load and pollution levels for Jharsuguda were calculated. The sections below discuss about the project findings and emission data analysis. Also, the report compares the business as usual and post implementation scenarios for Air Quality Management with the help of Smart Energy Management.

Activity Summary

Activity	Description of Work Undertaken During Reporting Period	Deliverables	Delivery Date	Status of Activity (Completed/ On-Going/ Delayed)	Comments - Brief Description of Implementing Challenges, Strategy / Actions which have been Adopted to Address the Challenges and Planned Actions to Mitigate any Identified Risks.
Activity 1: Improving the Understanding of Stakeholders	Coordinated and convened launch events and workshops with key partners present in Odisha and Gujarat including state pollution control board, health departments, department of industries etc. Develop a detailed work plan and collection pollution data, energy data and health data	1. Detailed work-plan including timeline for carrying workshop activities 2. Power point presentation delivered at workshop 3. Workshop report including agenda attendees list	15^{th} July 2019	Completed	The main challenge experienced while implementing the project activity 1 was to collaborate with the industrial organizations and convince them to provide required air pollution data. To overcome the barrier, the project team organized meetings with the State Pollution Control Boards (SPCBs) and requested their intervention on the same. Understanding the need for the study, the SPCBs collaborated with the project team. The project is now being implemented in the selected industrial areas with the help and support provided by SPCBs. The data from the industry organizations is being collected and routed through SPCBs.
Activity 2: Collection and Analysis of Data	Collection of available data from SPCBs, industry associations and utilities	1. Current scenario of extent/ source of air pollution and energy consumption in Odisha and Gujarat	July 2019	Completed	The main challenges faced by the project team, were the collection of data. To mitigate this the project team adopted the approach of taking the help of the authority of the Regional Offices at the state pollution control boards to collect data from the utilities and industrial associations.
Activity 2: Development of Detailed Methodologies	Develop detailed methodology for air quality assessment and impact attribution, in consultation with state PCBs and other stakeholders	1. Air quality and Health Impact Assessment	Aug 2020	Completed	The project Team is deploying highly accurate modelling software to generate the air quality models and patterns which would further be utilized to plot against the health indices and respiratory disease indices from these two states to establish a correlation

Activity	Description of Work Undertaken During Reporting Period	Deliverables	Delivery Date	Status of Activity (Completed/ On-Going/ Delayed)	Comments - Brief Description of Implementing Challenges, Strategy / Actions which have been Adopted to Address the Challenges and Planned Actions to Mitigate any Identified Risks.
					between the air quality and health. Major challenge is the inconsistent data.
Activity 3: Final Reporting	Submission of final reports to CCAC and stakeholders. Showcase Smart Energy Management pollution reduction potential and its corelated health impact benefits.	1. Completed CCAC Demonstrating Impacts reporting database questionnaire and submission of Annual Report 2. Final Report to Stakeholders	Aug 2020	Jharsuguda – Completed Ankleshwar – Ongoing	The project team is currently running Software modelling to estimate reduction potential of the EE measures to showcase BAU vs After EE adoption scenarios and corelated health benefits.

4 METHODOLOGY OF THE STUDY

In order to meet the specific objectives in the study, the following methodology has been adopted.

- **Step 1: Defining the Study Area:** The study area is confined to the Jharsuguda industrial area covering an area of 1961 Sq.Km (25 Kms radius of study area) **(Figure 5)**. The area falls under agro-climatic zone of "North Western Plateau" with hot and moist sub-humid environmental conditions **(Figure 4)**. The area experiences very high temperatures and moderate humidity conditions during summer conditions and low temperature and normal humidity conditions during winter season. Moderate to high wind speeds in the region enable effective dispersion of pollutants during summer season and due to lower mixing heights, the ventilation coefficient during winter season is generally lower than that of other seasons. Detailed meteorological scenario in the study area is presented in the subsequent sub-sections of the study area.

Figure 4: Agro-Climatic Zones of India

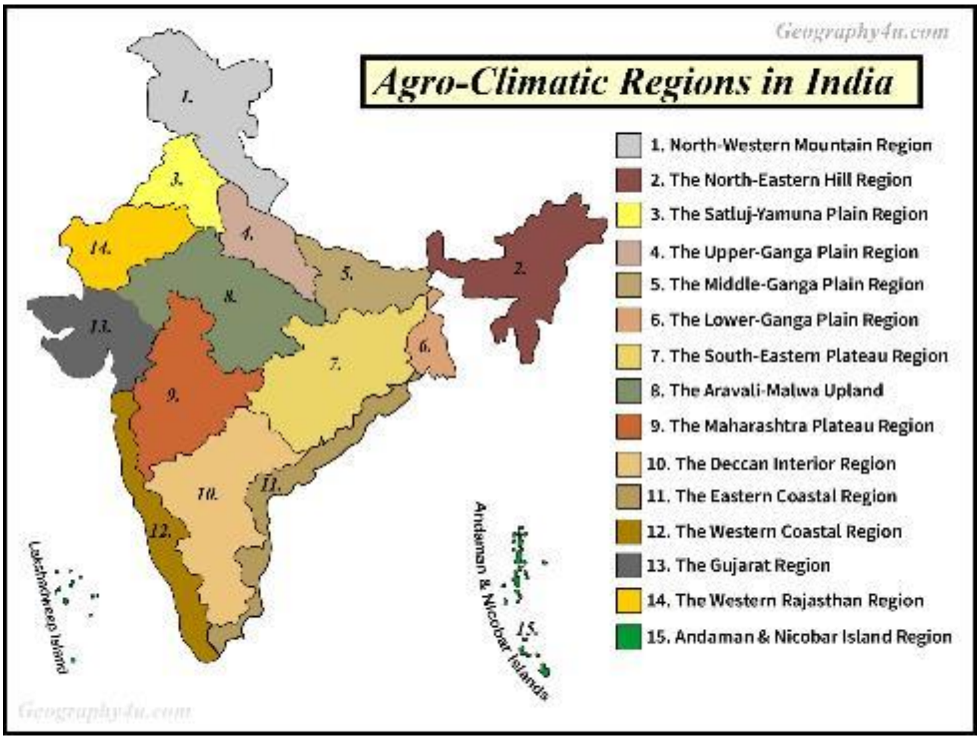


Figure 5: Study Area (Jharsuguda Industrial Area)

- **Step 2: Review of Published Baseline Air Quality in the Study Area** – As a part of the study, published secondary air quality data has been collected from online ambient air quality stations installed by Odisha State Pollution Control Board (OSPCB) at the Brajrajnagar location, and from published EIA reports at following locations such as Lapanga, Bomaloi, Gumkarama, Sripura, Brundamal, Tarikela and Thelkoloi villages. Continuous air quality monitoring data of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 levels are considered for the study.

- **Step 3: Developing Emission Inventories**: An attempt was made to develop baseline emission inventory data for all the large to medium scale industrial facilities in the study area based on the data presented in the consent to operate issued for the respective industries, continuous emission monitoring data available with OSPCB, published emission factors data for respective industrial clusters wherever primary data is not available. Various industries such as integrated steel plants, aluminum smelter, steel rerolling mills, sponge iron units, thermal power plants and captive power plants are covered under this emission inventory study. Since the proposed ENCON measures aim at industrial operations, emissions from vehicular traffic, fugitive emission from material handling facilities and natural dust emissions during the summer windy conditions are considered under this study. While the industries are required to meet emission standards for particulate matter, PM emission levels from the industrial source is less significant compared with SO_2 and NO_x. Although thermal power plants are required to meet the new thermal power plant emission norms notified by MoEF&CC under EP Act 1986 in 2015, all the CPPs and power plants in the study area are in the process of implementing the SO_2 and NO_X control technologies as per the directions of CPCB and OSPCB. It is assumed that respective industries are meeting the industry specific emission norms issued by CPCB/OSPB as per the consent conditions. Details of the emission inventory in the study area is discussed in the subsequent sections of this report.

- **Step 4: Predicting Ground Level Concentrations (GLCs) for the Baseline Emission Scenario Case**: In order to establish the possible Ground level Concentration (GLCs) due to release of emissions from local industries, the baseline emission inventory data is adopted. The modelled GLCs are plotted as isopleths to establish the spread and distribution of possible GLC in the study area. The 2nd height GLC's represent the worst-case emission release scenario. Since all the stacks in the study area buoyant dominant plumes, unstable conditions (Stability Class A and B as per Pasqual classification) represent the worst-case meteorological scenario. Since highest mixing heights with maximum number of unstable meteorological conditions will be experienced in hot and dry climatic conditions, summer season has been considered as a worst-case scenario for air quality modelling. Due to lower mixing heights during the winter season coupled with taller plume rise of the buoyant dominant plumes, the possibility of 24-hours average GLC during the winter season in the study area will be relatively lower than that of summer conditions. Details of modelled data are discussed in the subsequent sections.

- **Step 5: Evaluating the Reduction of Emissions due to Proposed Energy Conservation (ENCON) Measures**: Based on the discussion with technical experts revised inventory levels in the study area has been estimated to depict the reduced emission levels due to proposed ENCON measures and cleaner production opportunities. These inputs formed the basis for predicting the post project GLCs.

- **Step 6: Predicting Post ENCON GLCs in the Study Area and Evaluating the Benefits:** The revised estimated emission inventories are adopted to model the GLC to depict the possible reduction in the pollutant GLCs in the study area. Based on the results, an attempt was made to assess the possible benefits due to reduced ambient air pollutant concentration in the study area.

5 Published Air Quality Data for the Study

Based on the long-term published air quality data and latest EIA study reports made available on the MoEF&CC website for the region **(Table 5 and Table 6)**. It can be noted that the annual average particulate matter concentration (PM_{10} and $PM_{2.5}$) in the study area has exceeded the NAAQs. This could be attributed to fugitive dust emissions from mining operations, transportation of minerals, road dust emissions and natural wind-borne dust during high wind condition in dry weather days. The 24-hours and annual average concentrations of SO_2 and NO_2 are reported to be well within the stipulated NAAQs. Relatively NO_2 levels are higher than that of SO_2 levels due to longer resident time in the atmosphere and also other emission sources such as vehicular emissions and fertilizer decomposition in the agriculture areas. Lower SO_2 levels in the area also depict lesser impact from thermal power plants due to taller plume rise and effective dispersion of pollutants in the region. Based on the information presented in some of the EIA reports published on MOEF&CC website[1], it is noted that the ozone levels in the area are in the range of 10 to 30 µg/m³, which are far below the stipulated NAAQ. This aspect also confirms that impact of VOC emissions on the formation of secondary ozone in the presence of NO_x compounds is insignificant.

Table 5: Online Continuous AAQ Data for the Year 2018 (CPCB)[2]

Pollutant Range	R.O. Building Cox Colony			TRL Colony, M/s. TRL Krosaki Refractories Ltd. PO: Bhepahar		
	Minim (24-Hours Avg - µg/m³)	Maximum (24-Hours Avg - µg/m³)	Annual (µg/m³)	Minim (24-Hours Avg - µg/m³)	Maximum (24-Hours Avg - µg/m³)	Annual (µg/m³)
PM_{10}	71	153	106	80	139	109
$PM_{2.5}$	32	103	56	35	86	58
SO_2	5	24	10	4	11	7
NO_2	11	31	18	10	20	13

Table 6: Ambient Air Quality Data at the Settlements (24-Hours Avg - µg/m³)[3]

Location	Coordinates	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_x (µg/m³)	Ozone (µg/m³)
Brajrajnagar	182079.74 m E 2416375.25 m N	141	70.3	7.2	24.1	14.3
Lapanga Village	191233.77 m E 2405217.10 m N	86.6	45.1	8.2	29.8	23.6
Bomaloi Village	192953.47 m E 2402128.17 m N	81.7	43.5	8.0	29.1	<10

[1] Environmental Impact Assessment Report *of" Expansion of Integrated Iron & Steel Plant from 3.0 to 5.5 MTPA Capacity", BHUSHAN POWER & STEEL LIMITED, Sambalpur district, Odisha*

[2] http://www.cpcbenvis.nic.in/airpollution/2018/National%20Ambient%20Air%20Quality%20Monitoring%20Programme%20(NAMP)%20Data%20Year%202018%20CPCB%20ENVIS.pdf

[3] Environmental Impact Assessment Report *of" Expansion of Integrated Iron & Steel Plant from 3.0 to 5.5 MTPA Capacity", BHUSHAN POWER & STEEL LIMITED, Sambalpur district, Odisha*

Gumkarama Village	195297.80 m E 2408625.96 m N	80.4	42.1	8.5	25.2	<10
Sripura Village	193955.96 m E 2410889.85 m N	84	43.5	8.0	28.8	<10
Brundamal village	192154.54 m E 2414605.36 m N	83.4	44.5	8.0	26.3	<10
Tarikela village	189041.00 m E 2410328.63 m N	75.4	40	7.5	24.9	<10
Thelkoloi village	190844.32 m E 2409845.99 m N	78.8	44.5	8.2	29.8	21.7

6 Industrial Emission Inventory – Baseline Scenario

The Economy of the Jharsuguda District is solely industrial. Due to the availability of economically important minerals, especially coal, many small-scale & large-scale industries have found a conducive environment for their growth and development. Jharsuguda is an industrial hub of the state consisting mainly of the metallurgical industries. It is also popularly known as the powerhouse of Odisha due to the plentiful industry mostly thermal power plants. The list of major industries in the region considered for the study is presented in **Table 7** and shown in a satellite google imagery (**Figure 6**).

A total of 18 major industries in the study area along with captive power plants and independent base load thermal power plants are considered for the study. The stack physical characteristics details were extracted from the Odisha State Pollution Control Board server. In the case of data gaps, the stack details from the other plants (with the same capacity) were considered. The uncontrolled emissions were estimated based on the type of fuel and consumption details. For SO_2 emissions, the sulphur content of 0.6 % is considered which is most ideal for Indian coals. For NO_x and PM_{10}, the uncontrolled emission standard of 600 mg/Nm^3 (for power plant boilers before installed prior to 2003,) and 100 mg/Nm^3 respectively are considered for emissions estimation. The total estimated emissions from all the selected industries are in the order of 50.3 T/hr for SO_2, 24.5 T/hr for NO_x and 6.1 T/hr for PM respectively. About 101 stacks as a point-source emission are identified for detailed air quality modelling.

Emission factors adopted for estimating the emissions from the designated stacks are presented in **Annexure-IA**. Out of the total 50.3 TPH of SO_2 emissions from the industries in the study area, almost 95% of the SO_2 emissions are released from thermal power plants and captive power plants, whereas thermal power plants contributed about 92% of the total 24.5 TPH of NO_x emissions. Detailed emission inventory data is presented in **Annexure-IB** and **Annexure-IC**. Thermal power plant contributed only 33% of total PM emissions. It is noted from the above data that major emissions are envisaged from thermal power plant. Since the dispersion of emissions and GLCs are dependent on stack height, an attempt was made to estimate the emission release from various range of stack heights (**Table 4**). It can be inferred that 50% of SO_2 and NO_x emissions are released from stacks having height less than 150m, which contributes maximum GLCs due to lower stack height.

Table 7: List of Major Industries in Jharsuguda Industrial Area

S. N.	Industry Name	Type of Facility
1	Aditya Aluminium, Lapanga, Sambalpur	Aluminum Smelter with Captive power plant
2	Hindalco Industries Ltd, Smelter unit, Hirakud, Sambalpur	Aluminum Smelter
3	Hindalco Industries Ltd, Power Plant, Hirakud, Sambalpur	Thermal Power Plant
4	Hindalco Industries Ltd- FRP, Hirakud, Sambalpur	Rolling Mill
5	Bhushan Power and Steel Ltd, Thelkoloi, Sambaldpur	Iron & Steel with captive power plant

6	Aryan Ispat & Power Ltd, Bomaloi, Sambalpur	Iron & Steel with captive power plant
7	Shyam Metallics and Energy Limited, Pandloi, Sambalpur	Iron & Steel with captive power plant
8	Maa Samaleswari Industries (P) Ltd, Lapanga, Sambalpur	Iron & Steel
9	Viral Steel and Energy Limited, Gurupali, Rengali, Sambalpur	Iron & Steel with captive power plant
10	IB Thermal Power Station, OPGC (Ltd)	Thermal Power Plant
11	Seven Star Steels Ltd	Sponge Iron Plant, SMS and captive Power plant
12	Thakur Prasad Sao & Sons Pvt Ltd,	Sponge Iron Plant with captive power plant
13	Vedanta Ltd (TPP)	Thermal Power Plant
14	Vedanta Ltd (Smelter)	Aluminium Smelter
15	Vedanta Ltd (CPP)	Captive Power Plant
16	Ultratech Cement Ltd	Cement
17	SMC Power Generation Ltd	Captive Power Plant with captive power plant
18	TRL Krosaki Refractories Limited	Ceramics and Refractories

Table 8: Typical Emissions Release from Various Sources

Stack group (by height)	No. of Stacks (with no data gaps)	SO_2 emissions (T/hr)	NO_X emissions (T/hr)
< 50 m	35	10.7	5.3
50 - 150 m	54	5.7	2.3
150 - 275 m	12	33.9	17.0

Figure 6: Satellite Google Imagery Showing the Major Industries in Jharsuguda Industrial Area

7 Predicting Ground Level Concentrations (GLCs) for the Baseline Emission Scenario Case

The primary objective of the air quality modelling is to predict the most likely possible ground-level concentrations due to combined emissions from all possible combustion sources, captive power generation in the study area. US-EPA approved AERMOD is adopted to model the regional level dispersion pattern. The overview of air quality modelling and prediction of ground-level concentrations for the designated pollutants is shown in the block diagram below. The basic inputs required for the air quality modelling are emission source details (emission rate and stack physical characteristics including stack height, stack tip diameter, flue gas velocity, flue gas temperature), an hourly meteorological parameter such as wind speed, wind direction, ambient temperature and mixing heights. The site-specific online meteorological information adopted from March 2019 to May 2019(ref)[4] was adopted for air quality modelling exercise. The mixing height data (Mixing Height Atlas of India) published by the Indian Meteorological Department was adopted. The model output as 24-hours average ground level concentration was plotted in the form of Iso-pleths (also known as iso-concentration contours).

7.1 Meteorological Data

Increased turbulence in the atmosphere due to higher wind speeds and solar insolation, the pollutants will be subjected to rapid dispersion and dilution in the atmosphere. Mixing heights also play an important role, which can limit the vertical mixing potential of the atmosphere. In the event the plume rise is higher than the mixing height, then the pollutants will get trapped in the stable upper layer. In the event the plume rise is lower than that of the mixing height (afternoon and high solar insolation conditions), pollutants will get dispersed in the lower zone and would contribute a rise in ground-level concentrations. Since the plume rise of fossil fuel combustion sources such as boilers, power plant stacks, etc. experience higher buoyancy and hence most of the period of the plume penetrate the mixing height, thereby leading to lower ground level concentrations. The hourly meteorological data of the summer season (March 2019 to May 2019) was considered for modelling given in **Annexure II**. The wind rose diagrams from the data provided for the summer season (March 2019 to May 2019) are presented below in **Figure 7**. It is observed that the wind direction during the summer season (March 2019 to May 2019) predominantly blew from South West, West and South East with an average wind speed of 2.95m/s. The mixing height data pertaining to the region was collected from the Atlas of Hourly Mixing Height published by IMD New Delhi. The summer season 24 hr average mixing height variation is plotted and shown in **Figure 8**.

[4] *https://www.worldweatheronline.com/jharsuguda-weather-history/orissa/in.aspx*

Figure 7: Wind Rose Diagram for Summer Season

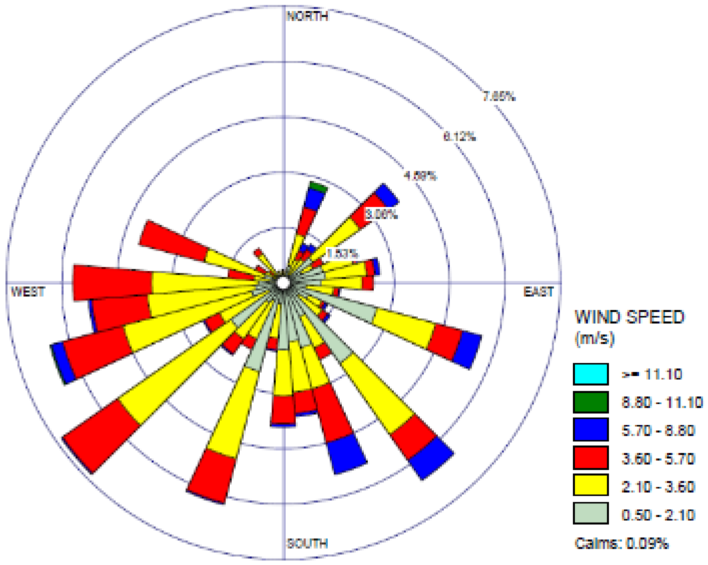
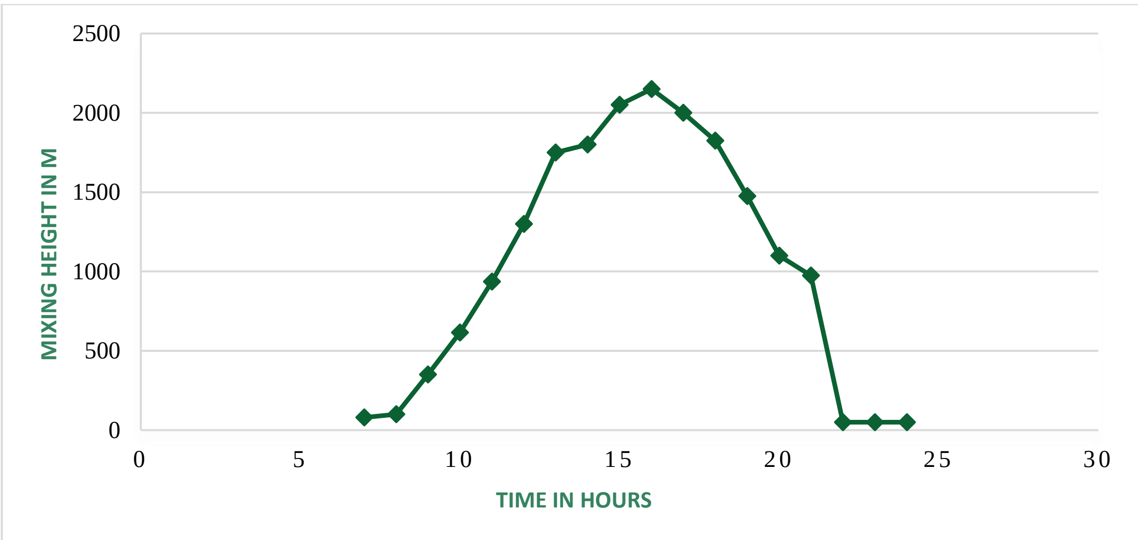


Figure 8: Hourly Variation of Mixing Height



7.2 Local and Regional Geographical Features

Undulating and valley type terrain experiences varied wind patterns and speeds, which can have a major impact on the pollutant plume travel in the atmosphere. In the current scenario, the study area is considered to be a plain land without any undulations. The area depicts a typical rural background.

7.3 The Source Parameters

Emissions from the sources are generally categorized as buoyant dominant and momentum dominant plumes based on the amount of thermal flux that is discharged into the atmosphere. Higher the thermal flux (higher gas volumes coupled with high stack gas temperatures) will experience large plume rise. In general, the thermal power plant stack gas will experience the highest plume rise in the order of 500 to 1000m during stable and normal wind speeds. Similarly, all industrial stacks connected to boilers and furnaces will also experience higher plume rise. Since thermal flux depends on the flue gas mass flow rate, flue gas temperature, stack tip diameter, and stack gas velocity are critical inputs to the air dispersion modelling.

7.4 Predicted GLC for Baseline Emission Scenario (Uncontrolled Emissions)

Air quality modelling exercise was undertaken to establish the most likely possible ground level concentration of PM_{10}, NO_x and SO_2 due to the combustion activities in the industries located in the Jharsuguda region. The predicted concentration of all three pollutants concerning the summer season (March 2019 to May 2019) is depicted in **Figures 9 to 11**. The summary of model results is presented in **Table 9**. The model output files are presented in **Annexure III**.

Table 9: Predicted GLC for Baseline Emission Scenario

Pollutant	2nd Height Predicted 24Hrs Avg GLC ($\mu g/m^3$)	Maximum Reported Baseline Air Quality Data	Location of Occurrence of 2nd Height Predicted GLC (UTM)
SO_2	254	24	192191.00m E, 2414300.00m N
NOx	123	31	192191.00m E, 2414300.00m N
PM_{10}	22.9	81.4	197171.00m E, 2414300.00m N

Predicted GLC of SO_2: Predicted 2nd height GLC is reported to be in the order of 254 $\mu g/m^3$ and the same was reported to be in the range of 40 to 80 $\mu g/m^3$ at various settlements in the study area. It can be noted that there is a large variation between predicted GLC and actual reported baseline data. This can be attributed due to possible chemical transformation of SO_2 into the sulphates in the presence of alkali matter moisture in the ambient air. Considering the half-life period of SO_2 in the atmosphere in the order of 13 to 16 hours, the predicted GLC with chemical transformation can be estimated as 25 to 60 $\mu g/m^3$, which corroborates with the actual baseline data reported. The predicted SO_2 concentrations were compared with that of the authentic published data and presented in **Table 10**.

Predicted GLC of NO_x: Predicted 2nd height GLC is reported to be in the order of 123 $\mu g/m^3$, whereas the same was reported to be in the range of 23 to 45 $\mu g/m^3$, which is at par with reported baseline levels of 23 to 35 $\mu g/m^3$. Similar to SO_2, NO_x will undergo photochemical reaction and also chemical transformation into salts of nitrates. The half-life of NO_x in the atmosphere is generally in the order of 18 to 20 hours and the corresponding corrected predicted GLC will be in the range of 20 to 35 $\mu g/m^3$, which is at par with reported baseline concentrations. The same is presented in **Table 11**.

Predicted GLCs of PM: The 2nd height 24 hrs peak predicted PM_{10} concentration is estimated as 23 µg/m^3 as against the reported baseline level of 80 to 153 µg/m^3. This aspect indicates that the existing industries are contributing to about 15 to 30% of the background PM levels. Although, all industries are adopting pollution control systems as per consent management, the overall PM emissions to the tune of 6 TPD from the existing industries are contributing considerable GLCs to the baseline air quality scenario. The comparison table is presented in **Table 12**.

Table 10: Predicted GLCs of SO_2 - Baseline Emission Scenario

Location	Coordinates	Predicted concentration of SO_2 (µg/m^3)	Published baseline concentration of SO_2 (µg/m^3)
Brajrajnagar	182079.74 m E 2416375.25 m N	62.3	7.2
Lapanga Village	191233.77 m E 2405217.10 m N	52.6	8.2
Bomaloi Village	192953.47 m E 2402128.17 m N	43.4	8.0
Gumkarama Village	195297.80 m E 2408625.96 m N	67.1	8.5
Sripura Village	193955.96 m E 2410889.85 m N	74.4	8.0
Brundamal village	192154.54 m E 2414605.36 m N	248.7	8.0
Tarikela village	189041.00 m E 2410328.63 m N	72.8	7.5
Thelkoloi village	190844.32 m E 2409845.99 m N	78.6	8.2

Table 11: Predicted GLCs of NO_x - Baseline Emission Scenario

Location	Coordinates	Predicted concentration of NO_x (µg/m^3)	Published baseline concentration of NO_x (µg/m^3)
Brajrajnagar	182079.74 m E 2416375.25 m N	35.7	24.1
Lapanga Village	191233.77 m E 2405217.10 m N	24.8	29.8
Bomaloi Village	192953.47 m E 2402128.17 m N	23.1	29.1
Gumkarama Village	195297.80 m E 2408625.96 m N	34.9	25.2
Sripura Village	193955.96 m E 2410889.85 m N	38.4	28.8
Brundamal village	192154.54 m E 2414605.36 m N	122.5	26.3
Tarikela village	189041.00 m E 2410328.63 m N	41.7	24.9
Thelkoloi village	190844.32 m E 2409845.99 m N	44.5	29.8

Table 12: Predicted GLCs of PM10 - Baseline Emission Scenario

Location	Coordinates	Predicted concentration of PM10 (µg/m³)	Published baseline concentration of PM10 (µg/m³)
Lapanga Village	191233.77 m E 2405217.10 m N	2.4	86.6
Bomaloi Village	192953.47 m E 2402128.17 m N	2.0	81.7
Gumkarama Village	195297.80 m E 2408625.96 m N	3.6	80.4
Sripura Village	193955.96 m E 2410889.85 m N	4.5	84
Brundamal village	192154.54 m E 2414605.36 m N	6.5	83.4
Tarikela village	189041.00 m E 2410328.63 m N	4.7	75.4
Thelkoloi village	190844.32 m E 2409845.99 m N	4.6	78.8

Figure 9: Isopleths Showing Predicted GLC of SO_2 (Base Line Emission Scenario)

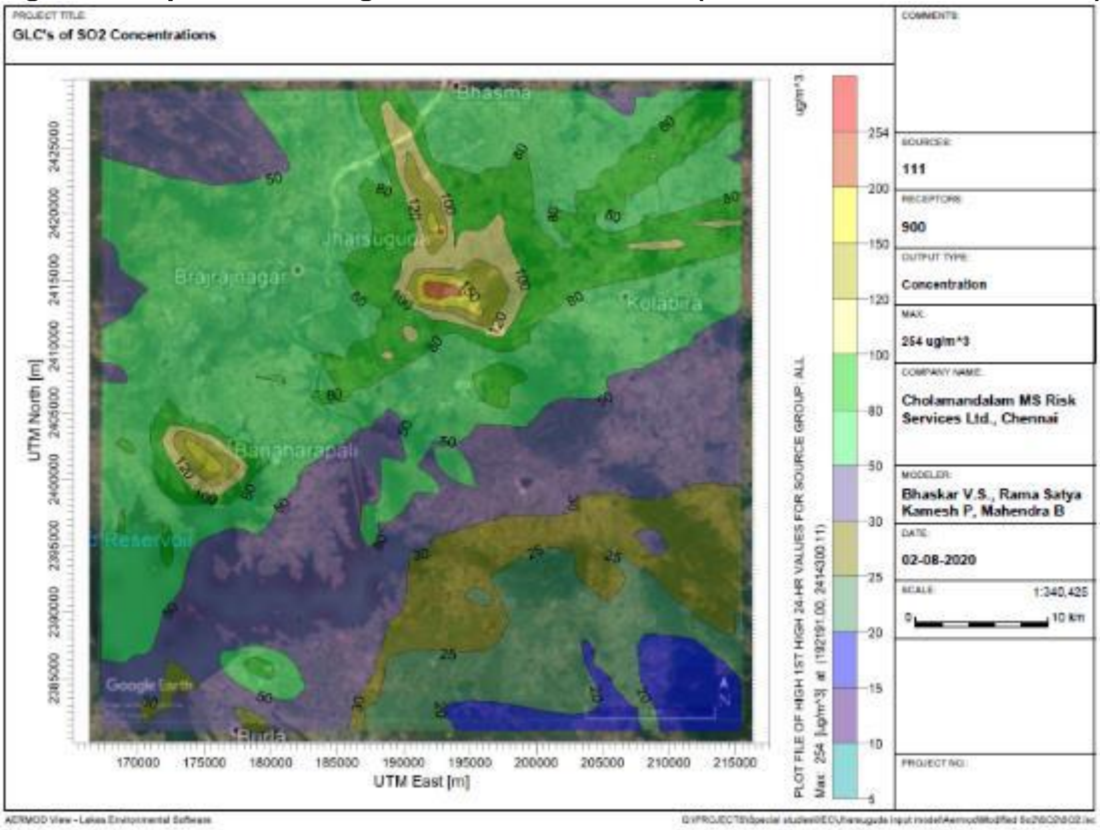


Figure 10: Isopleths Showing Predicted GLC of NO_x (Base Line Emission Scenario)

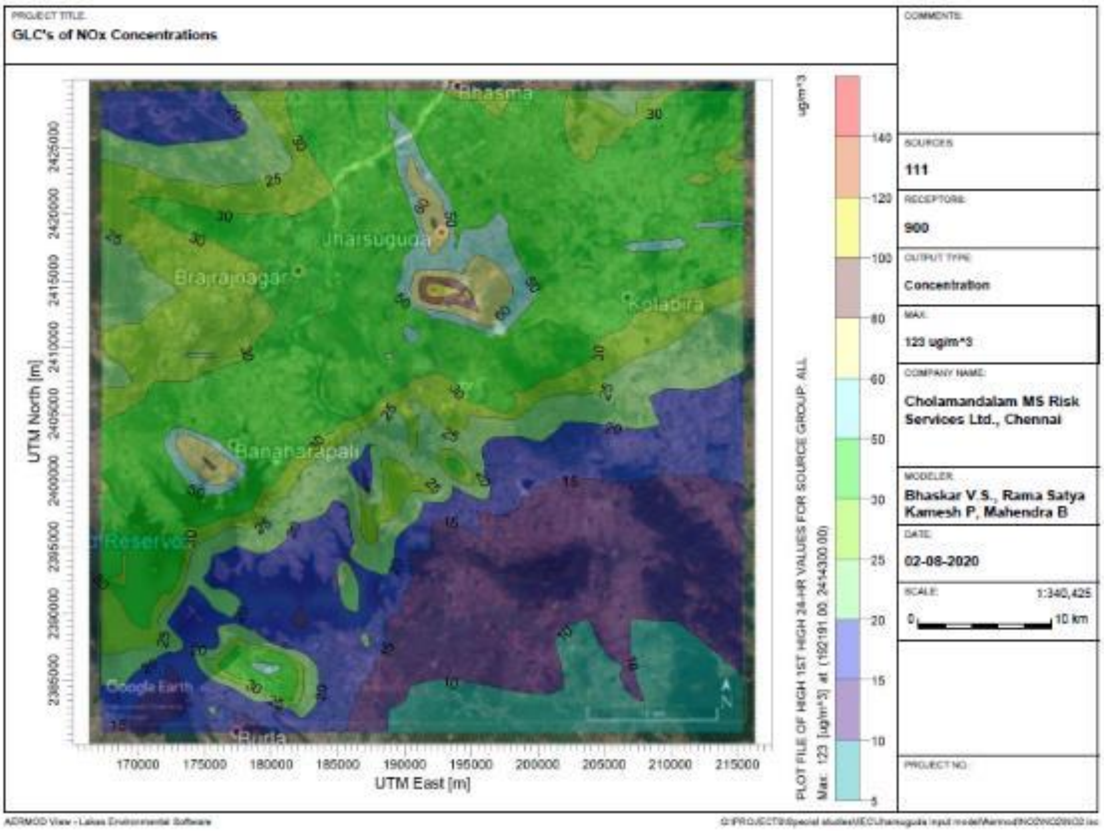
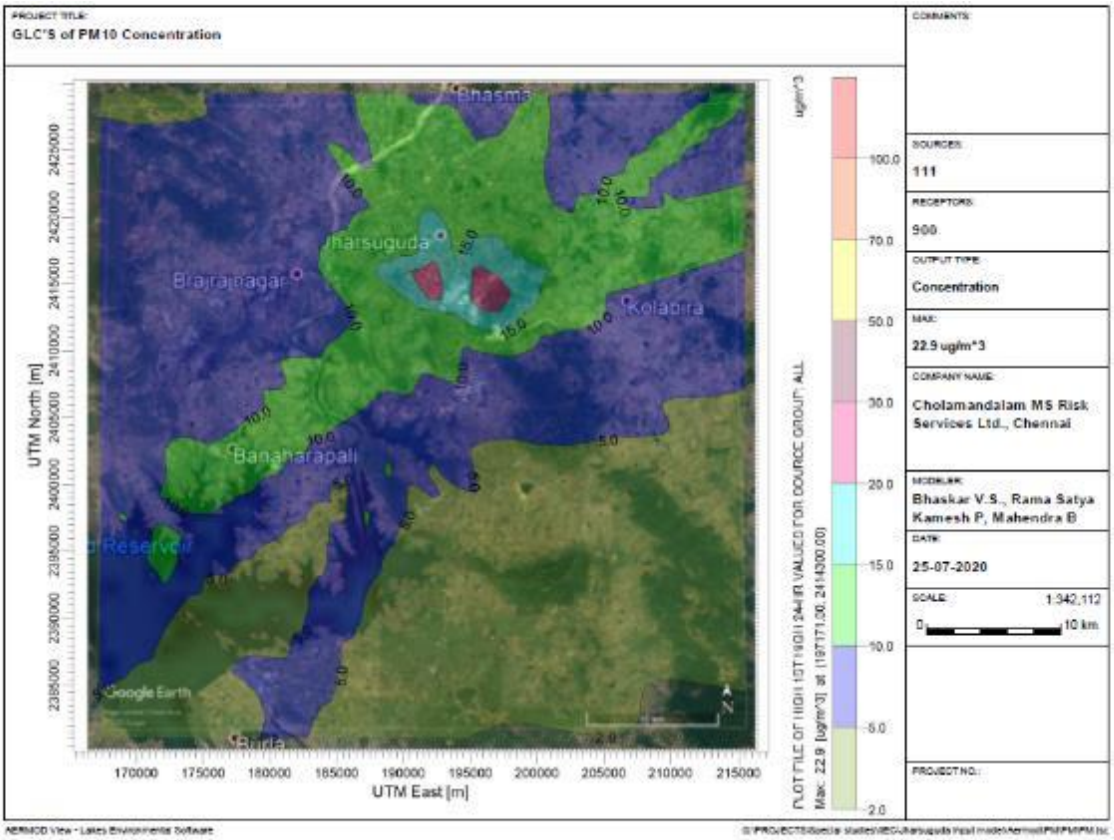


Figure 11: Isopleths Showing Predicted GLC of PM_{10} (Base Line Emission Scenario)



8 Efficiency Improvement in Existing Thermal Power Plants/ Captive Power Plants for Jharsuguda, Odisha

EFFICIENCY IMPROVEMENT MEASURES FOR EXISTING INDUSTRIAL UNITS

Increasing the efficiency of plants translates into increased generation of electricity from the same quantity of coal, which contributes to the energy security of the country while reducing specific emissions. This also means that installation of additional capacity can be avoided. For example, one of the expected outcomes of the PAT schemes of Ministry of Power was that 19 GW of capacity addition could be avoided by increasing efficiency across industrial sectors including power.

Various studies show that there are key areas in plants which can be specifically targeted for improvement of energy efficiency. Inefficient soot blowing, low condenser vacuum, un-optimised combustion in the boiler and poor-quality coal (lower than the quality for which boiler is designed) lead to the loss in efficiency of the plant. The list of key areas where improvements can be achieved between 1-5 percentage points, depending on the extent of measures taken up.

- **Combustion Optimisation:** Optimising the ratio of coal to air input in the boiler can reduce loss of efficiency due to unburned carbon in fly ash and reduce NO_x formation in the boiler. It can also potentially improve efficiency by 0.15-0.84 percentage points.

- **Coal Drying:** Sub-bituminous coal contains high moisture content, between 15 and 40 per cent. During combustion in the boiler, about 7 per cent of the heat input could be used due to the moisture present in the coal. Waste heat from the flue gas could be utilised to dry the coal before combustion. This could lead to an efficiency increase of 0.1-0.7 percentage points.

- **Optimisation of Soot-Blowers:** Soot blowers are used to remove ash from boiler tubes to ensure efficient heat transfer in the boiler. The timing of soot-blowing needs to be optimised in the boiler as excessive soot-blowing could lead to boiler-tube failures and too little could lead to a drop in efficiency. Timing optimisation could lead to an efficiency increase of 0.1-0.65 percentage points.

- **Steam Turbine Overhaul:** A complete turbine overhaul could be carried out for old turbines, which means replacing the turbine blades and casing and could also involve modification of steam parameters. However, this may prove to be capital intensive and a feasibility study is needed on a case-by-case basis. The improvement in efficiency, however, could be about 0.84-2.6 percentage points.

- **Flue Gas Heat Recovery:** A considerable portion of the energy input in a plant is lost through the stack in the form of waste heat. Recovering this waste heat by utilising either for feed-water pre-heating or for coal drying as mentioned could lead to a potential efficiency improvement of 0.3 to 1.5 per cent.

- **Condenser Vacuum:** High steam temperature and pressure at turbine entry and low steam temperature and pressure at turbine exit are the key conditions which dictate the overall efficiency of the steam cycle. The condenser in a power plant performs the key function of condensing steam back to water at the exit of the low pressure (LP) turbine, using vacuum conditions. Lower than optimal vacuum conditions lead to increased steam consumption and the work extracted from the steam is also lowered. Excessive vacuum can lead to the formation of water droplets in the last stage of the turbine, resulting in blade damage. A study conducted by CEA and GIZ in 2014 found that optimisation of condenser vacuum has the maximum potential for short-term efficiency improvement in the plants in the study.

TECHNOLOGY IMPROVEMENT FOR PROCESSES IN INDUSTRIES

- **Higher Steam Parameters:** The fundamental way to increase efficiency is to operate the plant at higher temperature and pressure. A typical Indian subcritical plant operates at 540°C and 17 megapascals (MPa) with average operating efficiencies around 28-34 per cent. In comparison, the state-of-the-art USC plants operate at temperature up to 620°C and pressure up to 29 MPa, achieving efficiencies up to 48 per cent (HHV basis).

  A new category of plants called Advanced-USC, which can achieve efficiencies up to 50 per cent using steam at a temperature of 700°C and pressure of 35 MPa, is being prepared for demonstration by 2020-25. A-USC boilers designed for Indian coal will require erosion resistant coatings because Indian coal contains a lot of ash (34-47%), which is highly erosive. Due to reduced heat transfer rates because of these coatings, the boiler will be much larger in terms of furnace volume area as compared to boilers designed for high-grade coal. This will increase the capital costs of the plant, but with policy-level interventions, the payback period of such units can be reduced.

- **Fluidised Bed Combustion (FBC) Boilers:** FBC boilers are a proven technology that can be implemented by domestic manufacturers. As combustion takes place at a lower temperature, it inherently lowers the formation of oxides of nitrogen. Limestone can be added into the process to lower the emission of oxides of sulphur as well. FBC units were earlier available only for subcritical units of smaller sizes, but the technology has been scaled up and FBC units are available in the same range as PC units. Fuel flexibility is the biggest advantage that FBC boilers offer in the Indian context. Unlike PC boilers, fuels with widely varying calorific values can be readily fired, without the need for oil support like in PC boilers. In addition, it eliminates the need of finely grinding the fuel before combustion. A 460 MW SC-FBC unit is currently under operation in Poland and bigger and better 550 MW USC-FBC units are expected to start commercial operation in South Korea. Currently, FBC boilers are in use in western India only for lignite plants. It is estimated that stricter SO_x and NO_x emission norms will make FBC boilers more economical as compared to PC boilers as they do not need additional equipment for SO_x and NO_x control. This also happens to be a technology that indigenous manufacturers like BHEL are familiar with, and can be adapted to larger sizes with more R&D.

- **Carbon Capture and Sequestration (CCS):** CCS is not yet a widely tested technology which can prevent CO_2 emissions from entering the atmosphere. This method uses chemical absorbents to separate CO_2 from the flue gas stream of the power plant. There are multiple methods for CO_2 capture, including:

Pre-combustion: Coal is converted into a mixture of hydrogen and CO_2 using chemical processes like steam reforming. This mixture is then used in typical power plants and the resulting flue gas consisting mainly of CO_2 is captured (as in IGCC systems).
Post-combustion: A chemical solvent is used to absorb CO_2 from the flue gas stream after combustion. The CO_2 is later captured by heating the solvent, which can be reused in the process by cleansing it of other impurities.

The CO_2 is then compressed to a liquid-like state and transported to storage sites. These storage sites are geological formations, such as deep-sea oilfields and sedimentary rock formations at depths of about 800 m, which are expected to have the ability to hold the gas permanently.

The largest unit on which CCS technology has been demonstrated is a 110-MW unit. The technology is inefficient – as much as 10-12 per cent of the plant's rated output is consumed in the CCS process. The technology is yet to mature for larger units and the capital costs are high. There is also the risk of instability of underground reservoirs which might lead a largescale release of stored CO_2. Since the gas is colourless and odourless, and given the large quantities that will be sequestered, there is a significant risk to human life in the event of release of gas from the reservoirs. Additionally, no study has been done in India to identify suitable sites for storage.

- **Integrated Gasification Combined Cycle (IGCC) and Oxy-Combustion:** Coal is first converted into syngas in an IGCC plant and then burnt in a conventional gas turbine and can reach efficiencies matching that of a SC plant. Worldwide, pilot scale plants are already in operation to test the feasibility of this technology, but commercial scale plants are still a few years away. India too announced a pilot IGCC plant at Vijayawada which was going to be a joint effort between APGENCO and BHEL, but the project has remained a non-starter. Indicative costs of about Rs 9 crore/MW also makes it expensive. It should also be noted that "entrained-flow gasifier"-based IGCC which are currently in use worldwide are not suitable for Indian coal. "Fluidised bed gasifier"-based IGCC system has been under development by BHEL, but the results of its testing are unknown.

  Oxy-combustion utilises pure oxygen rather than atmospheric air in the boiler for combustion. This involves setting up of an air separation unit (ASU) to separate oxygen from air and special boiler parts to withstand higher temperatures. This technology is especially advantageous when used with CCS systems as the flue gas consists mostly of pure CO_2 and can be captured without much processing. NO_x formation is also prevented as only oxygen is used for combustion. This process too, suffers the same drawbacks as IGCC – high auxiliary consumption, as ASUs are highly energy intensive. This technology is also under development worldwide and has not yet been demonstrated on a large scale.

CONCLUSION ON ENERGY CONSERVATION MEASURES FOR COAL BASED POWER PLANTS

Most of the Indian plants have efficiencies of 32-36 per cent. In comparison with plants around the world, these are among the lowest in the world. Lack of proper O&M practices is one of the main reasons for this. The problem is acute in state-owned plants where units are often not able to operate at their rated output due to bad operational practices combined with poor quality fuel.

Another issue affecting coal-based power plants is that they are often not run at full load. Usually coal-based plants are intended to be "base load" plants, to run at a constant load. Gas-based plants are used as "peaking plants" to provide power during specific hours of high demand. In India, however, coal-based plants are used as both base-load and peaking plants. The result is that when demand is low, plants are forced to run at their minimum technical load, which causes a loss of efficiency.

There is a large scope for reduction in auxiliary power consumption in plants. A notification was passed by the Ministry of Power in this regard in 2006 making it compulsory for all plants to monitor energy consumption by auxiliary equipment. The objective was that the plants crosscheck the logs of the metered consumption data with energy audits and carry out efficiency-improvement measures. In a 2010 revision to the notification, however, monitoring total auxiliary consumption by all the equipment was made compulsory rather than monitoring the detailed use. The result was the plants today know their total auxiliary consumption but are not able to identify how much is being consumed where. This makes it impossible to reduce auxiliary consumption. Most plants could not provide a breakup of auxiliary consumption to GRP as well. Very few plants, mostly privately owned ones, carry out voluntary monitoring and target-setting to reduce auxiliary consumption.

The PAT scheme was the first attempt to introduce the idea of energy efficiency in thermal power plants in India. However, the initial round of target setting was not ambitious enough. Moreover, the programme has been designed such that one of the ways for plants to achieve their targets is by reducing their auxiliary consumption (as the programme only considers net heat rates). However, in the absence of proper metering, this is not possible.

There are also regulatory gaps in the Indian electricity framework, which allow for inefficiencies to creep in at the plant level. Several such gaps still exist even today. A few of them are:

- **Merit Order Dispatch (MOD):** A MOD lists plants in increasing order of tariff. When a distribution company (DISCOM) requires power, the plant with the lowest tariff comes on first. Often, plants which have completely depreciated are high up on the list as they do not have capital costs. These plants also happen to be very polluting, but since tariff trumps all other parameters, these come on first.

  Integrating the costs of pollution into the tariff structure is one of the ways to overcome this problem. This makes sure that more efficient, less polluting plants are given priority in the dispatch over inefficient, highly polluting plants. China, for example, already has an environmental dispatch rule which provides for preparing dispatch lists based on a combination of environmental impacts and thermal efficiencies, instead of being based on average total price.

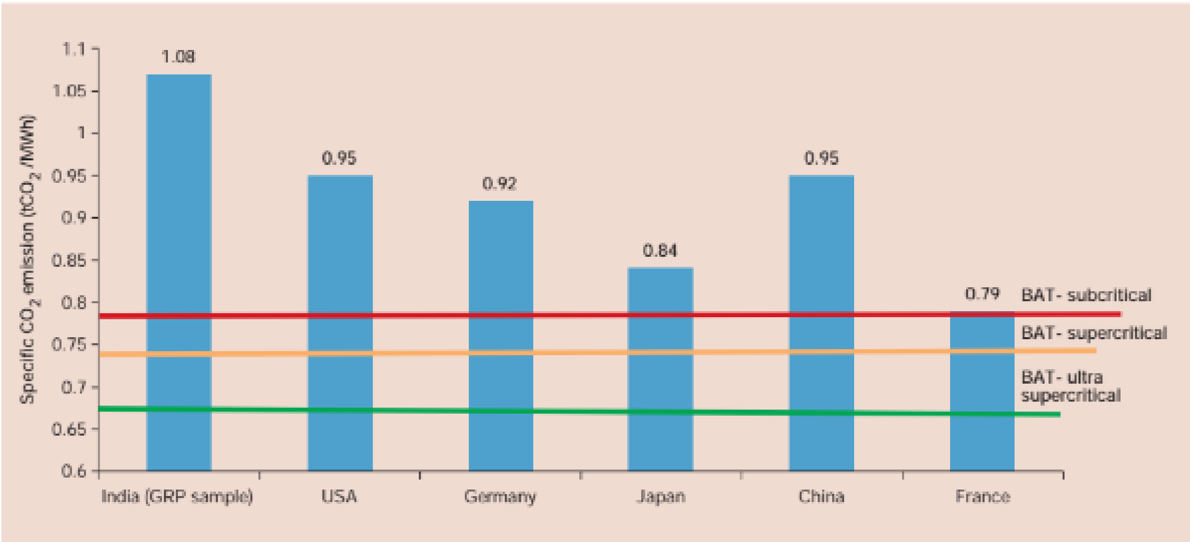
- **Fuel Transit Losses:** Plants are allowed a transit loss of 0.2-0.8 per cent on a normative basis. Since fuel transit loss is normative, it allows the plant to claim full losses rather than actual losses. Further it does not incentivise plants to adopt best practices to measure actual coal receipt and consumption.

- **Special Allowances:** Old and inefficient plants like NTPC Badarpur and DVC Bokaro are given exemptions from meeting heat rate norms. The benchmark for heat rates and specific fuel consumption is often set 10-20 per cent lower than for other plants. These plants happen to be egregious polluters as well and providing them exemptions gives them more incentive to not change.

CO_2 AND ENERGY EFFICIENCY

The thermal power sector is one of the most energy consuming and highest GHG-emitting industrial sectors

SPECIFIC CO_2 EMISSION RATES OF COUNTRIES, 2010-13
India has one of the highest CO_2-specific emission rates among countries



Note: India's specific CO_2 emission has been estimated for the period April 2011-March 2012
Source: Green Rating Project 2014; Hussy C., Klaassen E., Koornneef J. and Wigand F., 2014, International comparison of fossil power efficiency andCO_2 intensity– Update 2014
http://www.ecofys.com/files/files/ecofys-2014-international-comparison-fossil-power-efficiency.pdf, P 81, as viewed on January 6, 2015

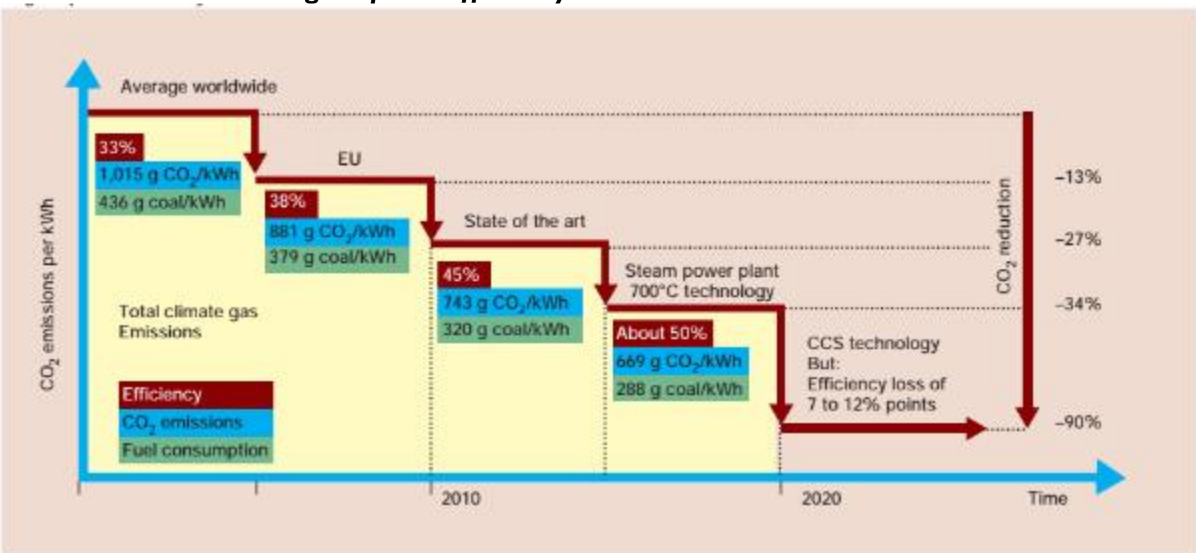
More than 40 per cent of total energy consumption in the world (5,251 million tonnes of oil equivalent, Mtoe, in 2012) is by the electricity sector. Of this, coal uses around 43 per cent (2,269 Mtoe in 2012).

More than 38 per cent of the global CO_2 emission from fuel combustion (13,346 million tonnes) comes from the electricity sector. India's CO_2 emissions (the third largest after China and USA)23 are nearly 6 per cent of the world's; 53 per cent of India's CO_2 emissions from fuel combustion are derived from electricity.

A report by UK-based consultancy, Ecofys, stated emission intensity of Indian coal-based power plants was 1.26 tCO_2/MWh25 in 2011. However, CEA reports a lower (1.03 tCO_2/MWh) emissions intensity of coal-powered plants in 2013-14.26 Plants evaluated under the GRP study had an average specific emission of 1.08 tCO_2/MWh during 2010-13. What is beyond dispute is India's specific CO_2 emission is one of the highest among countries with significant coal-based capacity (see Graph 4.13: Specific CO_2 emission rates of countries, 2010-13).

Energy efficiency is directly related to the intensity of CO_2 emission per unit of electricity generated. Emissions from Indian plants are high because most plants still use subcritical technology with low efficiency (around 32-33 per cent). Moving to SC plants27 with higher efficiencies can lower specific CO_2 emissions to 743 g/kWh. A further reduction in intensity to 600-670 g/kWh is possible using Advanced-USC technology which is still at the development stage (see Graph 4.14: Relation between CO_2, efficiency and technology).

Relation between CO_2, efficiency and technology
Higher plant efficiency means lower emission rates



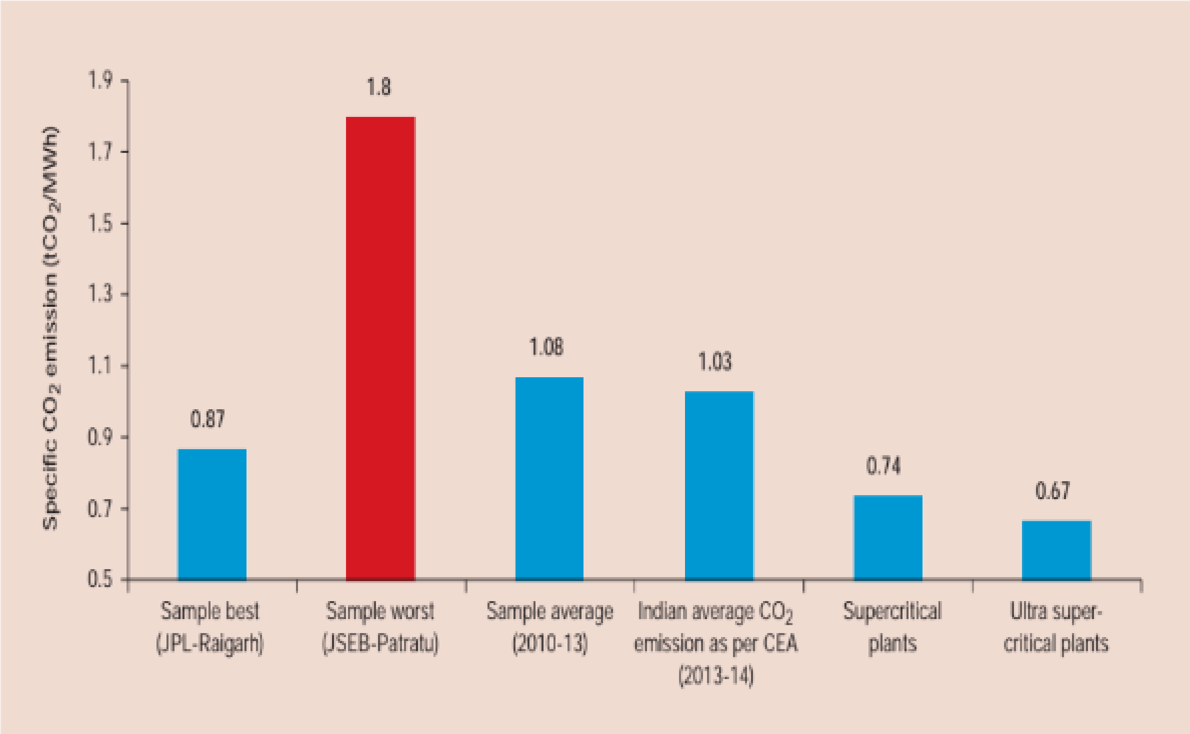
Source: Electricity Generation: Facts and Figures, VGB Powertech, 2013-14, pages 16-17

Although plants based on SC technology have been in operation since the early 1960s, India's first SC unit was commissioned only in 2010-11. The 12th Five-Year Plan (2012-17) envisions 50-60 per cent of the new capacity added during this period will be based on SC technology. The average specific CO_2 emission of the plants in the GRP study is 1.08 tCO_2/MWh, which is slightly higher than the Indian average emission of 1.03 tCO_2/MWh reported by CEA.28 Graph 4.15 shows the distribution of the plants in the study: 17 plants had an average emission lower than the Indian average emission, of which only three are state owned; JPL-Raigarh had the lowest specific emission at 0.87 tCO_2/MWh while JSEB- Patratu was the worst at 1.80 tCO_2/MWh.

Plants with high specific emissions (1.2 tCO_2/MWh and above) contribute just 17 per cent of the total generation (see Graph: Generation contribution (in per cent) from plants, 2010-13). The largest share of generation was from the 0.9-1.1 tCO_2/MWh (over 65 per cent).

SPECIFIC CO_2 EMISSION OF SAMPLE PLANTS, 2010-13

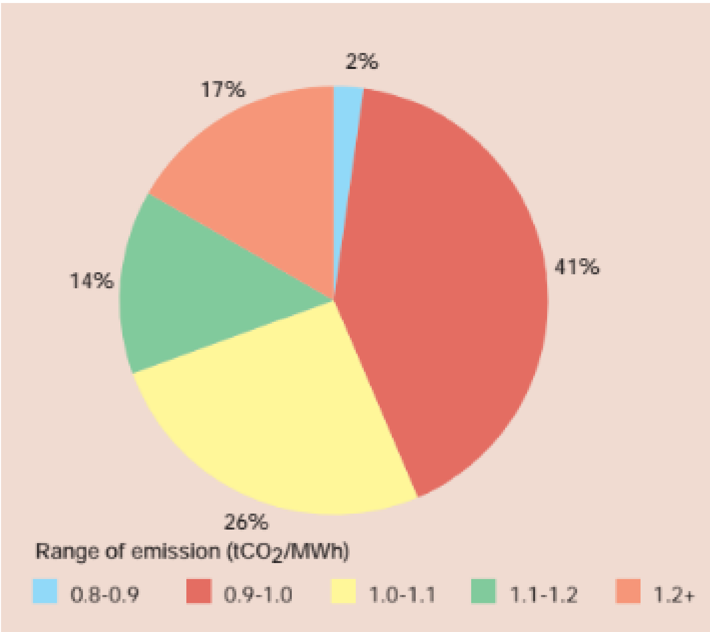
Wide variation between the best and worst performers in terms of specific CO_2 emissions



Source: Green Rating Project, 2014-15, CSE, New Delhi

GENERATION CONTRIBUTION FROM PLANTS, 2010-13

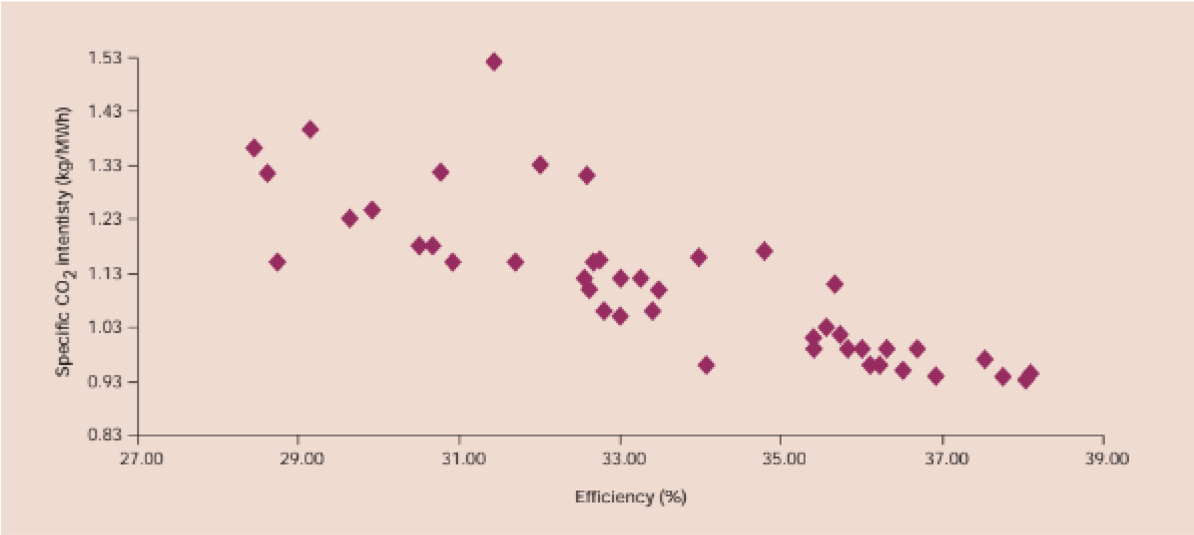
Plants with highest emission contribute the least to generation



Source: Green Rating Project, 2014-15, CSE, New Delhi

The plants which fell in the lowest efficiency band of 25-30 per cent had an average emission of 1.30 tCO_2/MWh. All plants in this band were state-owned, except KSK-Wardha, which is privately owned. The efficiency range of 32-34 per cent included the largest number of plants with an average emission of 1.13 tCO_2/MWh. Plants with an efficiency of 34 per cent and higher had CO_2 emissions that were lower than the Indian average

AVERAGE SPECIFIC CO_2 EMISSION OF PLANTS CONSIDERED
Plants with higher efficiency showed less emission intensity



Source: Green Rating Project, 2014-15, CSE, New Delhi

The three supercritical plants in the study – TataMundra, NTPC-Sipat and Adani-Mundra – had an average emission of 1.00 tCO_2/MWh. Adani Mundra had the highest emission among the three at 1.10 tCO_2/MWh.

THE CHALLENGE AHEAD: EFFICIENCY VERSUS CO_2 REDUCTION

The big challenge for India is to ensure affordable energy to all while simultaneously controlling CO_2 emissions. Currently, the most cost-effective method for reducing CO_2 emissions is improving efficiency. The APEC (Asia Pacific Economic Cooperation) Energy Working Group's report suggests that a 3.5 percentage point efficiency improvement can result in 9 per cent reduction in CO_2 emissions, which could be achieved through optimisation of combustion, steam cycle, and operation and maintenance. This cost-effective method also increases the plant's life.

The capacity additions need to have efficient and clean technologies. The existing plants need to be retrofitted with clean technologies where possible. Plants which are too old, where retrofits cannot work anymore, need to be phased out. Since poor O&M practices are a major reason for low efficiency of plants, the scope for efficiency improvement through adoption of best practices is high.

However, because of the limitations of how much efficiency improvement is achievable with older technology, deeper cuts in CO_2 emissions would require exploration of options such as implementation of carbon capture and storage (CCS) (with high-efficiency units), which are expensive and in the experimental stage. Thus, efficiency improvement remains the most cost-effective way to achieve significant cuts in emissions from coal-based power plants in India.

SO_2 ABATEMENT TECHNOLOGY

In India very few plants that are dependent on imported coal have installed SO_2 control systems. The remaining have no end-of-pipe SO_2 control measures. CPCB/ MOEF have given time upto 2021 to meet the new notified standard.

The primary measure to control SO_2 emission is to use low-sulphur coal itself. For fluidised bed combustion (FBC) plants, the use adsorbent materials (CaO, Ca (OH)2 or CaCO3) directly in the boiler helps to retain sulphur in ash. The reaction needs a fuel vs adsorbent ratio of 1.5:7, depending on the fuel.

Flue gas desulphurisation is the secondary measure to capture SO_2 emission from flue gas. It can be done using wet scrubbing (wet process), spray-dry scrubbers (semi-dry process), adsorbent injection (dry process) and regenerative processes (both the wet and dry type, where scrubbing material is recovered and reused).

Wet process is the most efficient and popular technique in which an aqueous suspension of limestone/lime or seawater is used for flue gas scrubbing. There are other advantages: HCl, HF, dust and heavy metals emissions are reduced.

A few imported coal-based coastal plants in India, such as JSW-Ratnagiri, Tata-Trombay, Adani-Mundra etc., have adopted seawater-based FGD technology. The process saves chemical cost but does not generate gypsum; however, it could have localised side effects from the release of sulphate, chloride and heavy metals with effluent or waste water into the sea.

The semi-dry process is the second most popular choice. It is generally used in small- or medium-sized boilers that use up to 1.5 per cent sulphur coal.

DIFFERENT TYPES OF FGD SYSTEMS TO CONTROL SO_2

Flue Gas Desulphurisation (FGD) systems can increase the capital cost by up to 14 per cent

Types of FGD	Characteristics	Increase in capital cost
Wet FGD	• Limestone ($CaCO_3$) used as reagent	
	• Removal efficiency up to 98 per cent	
	• Use 1-1.5 per cent of electricity generated	
	• High water consumption, therefore need to treat wastewater	
	• Gypsum as a saleable byproduct	11-14 per cent
Semi-dry FGD	• Also called "dry scrubbing" under controlled humidification	
	• Lime (CaO) as reagent	
	• Removal efficiency up to 94 per cent	
	• Can remove SO_3 as well at higher removal rate than wet FGD	
	• Use 0.5-1.0 per cent of electricity	
	• No wastewater generation	
	• Waste – mixture of fly ash, unreacted additive and $CaSO_3$	9-12 per cent
Seawater FGD	• Removal efficiency up to 90 per cent	
	• Not practical for high sulphur coal (>1%S)	
	• Use 0.8-1.6 per cent of electricity	
	• No wastewater or solid waste	
	• May result in reduction of pH, release of heavy metals, fly ash and sulfate, increase of temperature, dissolved oxygen, and chemical oxygen demand in sea water	7-10 per cent

Source: International Finance Corporation (IFC), 2008, Environment, Health and Safety guidelines: Thermal Power Plants *http://www.ifc.org/wps/wcm/connect/dfb6a60048855a21852cd76a6515bb18/FINAL_Thermal%2BPower.pdf?MOD=AJPERES&id=1323162579734, p. 4, as viewed on October 2014*

NO_x Abatement Technology: Rare in Indian Coal-Based Power Plants

The primary means to control NO_x emission is to reduce its formation, mainly through optimising the design and operational parameters, such as fuel staging, air staging, flue gas recirculation, reduced air preheat and low excess air. The second method is to convert the end-of-pipe NO_x into molecular nitrogen to be released in the atmosphere.

The main technologies for NO_x control in coal-fired boilers are listed in table below. These methods may, however, adversely impact boiler efficiency and release other pollutants. Therefore, operational optimisation of boiler is essential.

End-of-pipe NO_x control techniques include Selective Catalytic Reduction (SCR) with 80-95 per cent efficiency and Selective Non-Catalytic Reduction (SNCR) with 30-50 per cent efficiency. In the SCR process (widely used in TPPs in Europe, Japan and USA) a reducing agent such as ammonia is injected in the flue gas path in the presence of catalysts (such as base metal oxides, iron oxides, zeolites, activated carbon at temperatures of 170-510°C) in honeycomb or plate form. SNCR does not need a catalyst but is sensitive to temperatures of 850-1,100°C, depending on the reagent used. Both technologies need to have safety measures to handle liquid ammonia. None of the plants in India has end of-pipe NO_x control technology.

EFFICIENCY AND LIMITATIONS OF PRIMARY NO_X COMBUSTION TECHNIQUES
Low NO_x burners and air staging are available in few new thermal power plants in India

Process	Efficiency	Drawbacks
Reduction of excess air	10-44 per cent	Incomplete combustion
Air staging	10-70 per cent	Incomplete combustion, higher CO and unburnt carbon
Fuel staging		Suitable for gaseous fuel, more secondary fuel
Flue gas recirculation	<20 per cent	Flame instability in boiler
Reduction of air preheat	20-30 per cent	Not suitable for coal fired, wet bottom boiler
Low NOx burner + fuel staging	50-60 per cent	Incomplete combustion, flame instability
Low NOx burner + air staging	25-35 per cent	Incomplete combustion, flame instability
Low NOx burner + flue gas recirculation	Up to 20 per cent	Flame instability

Source: IPPC, Best Available Techniques for Large Combustion Plants, 2006

DIFFERENT TYPES OF NO_X REDUCTION SYSTEMS
NO_x control systems can increase capital costs by 10 per cent

Types of NOx control technology	Characteristics	Increase in capital cost
SCR	• NOx emission reduction rate of 80-95 per cent	4-9 per cent
	• Use 0.5 per cent of electricity generated	
	• Use ammonia or urea as reagent	
	• Ammonia slip increases with increasing NH_3/NOx ratio may cause a problem (e.g., too high ammonia in the fly ash). So larger catalyst volume may be needed to avoid this problem	
	• Catalysts may contain heavy metals so proper handling and disposal/recycle of spent catalysts is needed.	
	• Life of catalysts has been 6-10 years for coal-fired plants	
SCNR	• NOx emission reduction rate of 30-50 per cent	1-2 per cent
	• Use 0.1-0.3 per cent of electricity generated	
	• Use ammonia or urea as reagent	
	• Operates without using catalysts	

Source: International Finance Corporation (IFC), 2008, Environment, Health and Safety guidelines: Thermal Power Plants http://www.ifc.org/wps/wcm/connect/dfb6a60048855a21852cd76a6515bb18/FINAL_Thermal%2BPower.pdf?MOD=AJPERES&id=1323162579734, p. 5, as viewed on November 2014.

9 Estimated Emissions Post ENCON Measures and Cleaner Technology Options

Based on the studies conducted, the following energy conservation measures and cleaner technologies are suggested, and the corresponding envisaged emission reduction levels are listed hereunder:

Table 13: Estimated Emissions after Implementation of ENCON Measures

Sector/Emission Source	Thermal Energy Consumption Benchmark for the Sector	Type of Energy Conservation Measures & Cleaner Technologies Suggested by IIEC	Existing Emission Levels (Uncontrolled Emissions)	Envisaged reduced Emissions Scenario (Post ENCON and Clean Technology)
Integrated Steel Plant (Blast Furnace & Sponge Iron Plant)	Blast furnace- 3.5 Million Kcal/DR product Sponge iron plant- 7 million Kcal/DR product	Based on the IIEC report on energy conservation measures and cleaner technology options, implementation of following measures may help to reduce the emissions by an order of 30%: • Covered raw material storage area, paved and impermeable storage surface area (applicable areas) and appropriate drainage system, • Transfer of raw materials through closed conveyors to control fugitive dust emissions • Maintaining tallest carbonization chamber for coke ovens for coke making, stamp charging over the conventional top charging, • Installation of stationary land-based pushing emission control system in new and renovated (rebuilt) batteries has been mandated in India by the MoEF as per the GSR 46 (E) notification. • Installation of sinter machines with larger surface area enables installation of all energy conservation technologies such as sinter cooler waste heat recovery and thus help in minimizing specific energy consumption of sintering process.	PM: 196 Kg/hr SO_2: 388 Kg/hr NO_x: 222Kg/hr	PM: 137 kg/hr SO_2: 295 kg/hr NO_x:155 kg/hr

Sector/Emission Source	Thermal Energy Consumption Benchmark for the Sector	Type of Energy Conservation Measures & Cleaner Technologies Suggested by IIEC	Existing Emission Levels (Uncontrolled Emissions)	Envisaged reduced Emissions Scenario (Post ENCON and Clean Technology)
		• The installation of selective waste gas recycling technology in sinter plants to minimize the solid fuel energy required in the beds. • Large working volume of blast furnace shell enables the installation of clean technologies such as pulverized coal injection, high top pressure and top pressure recovery turbine (TRT), bell less top and higher hot blast temperature, cast house slag granulation, waste heat recovery from hot blast stoves can reduce the coal consumption and increase the energy efficiency. • Consumption of coke in large blast furnaces can be reduced by up to 50% in large volume blast furnace by adopting energy conservation measures. Higher the productivity of a blast furnace, lower the coke consumption and higher the energy efficiency. • Oxyfuel combustion technology to eliminate heat loss and can achieve much higher temperature, centralized and high efficiency recuperator, improved insulation and refractories of reheating furnace. • The Energy pulse super imposition/micro pulse discrimination technique used in ESP at sinter plant can reduce the dust emission to as low as 20 mg/Nm^3		
Steel rolling mills	3.5 GJ/T	The following Encon and cleaner technologies can help to reduce emissions. It is assumed that SO_2 and NO_x emissions will be reduced by an order of about 20% from the baseline scenario.	PM: 4 kg/hr SO_2: 23 kg/hr NO_x: 62 kg/hr	PM: 2 kg/hr SO_2: 18 kg/hr NO_x: 50 kg/hr

Sector/Emission Source	Thermal Energy Consumption Benchmark for the Sector	Type of Energy Conservation Measures & Cleaner Technologies Suggested by IIEC	Existing Emission Levels (Uncontrolled Emissions)	Envisaged reduced Emissions Scenario (Post ENCON and Clean Technology)
		• Upgradation of technical use of biomass gas as fuel, • Various technologies can be adopted for recovery of heat using regenerative burners or self-recuperative, top and bottom firing system, • Local exhaust ventilation and installation of bag filters for capturing fugitive dust emissions		
Aluminum smelters	37 GJ/T	About 40% reduction in PM emissions can be achieved due to adoption of higher efficiency dust collection system and bag filter systems etc. All the aluminum industries can aim at achieving PM levels of 30 mg/Nm^3 as against the prescribed standard limit of 50 mg/Nm.	PM: 2241 kg/hr SO_2, NO_x -BDL	PM: 1357 kg/hr @ 30 mg/Nm^3 SO_2, NO_x -BDL
Captive power plant	2300 KCal/kWhr	Some of the Encon measures and cleaner systems can be adopted in the thermal power plants to improve in the plant efficiency and air pollution load to the atmosphere: • The vital areas can be aimed for improving plant efficiency such as optimizing the ratio of coal to air input can reduce loss of efficiency due to unburned carbon in fly ash and reduce NOx formation in boiler, optimization of soot blowers, flue gas heat recovery etc. • The installation of Fluidized bed combustion (FBC) boilers are a proven technology that can be implemented, combustion takes place at a lower temperature inherently lowers the formation of oxides of nitrogen. Limestone can be added into the process to lower the emission of oxides of Sulphur as well. • By implementing technologies such as Wet flue gas	PM: 848 kg/hr SO_2: 17244 kg/hr NO_x: 7600 kg/hr	PM: 392kg/hr SO_2: 1307 kg/hr NO_x: 1307 kg/hr

Sector/Emission Source	Thermal Energy Consumption Benchmark for the Sector	Type of Energy Conservation Measures & Cleaner Technologies Suggested by IIEC	Existing Emission Levels (Uncontrolled Emissions)	Envisaged reduced Emissions Scenario (Post ENCON and Clean Technology)
		desulphurization (WFGD), dry flue gas desulphurization (dry FGD) utilizing a dry scrubber of circulating type, spray dry absorber, and dry absorbent injection would control the SO2 emissions. • The NOx emissions can be controlled by adopting the low NOx combustion burners and proper selection of fuel. The post combustion NOx control technologies include selective non-catalytic reduction system (SNCR) or selective catalytic reduction (SCR) systems. • As per MoEF&CC notification issued on 7th December 2015, it is mandatory that the thermal power plants shall be complied with the emission standards norms of PM: 30 mg/Nm3, SO2: 100 mg/Nm3, NOx: 100 mg/Nm3. Hereby the same emission standards are considered for post ENCON measures to comply.		
Base load thermal power plant	2300 KCal/kWhr	Same as above ENCON measures and standard emission rate in captive power plant is considered.	PM: 2774 kg/hr SO_2: 32645 kg/hr NO_x: 16643kg/hr	PM:832 kg/hr SO_2:2774 kg/hr NO_x:2774 kg.hr

10 Predicated GLC's -Post ENCON Measures and Clean Technology Scenario

As discussed in the sections above, the ENCON measures and cleaner technologies options are suggested and the corresponding detailed envisaged emission reduction levels are presented in **Annexure-IB** and **Annexure-IC**. It can be noted that the overall SO_2 emission levels can be reduced from current baseline scenario of 50 TPH to 4.4 TPH due to adoption of various ENCON measures and clean technology options. Similarly, NO_x levels will be reduced from current levels of 24.5 TPH to 4.3 TPH. It is also estimated that about 56% reduction in PM emission load could be achieved due to implementation of ENCON and cleaner technologies.

Based on the envisaged reduced emission loads, the air quality modelling exercise was undertaken to compare the GLC's of PM_{10}, NO_x and SO_2 due to reduced emission levels as against the uncontrolled emission scenario in the region. The predicated concentrations of all the three pollutants are depicted in **Figures 12 to 14**. The summary of model results before and after implementation of ENCON measures and clean technology options are presented in **Table 14**. The model output files are presented in **Annexure IV**.

Table 14: Predicted GLC for Baseline Emission Scenario Vs. Post ENCON Scenario

Pollutant	Uncontrolled Emission Scenario		Envisaged Reduced Emission Scenario (Post ENCON Measures & Clean Technology Options)		Maximum Reported Baseline Air Quality Data
	Pollutant load (T/hr)	2nd Height Predicted 24Hrs Avg GLC (µg/m³)	Revised pollutant load (T/hr)	2nd Height Predicted 24Hrs Avg GLC (µg/m³)	
SO_2	50.3	254	4.4	20.2	24
NO_x	24.5	123	4.3	26.9	31
PM_{10}	6.1	22.9	2.7	14.1	81.4

Predicted GLC of SO_2: Predicted 2nd height GLC is reported to be in the order of 20.2 µg/m³ as against the uncontrolled emission scenario of 254 µg/m³. It can be noted that a significant reduction in GLCs can be achieved due to implementing various ENCON measures and clean technology options in thermal power plants, integrated iron and steel plants, aluminium smelters and steel rolling industries. The predicted SO_2 concentrations were compared with that of the authentic published data and presented in **Table.15**.

Predicted GLC of NO_x: Predicted 2nd height GLC is reported to be in the order of 26.9 µg/m³ as against the uncontrolled emission scenario of 123 µg/m³. It can be noted that a significant reduction in GLCs can be achieved due to implementing various ENCON measures and clean technology options. The predicted NO_x concentrations were compared with that of the authentic published data and presented in **Table.16**.

Predicted GLCs of PM: Predicted 2nd height GLC is reported to be in the order of 14.1 µg/m^3 as against the uncontrolled emission scenario of 22.9 µg/m^3. The predicted GLC's is compared with reported baseline concentration which is presented in below **Table.17**.

Table 15: Predicted GLCs of SO_2 – Post ENCON Measures and Clean Technology Options

Location	Coordinates	Predicted concentration of SO_2 (µg/m^3)		Published Baseline Concentration of SO_2 (µg/m^3)
		Uncontrolled Scenario	Reduction Emission Scenario	
Brajrajnagar	182079.74 m E 2416375.25 m N	62.3	2.3	7.2
Lapanga Village	191233.77 m E 2405217.10 m N	52.6	2.0	8.2
Bomaloi Village	192953.47 m E 2402128.17 m N	43.4	1.6	8.0
Gumkarama Village	195297.80 m E 2408625.96 m N	67.1	2.9	8.5
Sripura Village	193955.96 m E 2410889.85 m N	74.4	3.9	8.0
Brundamal village	192154.54 m E 2414605.36 m N	248.7	6.2	8.0
Tarikela village	189041.00 m E 2410328.63 m N	72.8	3.1	7.5
Thelkoloi village	190844.32 m E 409845.99 m N	78.6	3.6	8.2

Table 16: Predicted GLCs of NO_x– Post ENCON Measures and Clean Technology Options

Location	Coordinates	Predicted concentration of NO_x (µg/m^3)		Published baseline concentration of NO_x (µg/m^3)
		Uncontrolled Scenario	Reduction emission scenario	
Brajrajnagar	182079.74 m E 2416375.25 m N	35.7	2.3	24.1
Lapanga Village	191233.77 m E 2405217.10 m N	24.8	2.0	29.8
Bomaloi Village	192953.47 m E 2402128.17 m N	23.1	1.8	29.1
Gumkarama Village	195297.80 m E 2408625.96 m N	34.9	2.7	25.2
Sripura Village	193955.96 m E 2410889.85 m N	38.4	3.4	28.8
Brundamal village	192154.54 m E 2414605.36 m N	122.5	4.4	26.3
Tarikela village	189041.00 m E 2410328.63 m N	41.7	3.1	24.9
Thelkoloi village	190844.32 m E 2409845.99 m N	44.5	3.3	29.8

Table 17: Predicted GLCs of PM – Post ENCON Measures and Clean Technology Option

Location	Coordinates	Predicted Concentration of PM (µg/m³)		Published Baseline Concentration of PM (µg/m³)
		Uncontrolled Scenario	Reduction Emission Scenario	
Brajrajnagar	182079.74 m E 2416375.25 m N	3.1	1.4	141
Lapanga Village	191233.77 m E 2405217.10 m N	2.4	1.5	86.6
Bomaloi Village	192953.47 m E 2402128.17 m N	2.0	0.8	81.7
Gumkarama Village	195297.80 m E 2408625.96 m N	3.6	1.8	80.4
Sripura Village	193955.96 m E 2410889.85 m N	4.5	2.0	84
Brundamal village	192154.54 m E 2414605.36 m N	6.5	3.5	83.4
Tarikela village	189041.00 m E 2410328.63 m N	4.7	2.2	75.4
Thelkoloi village	190844.32 m E 2409845.99 m N	4.6	2.7	78.8

Figure 12: Isopleths Showing Predicted GLC of SO_2

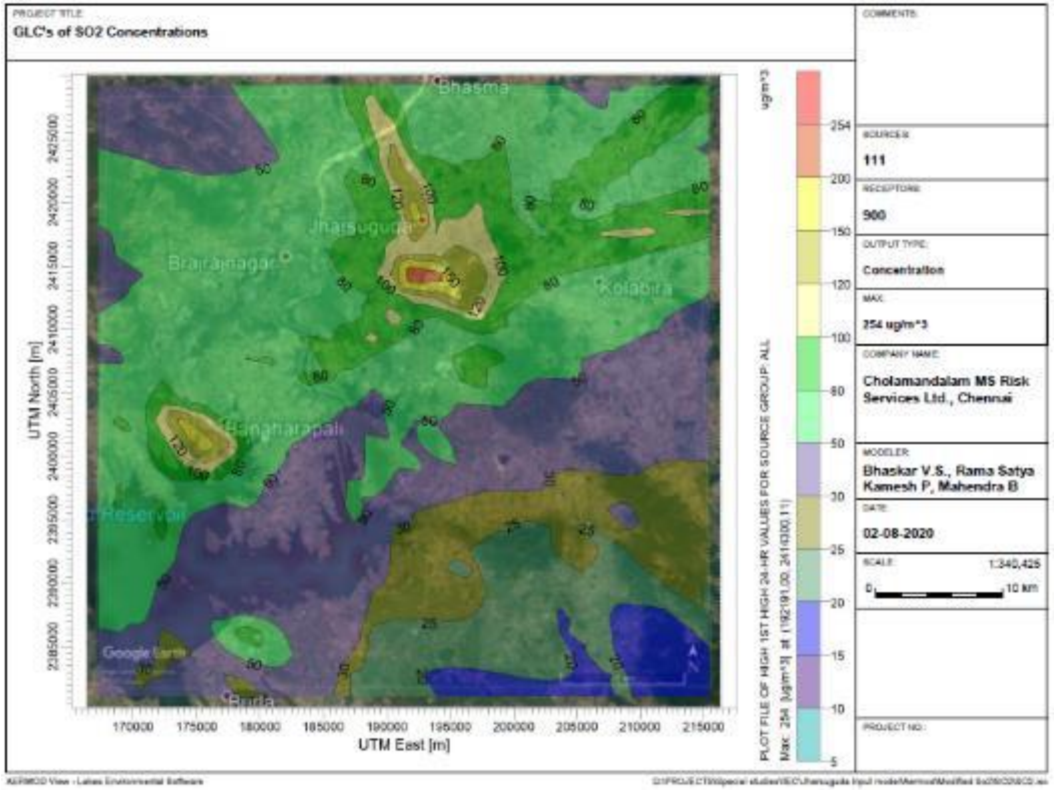
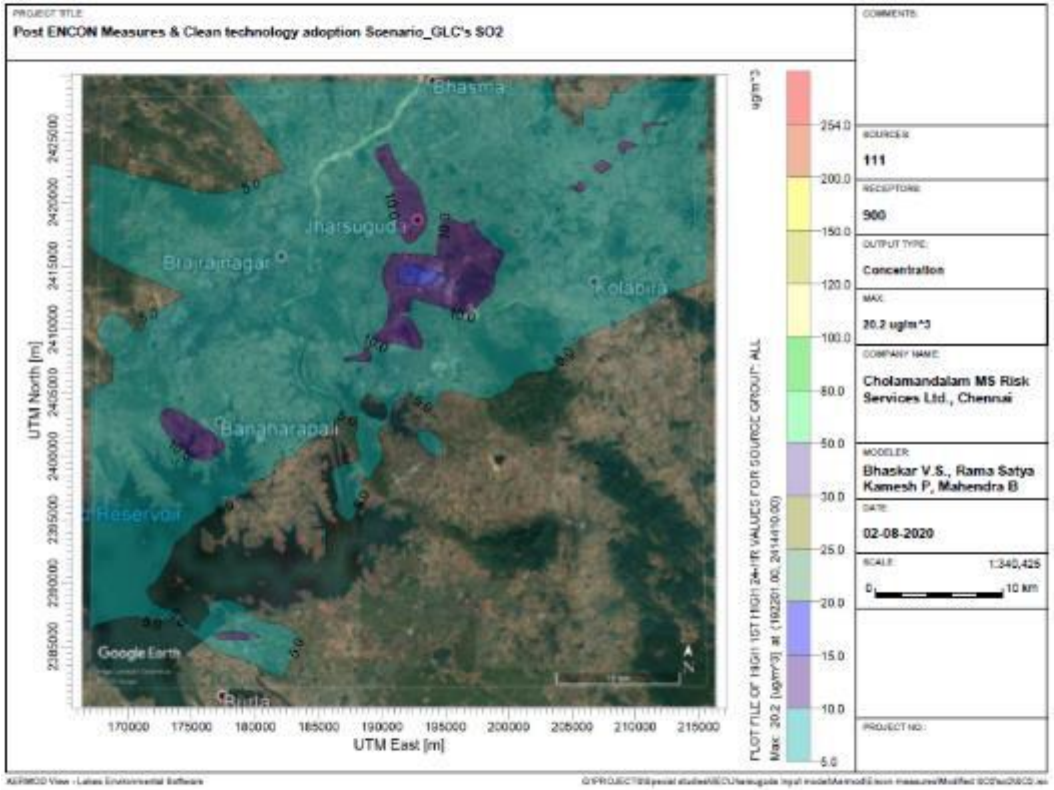
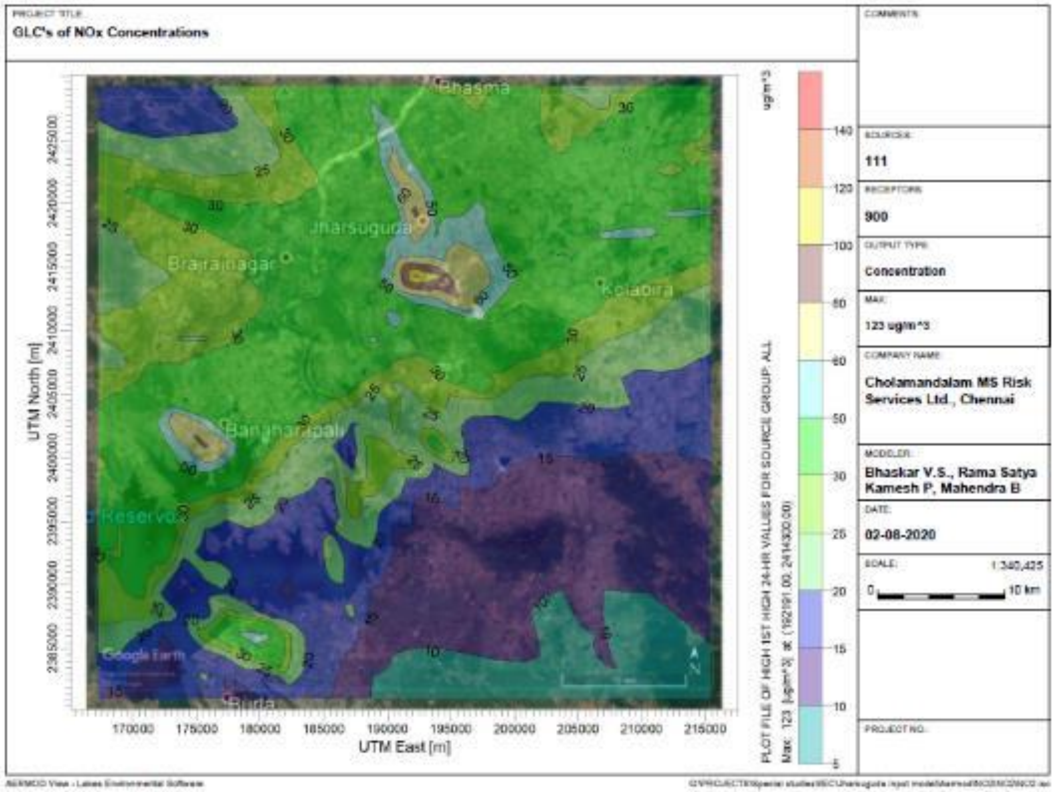
Uncontrolled Emission Scenario -Predicted GLC of SO_2	Envisaged Reduced Emission Scenario-Predicted GLC of SO_2
	

Figure 13: Isopleths Showing Predicted GLC of NO_x- Envisaged Reduction Emission Scenario

Uncontrolled Emission Scenario -Predicted GLC of NO_x



Envisaged Reduced Emission Scenario-Predicted GLC of NO_x

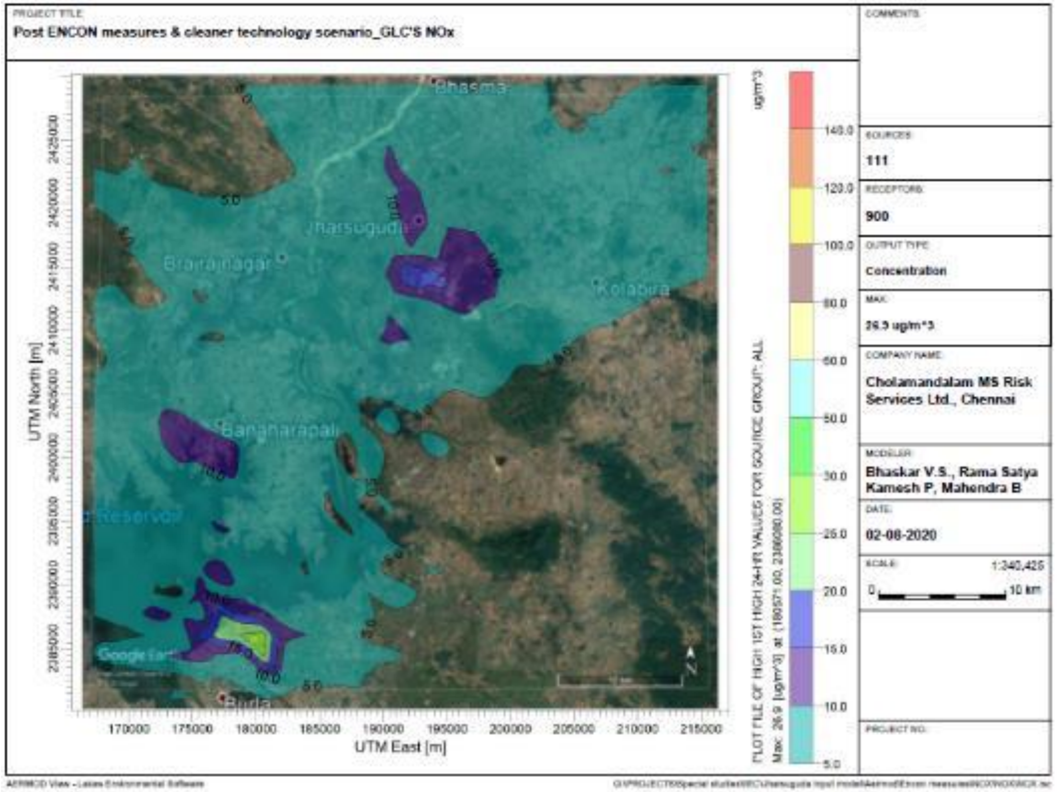
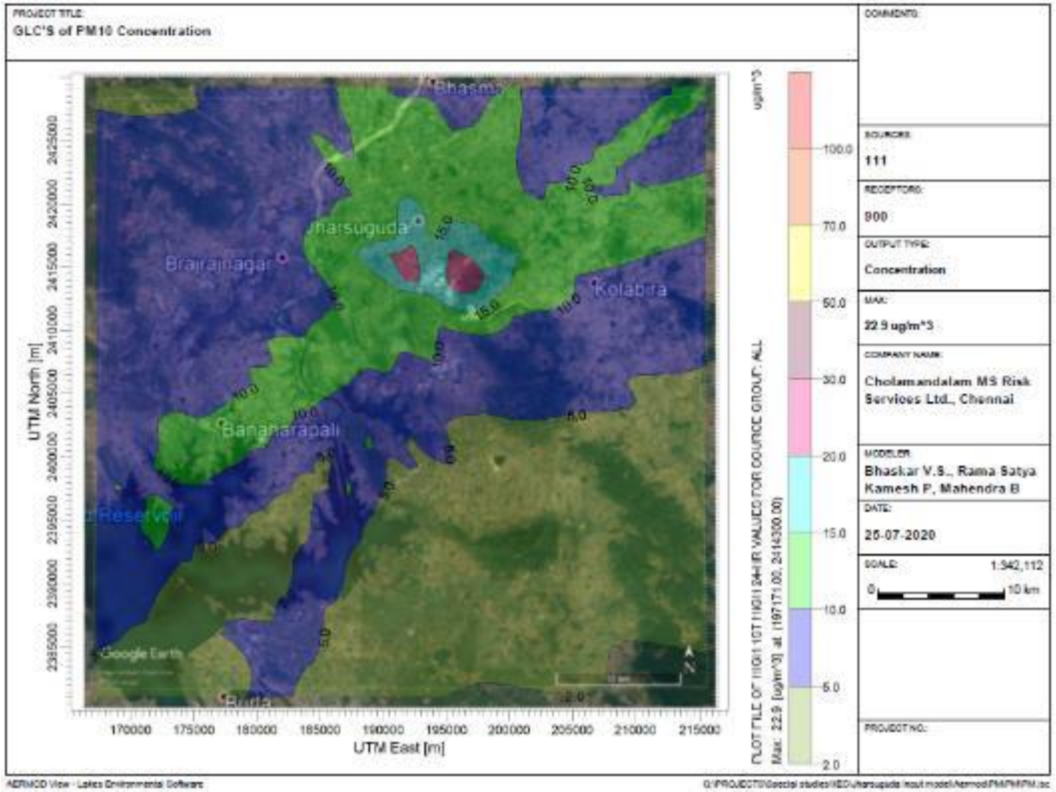
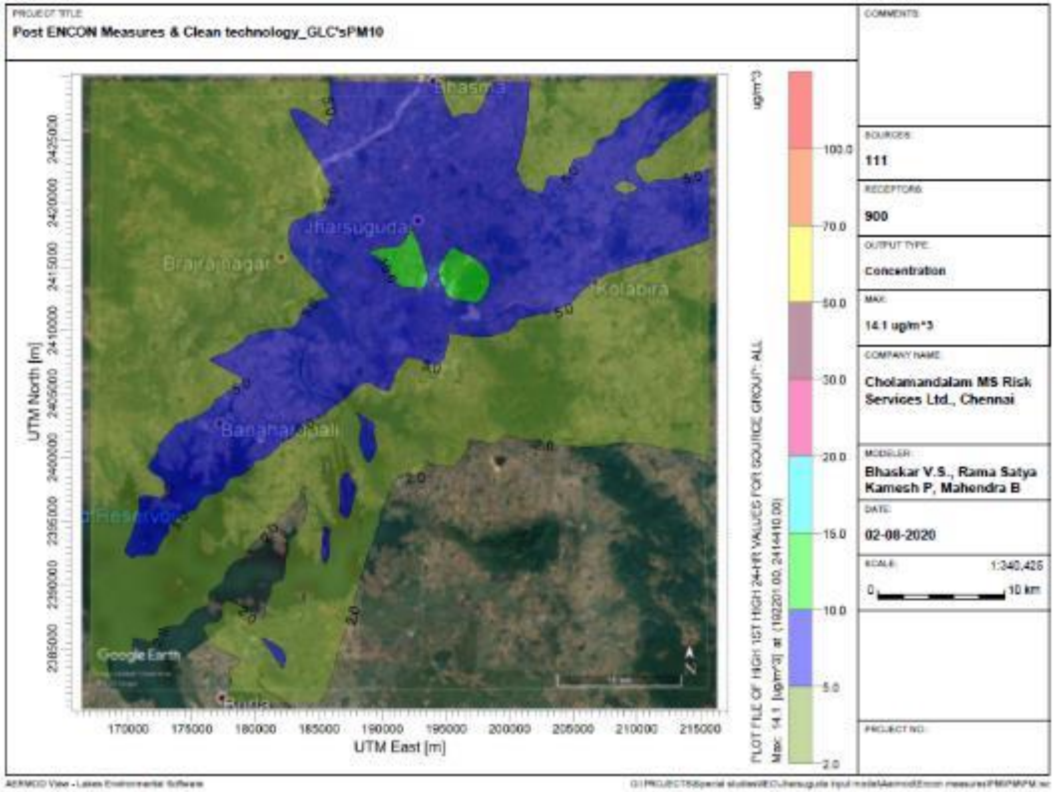


Figure 14: Isopleths Showing Predicted GLC of PM10- Envisaged Reduction Emission Scenario

Uncontrolled Emission Scenario -Predicted GLC of PM10	Envisaged Reduced Emission Scenario-Predicted GLC of PM10
	

11 Impact of Air Pollutants on Health after Implementation of Recommended ENCON & Clean Technological Measures by Industries

In India, CPCB under section 16 (2) (h) of Air Pollution Control Act 1981 has notified following Ambient Air Quality Standards (AAQS) based on health effects of pollutants: -

Table 18: REVISED NATIONAL AMBIENT AIR QUALITY STANDARDS (2009)

S. N.	Pollutants	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
			Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (notified by Central Government)	
1	Sulphur Dioxide (SO_2), µg/m^3	Annual*	50	20	1. Improved West and Gaeke 2. Ultraviolet Fluorescence
		24 Hours**	80	80	
2	Nitrogen Dioxide (NO_2), µg/m^3	Annual*	40	30	1. Modified Jacob & Hochheiser (Na-Arsenite) 2. Chemiluminescence
		24 Hours**	80	80	
3	Particulate Matter (Size <10µm) or PM_{10} µg/m^3	Annual*	60	60	1. Gravimetric 2. TOEM 3. Beta attenuation
		24 Hours**	100	100	
4	Particulate Matter (Size <2.5 µm) or $PM_{2.5}$ µg/m^3	Annual*	40	40	1. Gravimetric 2. TOEM 3. Beta attenuation
		24 Hours **	60	60	
5	Ozone (O_3), µg/m^3	8 hours**	100	100	1. UV photometric 2. Chemiluminescence 3. Chemical Method
		1 hours **	180	180	
6	Lead (Pb), µg/m^3	Annual *	0.50	0.50	1. AAS/ICP Method after sampling using EPM 2000 or equivalent filter paper 2. ED-XRF using Teflon filter
		24 Hour**	1.0	1.0	
7	Carbon Monoxide (CO), mg/m^3	8 Hours **	02	02	Nondispersive Infra-Red (NDIR) Spectroscopy
		1 Hour**	04	04	
8	Ammonia (NH_3), µg/m^3	Annual*	100	100	1. Chemiluminescence 2. Indophenol blue method
		24 Hour**	400	400	
9	Benzene (C_6H_6) , µg/m^3	Annual *	05	05	1. Gas chromatography based continuous analyzer 2. Adsorption and Desorption followed by GC analysis
10	Benzo(a)Pyrene (BaP)- particulate phase only, ng/m^3	Annual*	01	01	Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m^3	Annual*	06	06	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper

12	Nickel (Ni), ng/m^3	Annual*	20	20	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper

** Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform interval.*

*** 24 hourly 08 hourly or 01 hourly monitored values, as applicable shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.*

***NOTE:** Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation*

This implies that if air quality is within the prescribed limit of notified standards then there will not be any significant impact of air pollutants on human health. In Jharsuguda if the major industries namely coal fired thermal power plants, integrated steel plants, sponge iron plants, aluminium plants etc. adopt the ENCON and clean technological measures recommended in the report then the air pollution scenario based on air quality modelling analysis shall be as follows:-

Table 19: Predicted GLC for Baseline Emission Scenario Vs. Post ENCON Scenario and Clean Technology options

Pollutant	Uncontrolled Emission Scenario		Envisaged Reduced Emission Scenario (Post ENCON Measures & Clean Technology Options)		Maximum Reported Baseline Air Quality Data
	Pollutant Load (T/hr)	2nd Height Predicted 24Hrs Avg GLC ($\mu g/m^3$)	Revised Pollutant Load (T/hr)	2nd Height Predicted 24Hrs Avg GLC ($\mu g/m^3$)	
SO_2	50.3	254	4.4	20.2	24
NO_x	24.5	123	4.3	26.9	31
PM_{10}	6.1	22.9	2.7	14.1	81.4

Therefore, even in worst case (second highest value of GLC) the air pollutants shall be well within the stipulated standards as evident from the following table:

Table 20: Maximum Baseline Air Quality if ENCON and Clean Technology Adopted

Pollutant	Second Highest GLC if ENCON and Clean Technology Aspects are Implemented	Maximum Baseline Air Quality
SO_2	20.2 $\mu g/m^3$	24.0 $\mu g/m^3$
NO_x	26.9 $\mu g/m^3$	31.0 $\mu g/m^3$
PM_{10}	14.1 $\mu g/m^3$	81.4 $\mu g/m^3$

Thus, it may be concluded that even in worst case scenario air quality shall be within the notified ambient air quality standards, if industries adopts ENCON and clean technological options recommended in the report, and there will not be any significant impact on health of the people in and around Jharsuguda area.

12 Annexures

1. Baseline Industry Emission Inventory

Annexure 1A: Typical Emission Factors for Various Industries

(Based on USEPA, Technology Benchmark and Recent EIA Studies)

S. N.	Parameter	Unit	Indian Coal Fired Super Critical Power Plants Installed After 2016	Indian Coal Fired Thermal Power Plants Installed Prior to 2003	Imported Coal Fired Thermal Power Plants Installed Prior to 2003	Blast Furnace Pig Iron Making - using Steel Grade High Calorific Indian Coal	Sponge Iron Plant using Steel Grade Calorific Value Coal
1	Typical thermal energy requirement in steel plant[5]	Million KCal/DR product	NA	NA	NA	3.5	7.0
2	Typical thermal energy requirement in power plant	KCal/MW	1850	2300	2200	NA	NA
3	Typical coal calorific value	KCal/Kg	3500 to 3900	3500 to 3900	4500 to 5500	4500 to 5500	4500 to 5500
4	Typical coal consumption in steel plant (peak)	T/T of DR	NA	NA	NA	0.5	1.2
5	Typical coal consumption in power plant (oeak)	T/MW	0.52	0.65	0.48	NA	NA
6	Gas volume from furnace stacks	Nm^3/hr/T of DR	NA	NA	NA	1200 to 1300	1500
7	Gas volume from power plants	Nm^3/MW	3700 to 4000	4500 to 4700	4200 to 4500	NA	NA
8	Stack gas temperature	^oC	150	150	150	120	120
9	Stack height range	M	275	100 to 225	100 to 275	40 to 50m	40 to 50m
10	Sulphur content in coal	%w/w	0.5 to 0.6	0.5 to 0.6	0.6 to 1	0.5 to 0.6	0.5 to 0.6
11	SO_2 emissions based on published EIA reports	Grams/T of steel	NA	NA	NA	0.5	0.5
9	NO_x emissions based on EIA reports steel plants	Grams/T of steel	NA	NA	NA	2.2	2.2
10	PM emissions @ 150 mg/Nm^3	Kg/T of product	NA	NA	NA	0.3	0.3
11	SO_2 emissions based 0.6% S	Kg/MW	10.5	12.5	10.0	NA	NA

[5] https://beeindia.gov.in/sites/default/files/Iron-and-Steel-45-85.pdf

11	NO_x emissions based on 600 mg/Nm^3	Kg/MW	2.4	2.8	2.7	NA	NA
12	PM emissions @ 50 mg/Nm^3	Kg/MW	0.2	0.225	0.215	NA	NA

Annexure 1B: Estimated Emission Inventory from Identified 18 Large & Medium Industries for Air Quality Modelling

Type of Industries	No. of Industries	No. of Stacks as per OSPCB	Stacks with Physical Parameters Available in OSPCB	Stacks with PM Emission Details Available in OSPCB	Stacks with SO_2 Emission Details Available in OSPCB	Stacks with NO_X Emission Details Available in OSPCB	Uncontrolled Emission Inventory (Kg/hr)	Post Encon Measures & Clean Technology Scenario (kg/hr)	Emission Factors/ Assumptions/ Remarks
Standalone Thermal Power Plants	3	11	11	10	3	0	PM: 2774 SO_2: 32645 NO_X: 16643	PM: 832 SO_2: 2774 NO_X: 2774	**Uncontrolled Emission inventory Scenario:** i. For PM - old boiler emission standard of 100 mg/Nm^3 ii. For SO_2 - Coal consumption and sulphur content of 0.6% (uncontrolled emissions) iii. For NO_X - old boiler emission standard of 600 mg/Nm^3 **Post ENCON Measures and adoption of clean technology scenario:** i. After ENCON Measures and clean technology adopting, the thermal power plants standard limits as per MoEF&CC are PM: 100 mg/Nm^3, SO_2: 100 mg/Nm^3, NOx: 100 mg/Nm^3
Captive power plants	10	29	25	9	10	5	PM: 848 SO_2: 17244 NO_X: 7600	PM: 392 SO_2: 1307 NO_X: 1307	
Sponge Iron Plants	6	5	3	4	4	0	PM: 15 SO_2: 49	PM: 11 SO_2: 34	Two out of 6 Industries namely Maa Samaleswari Industries (P) Ltd. and Seven Star Steels Ltd. could not identify in OSPCB in the Jharsuguda

							NO_X: 7	NO_X: 5	area. Hence it is omitted for modelling. **Uncontrolled Emission inventory Scenario:** For Sponge Iron DRI Kilns, emission standards considered based on COINDS report shared by the client and referring to TATA sponge iron plant data. (PM: 110 mg/Nm^3, SO_2: 520 mg/Nm^3, NO_X: 78 mg/Nm^3) **Post ENCON Measures and adoption of clean technology scenario:** The pollution load can be reduced to 30% of the total pollution load
Integrated Steel Plants	2	40	33	40	32	25	PM: 181 SO_2: 373 NO_X: 215	PM: 126 SO_2: 261 NO_X: 150	Out of 2 industries, data for one plant (Bhushan steels) was extracted from the published EIA report. For another plant (Shyam metallics), Due to data gaps in stack gas volumes (for 7 stacks), emission loads could not be estimated even with reference of Bhushan Steels EIA report. **Post ENCON Measures and adoption of clean technology scenario:** The pollution load can be reduced to 30% of the total pollution load
Steel Processing Plants (Rolling Mill)	1	3	3	3	0	0	PM: 4 SO_2: 23 NO_X: 62	PM: 4 SO_2: 18 NO_X: 50	PM emission details are available in OSPCB **Other Emissions for rolling mill plants are estimated based on**

									TATA steel EIA report shared by client: PM: 20 mg/Nm^3, SO_2: 10 mg/Nm^3, NO_X: 150 mg/Nm^3. **Post ENCON Measures and adoption of clean technology scenario:** The pollution load can be reduced to 20% of the total pollution load
Aluminium Smelters	3	26	26	9	0	0	PM: 2241 SO_2: 0 NO_X:0 SO_2: 0 NO_X: 0	PM: 1357 SO_2: 0 NO_X:0	**Other Emissions for Aluminium Smelter flue gas stacks are estimated based on EIA reports published in the region:** PM: 50 mg/Nm^3, SO_2 and NO_X: BDL, F: 0.2 to 0.4 mg/Nm^3 **Post ENCON Measures and adoption of clean technology scenario:** For PM: 30 mg/Nm^3
Total in kg/day		**154**	**101**	**75**	**49**	**30**	**PM: 6063** **SO_2: 50335** **NO_X: 24527**	**PM: 2722** **SO_2: 4395** **NO_X: 4274**	

Notes:

a. The stack details available in the OSPCB online portal are only considered. No assumptions or approximations were made for arriving stack physical parameters in order to reduce the uncertainty. The stack connected to various processes were mapped as per OSPCB data.
b. For Power plant stacks: Due to a wide variation in the stack gas volumes specified in the OSPCB online emission data, we have assumed a benchmark value of 4500 Nm^3/MW as per the combustion gas stoichiometry with 25% excess air as per industry practice.
c. Emissions from the cement plant, refractories plant, could not be estimated due to data gaps in stack physical parameters.

Summary of Emission Loads Based on Stack Heights

	No. of Stacks (with no Data Gaps)	SO_2 Emissions (T/hr)		NO_X Emissions (T/hr)	
		Uncontrolled Scenario	Post ENCON Measures Scenario	Uncontrolled Scenario	Post Encon Measures Scenario
< 50 m	35	10.7	0.9	5.3	0.92
50 - 150 m	54	5.7	0.7	2.3	0.5
150 - 275 m	12	33.9	2.8	17.0	2.8

Annexure 1C: Detailed Emission Inventory Data

S. N.	Industry Name	Type of Plant	Capacity of Plant	Capacity of Power Plant	Type of fuel	Fuel Consumption	Point sources	Stack Connected to	Stack Height (m)	Temp (°C)	Diameter (m)	Velocity (m/s)	Volume (Nm^3/hr)	Uncontrolled			Post ENCON measures Scenario		
														PM (kg/hr)	SO_2 (kg/hr)	NO_X (Kg/hr)	PM (kg/hr)	SO_2 (kg/hr)	NO_X (Kg/hr)
1	Aditya Aluminium, Lapanga, Sambalpur	Aluminium Smelter	3.8 LTPA	900 MW	Coal and Electricity	Coal-10000 T/day	1	CPP	275	128	3.7	11.6	449288	44.9	833.3	269.6	13.48	44.93	44.93
							2	CPP	275	128	3.7	11.6	449288	44.9	833.3	269.6	13.48	44.93	44.93
							3	CPP	275	128	3.7	11.6	449288	44.9	833.3	269.6	13.48	44.93	44.93
							4	CPP	275	128	3.7	11.6	449288	44.9	833.3	269.6	13.48	44.93	44.93
							5	CPP	275	128	3.7	11.6	449288	44.9	833.3	269.6	13.48	44.93	44.93
							6	CPP	275	128	3.7	11.6	449288	44.9	833.3	269.6	13.48	44.93	44.93
							7	Pot Room	100	80	10.4	5.2	1587600	0.2	-	-	0.2	-	-
							8	Pot Room	100	80	10.4	5.2	1587600	0.3	-	-	0.3	-	-
							9	Anode baking Furnace	70	110	2.1	15.0	180000	0.1	-	-	0.1	-	-
							10	Anode baking Furnace	70	110	1.6	24.9	180000	0.6	-	-	0.6	-	-
2	Hindalco Industries Ltd, Smelter unit, Hirakud, Sambalpur	Aluminium Smelter	2.16 LTPA	NA	Electricity		1	Fume treatment plant (FTP)	50	80	3.4	25.9	654000	2.8	-	-	2.8	-	-
							2	FTP	50	80	4.4	25.9	1096000	9.9	-	-	9.9	-	-
							3	FTP	50	80	5.6	25.9	1774100	8.7	-	-	8.7	-	-
							4	FTP	50	80	4.4	21.2	896300	4.1	-	-	4.1	-	-
							5	FTP	80	80	5.3	11.1	684288	4.3	-	-	4.3	-	-
3	Hindalco Industries Ltd,Power Plant, Hirakud, Sambalpur	Thermal Power Plant	467.5 MW	467.5 MW	Coal	7500 T/Day	1	CPP	130	136	3.9	9.6	270720	27.1	469.5	162.4	8.12	27.07	27.072
							2	CPP	130	140	3.5	20.7	472848	47.3	820.1	283.7	14.19	47.28	47.2848
							3	CPP	130	140	3.5	20.7	472848	47.3	820.1	283.7	14.19	47.28	47.2848
							4	CPP	130	140	3.5	20.7	472848	47.3	820.1	283.7	14.19	47.28	47.2848
							5	CPP	130	140	3.5	20.7	472848	47.3	820.1	283.7	14.19	47.28	47.2848
4	Hindalco Industries Ltd-FRP, Hirakud, Sambalpur	Rolling Mill	1,35,000 TPA	NA	Electricity	-	1	Hot Rolling Mill	30	35	2.0	4.1	40776	0.4	3.1	6.1	0.43	2.45	4.89312
							2	Hot Finishing Mill	30	33	2.6	15.0	254850	1.4	19.1	38.2	1.42	15.29	30.582
							3	Cold Rolling Mill	27	33	1.5	20.3	120000	1.9	1.2	18.0	1.95	0.96	14.4
5	Bhushan Power and Steel Ltd, At/P.O: Thelkoloi, Dist: Sambaldpur	Iron & Steel	Crude Steel-3 0 MTPA	560 MW	Coal, Coke, LPG, HSD, Coke oven gas	1. Coal DRI - 120563.28 MT/month, (6251 TPD for CPP - estimated) 2. Coal CPP- 155981.71 MT/month, 3. Coking Coal-92123.63 MT/Month, 4. HSD-531 MT/Month, 5. LPG -3500 MT/ Month, 6. BF Gas - 151200000 NM3/ Month, 7. Coke Oven	1	CPP	130	144	4.0	16.0	120469	4.1	17.0	8.6	3.61	12.05	12.05
							2	CPP	130	145	4.0	15.9	119523	5.1	17.7	8.3	3.59	11.95	8.33
							3	CPP	130	147	4.0	17.0	122654	4.4	14.8	9.5	3.68	12.27	9.53
							4	CPP	95	152	2.5	16.6	105103	3.5	13.5	7.7	3.15	10.51	7.74
							5	CPP	76	148	2.0	15.9	89563	2.6	10.3	6.8	2.69	8.96	6.81
							6	DRI/WHRB 1	76	133	2.0	16.3	123592	4.0	15.0	10.5	2.80	10.500	7.32
							7	DRI/WHRB 2	76	154	2.0	17.3	125197	3.7	16.2	11.1	2.58	11.361	7.80
							8	DRI/WHRB 3	76	170	2.0	17.1	119097	4.5	15.2	9.3	3.13	10.619	6.48
							9	DRI/WHRB 4	76	168	2.0	16.8	117510	3.9	15.9	9.6	2.76	11.158	6.75
							10	DRI/WHRB 5	76	166	2.0	17.9	125806	3.9	14.8	10.5	2.73	10.360	7.34
							11	DRI/WHRB 6	76	158	2.0	17.1	122628	3.7	14.3	9.9	2.60	9.989	6.95
							12	DRI/WHRB 7	76	164	2.0	16.5	116467	3.4	13.6	9.7	2.36	9.513	6.82
							13	DRI/WHRB 8	76	167	2.0	17.4	121758	4.2	15.2	10.6	2.96	10.654	7.39
							14	DRI/WHRB 9	76	168	2.0	17.5	122740	4.4	15.3	10.2	3.11	10.738	7.13
							15	DRI/WHRB 10	76	158	2.0	17.0	121365	4.0	15.6	10.0	2.79	10.906	6.99
							16	DRI/WHRB 11 & 12	76	162	4.2	8.0	247030	7.8	30.8	19.9	5.46	21.553	13.94
							17	DRI Dedusting 1&2	45	47	2.2	10.9	127596	4.5	0.0	0.0	3.12	0.000	0.00
							18	DRI Dedusting 3&4	45	48	2.2	12.6	147227	4.5	0.0	0.0	3.15	0.000	0.00
							19	DRI Dedusting 5&6	45	52	2.2	11.3	130366	3.8	0.0	0.0	2.64	0.000	0.00

S. N.	Industry Name	Type of Plant	Capacity of Plant	Capacity of Power Plant	Type of fuel	Fuel Consumption	Point sources	Stack Connected to	Stack Height (m)	Temp (°C)	Diameter (m)	Velocity (m/s)	Volume (Nm^3/hr)	Uncontrolled			Post ENCON measures Scenario		
														PM (kg/hr)	SO_2 (kg/hr)	NO_x (Kg/hr)	PM (kg/hr)	SO_2 (kg/hr)	NO_x (Kg/hr)
						Gas - 19440000 NM^3/ Month	20	DRI Dedusting 7&8	45	47	2.2	12.7	147767	4.3	0.0	0.0	3.02	0.000	0.00
							21	DRI Dedusting 9&10	45	48	2.2	12.8	148316	5.0	0.0	0.0	3.53	0.000	0.00
							22	DRI Dedusting 11&12	45	50	2.9	8.6	172040	5.3	0.0	0.0	3.68	0.000	0.00
							23	SMSII (Stack 1)	60	85	3.0	15.0	291264	7.3	8.1	8.2	5.11	5.642	5.71
							24	SMSII (Stack 2)	60	83	3.0	14.5	282225	8.3	9.1	7.3	5.80	6.391	5.14
							25	BF-cast house dedusting	35	84	2.4	14.4	179788	9.0	0.0	8.1	6.29	0.000	5.66
							26	BF-stock house dedusting	30	29	2.4	10.5	154887	7.7	0.0	0.0	5.38	0.000	0.00
							27	BF-stove stack	65	350	2.5	14.6	112878	1.2	0.0	22.4	0.81	0.000	15.66
							28	Lime Plant-Stack-1	50	72	0.8	11.3	16106	0.6	0.8	0.9	0.39	0.581	0.64
							29	Lime Plant-Stack-2	50	74	0.8	11.2	15985	0.5	0.9	0.9	0.35	0.595	0.64
							30	Lime Plant-Stack-3	50	71	0.8	11.2	15993	0.5	0.8	0.9	0.34	0.560	0.62
							31	Pellet Plant-dedusting	50	54	3.0	14.5	308528	15.4	0.0	0.0	10.80	0.000	0.00
							32	Pellet Plant-windbox & hood exhaust	85	123	3.0	16.1	300000	15.0	2.2	5.4	10.50	1.540	3.78
							33	Coke ovens-WHRB (2 Nos.)	70	174	2.5	17.3	186043	3.9	30.5	8.2	2.72	21.315	5.73
							34	Coke ovens-WHRB (2 Nos.)	70	164	2.5	17.2	189969	4.9	32.4	7.0	3.40	22.694	4.88
							35	Sinter plant-charging	100	142	4.0	15.1	449970	13.3	106.0	7.7	9.28	74.200	5.36
							36	Sinter plant-discharging	40	132	3.0	12.9	221609	8.4	0.0	4.4	5.85	0.000	3.10
							37	Sinter plant-dedusting	40	34	2.5	15.0	235706	8.3	0.0	0.0	5.79	0.000	0.00
							38	Wire rod mill-reheating furnace	60	250	2.0	0.0	40000	2.0	0.6	12.0	1.40	0.448	8.40
6	Aryan Ispat & Power Ltd, Bomaloi, Sambalpur	Iron & Steel	Sponge Iron-Kiln-I& II-2X100 TPD, Sponge Iron-Kiln-III-1X350 TPD, Captive Power Plant - 18 MW (4 MW- WHRB + 6 MW AFBC), Coal Washery-7.0 LTPA, Coal Crushing an sizing unit (For railway siding) - 200 TPH, Railway Siding (Captive and commercial use)- Iron ore, coal, dolomite, manganese, Coke and MS billet-31 LTPA	Captive Power Plant - 18 MW (4 MW-WHRB + 6 MW AFBC)	Coal	Power Plant-Coal-150 T/day, Sponge iron-Coal-1000 MT/Day	1	2x100 DRI Kiln	45	120	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							2	DRI 350 & AFBC	75	109	1.8	9.2	60469	6.0	75.0	36.3	1.81	6.05	6.05

S. N.	Industry Name	Type of Plant	Capacity of Plant	Capacity of Power Plant	Type of fuel	Fuel Consumption	Point sources	Stack Connected to	Stack Height (m)	Temp (°C)	Diameter (m)	Velocity (m/s)	Volume (Nm^3/hr)	Uncontrolled			Post ENCON measures Scenario		
														PM (kg/hr)	SO_2 (kg/hr)	NO_x (Kg/hr)	PM (kg/hr)	SO_2 (kg/hr)	NO_x (Kg/hr)
7	Shyam Mettalics and Energy Limited, Pandloi, Sambalpur	Iron & Steel	Crude Steel-1.44 MTPA	Power Plant - 115 MW	Coal, Furnace Oil	Coal -1500 T/day, Furnace Oil-10 KLD	1	AFBC-1,WHRB-1 and WHRB-2	70	70	4.0	8.3	302344	30.2	375.0	181.4	9.07	30.23	30.23
							2	AFBC-2 and AFBC-3	86	40	2.6	17.6	302344	30.2	375.0	181.4	9.07	30.23	30.23
							3	WHRB-3 and WHRB-4	70	100	3.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							4	PELLET PLANT	65	100	3.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							5	Induction Furnace	40	60	1.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							6	Induction Furnace	40	60	1.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							7	Induction Furnace	40	60	2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							8	Induction Furnace	40	60	2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							9	WHRB-5&6	60	100	3.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	Maa Samaleswari Industries (P) Ltd, At/P.O: Lapanga, Dist: Sambalpur	Iron & Steel	Sponge Iron-2X100 TPD	NA	Coal	Coal-235 T/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	Viraj Steel and Energy Limited, Gurupali, Rengali, Sambalpur	Iron & Steel	Sponge Iron-Kiln-1-1X350 TPD, Sponge Iron-Kiln-1l-1X350 TPD, Power Plant - 28 MW (2X8 MW-WHRB + 12 MW AFBC), Induction furnace-2X12 T/H.	Power Plant - 28 MW (2X8 MW-WHRB + 12 MW AFBC)	Coal & Dolo Char	Power Plant-Coal -1.0 Ton/ MW and Dolo char - 1.0/MW, Sponge Iron-Coal-1.2 T/sponge iron production.	1	WHRB	65	120	4.5	2.3	90000	1.6	0.8	-	1.11	**0.56**	-
							2	WHRB	65	120	4.5	2.3	90000	3.8	1.5	-	2.69	**1.04**	-
							3	AFBC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	IB Thermal Power Station,OPGC (Ltd)	Thermal Power Plant	Plant 1-210x2 MW, Plant 2-2X660 MW	Plant 1-210x2 MW, Plant 2-2X660 MW	Coal, LDO and Diesel	**Plant 1**-LDO-6 KL/Day, Coal-8000 MT/Day, **Plant-2**-LDO-4KL/Day, HFO-3 KL/Day, Coal-23000 MT/Day	1	Attached to boiler of Unit#1	220	130	4.6	31.0	6248438	624.8	7750.0	3749.1	187.45	624.84	624.8
							2	Attached to boiler of Unit#2	220	130	4.6	31.0	6248438	624.8	7750.0	3749.1	187.45	624.84	624.8
11	Seven Star Steels Ltd	Sponge Iron Plant, SMS and Power plant	DRI Kiln-2x100 TPD, 1X12 TPH SMS and 8 MW Power plant	8 MW	Coal & HSD	Coal-430 T/Day, HSD-0.540 KL/Day	-N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	Thakur Prasad Sao & Sons Pvt Ltd.	Sponge Iron Plant, TMT Power plant, Induction furnace , Coal washery and Producer gas plant	Sponge Iron-350 TPD, Power Plant-12 MW, Induction furnace-4x8 T/H, Coal Washery-5.76 LPA, TMT Bar-1 LTPA, PGP-6000 Nm^3/Hr	12 MW	Coal & Furnace Oil	Coal-920 T/day, FO-0.25 KL/Day	1	DRI Kiln	60	150	2.6	7.1	90000	9.9	46.8	7.0	6.93	32.76	4.91
							2	AFBC boiler	60	150	2.4	35.3	370875	46.1	460.0	276.5	11.13	37.09	37.09
13				2400 MW			1	IPP,Phase-1,Unit-1	275	140	6.8	37.9	3269790	327.0	3348.8	1961.9	98.09	326.98	326.98

S. N.	Industry Name	Type of Plant	Capacity of Plant	Capacity of Power Plant	Type of fuel	Fuel Consumption	Point sources	Stack Connected to	Stack Height (m)	Temp (°C)	Diameter (m)	Velocity (m/s)	Volume (Nm³/hr)	Uncontrolled PM (kg/hr)	Uncontrolled SO_2 (kg/hr)	Uncontrolled NO_X (Kg/hr)	Post ENCON measures Scenario PM (kg/hr)	Post ENCON measures Scenario SO_2 (kg/hr)	Post ENCON measures Scenario NO_X (Kg/hr)
	Vedanta Ltd (TPP)	Thermal Power Plant	Electricity-2400 MW		Coal, LDO and Diesel	Coal-10037 MT/Day, LDO-2.32 KL/Hour, Diesel-0.383-KL/Hour	2	IPP,Phase-1,Unit-2	275	140	6.8	37.9	3269790	327.0	3348.8	1961.9	98.09	326.98	326.98
							3	IPP,Phase-2,Unit-3	275	140	6.8	37.9	3269790	327.0	3348.8	1961.9	98.09	326.98	326.98
							4	IPP,Phase-2,Unit-4	275	140	6.8	37.9	3269790	327.0	3348.8	1961.9	98.09	326.98	326.98
14	Vedanta Ltd (Smelter)	Aluminium Smelter	Aluminium smelter plant-16LTPA	NA	Electricity and Furnace Oil-0.03 KL/MT of Al	NA	1	Smelter-1, Potline-1 ,FTP-1	80	110	9.3	16.9	2923085	146.2	-	-	87.69	-	-
							2	Smelter-1, Potline-1 ,FTP-2	80	110	9.3	16.9	2923085	146.2	-	-	87.69	-	-
							3	Smelter-1, Potline-2 ,FTP-3	80	110	9.3	16.9	2923085	146.2	-	-	87.69	-	-
							4	Smelter-1, Potline-2 ,FTP-4	80	110	9.3	16.9	2923085	146.2	-	-	87.69	-	-
							5	Smelter-2, Potline-3 ,FTP-5	80	120	8.3	28.8	3900024	195.0	-	-	117.00	-	-
							6	Smelter-2, Potline-3 ,FTP-6	80	120	8.3	28.8	3900024	195.0	-	-	117.00	-	-
							7	Smelter-2, Potline-4 ,FTP-7	80	120	8.3	28.8	3900024	195.0	-	-	117.00	-	-
							8	Smelter-2, Potline-4 ,FTP-8	80	120	8.3	28.8	3900024	195.0	-	-	117.00	-	-
							9	Smelter-2, Potline-4 ,FTP-9	80	120	8.3	28.8	3900024	195.0	-	-	117.00	-	-
							10	Smelter-2, Potline-4 ,FTP-10	80	120	8.3	28.8	3900024	195.0	-	-	117.00	-	-
							11	Smelter-2, Potline-4 ,FTP-11	80	120	8.3	28.8	3900024	195.0	-	-	117.00	-	-
							12	Smelter-2, Potline-4 ,FTP-12	80	120	8.3	28.8	3900024	195.0	-	-	117.00	-	-
							13	Smelter-1, Bake Oven ,FTP-1	50	100	3.8	8.2	238658	11.9	-	-	7.16	-	-
							14	Smelter-1, Bake Oven ,FTP-2	50	100	3.8	8.2	238658	11.9	-	-	7.16	-	-
							15	Smelter-2, Bake Oven ,FTP-3	50	100	2.8	16.4	273758	13.7	-	-	8.21	-	-
							16	Smelter-2, Bake Oven ,FTP-4	50	100	2.8	16.4	273758	13.7	-	-	8.21	-	-
							17	Smelter-2, Bake Oven ,FTP-5	50	100	2.8	16.4	273758	13.7	-	-	8.21	-	-
15	Vedanta Ltd (CPP)	Captive Power Plant	Power plant-9x135 MW		Coal and Furnace Oil	Coal-0.734 MT/MWH, Furnace Oil-0.00168 KL/MWH	1	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
							2	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
							3	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
							4	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
							5	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
							6	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
							7	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
							8	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
							9	CPP	50	150	3.5	42.9	958696	47.9	1189.1	575.2	28.76	95.87	95.87
16	Ultratech Cement Ltd	Cement	Cement-4MTPA	NA	NIL	NA	1	Cement Mill Outlet	43	100	1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							2	Cement Mill Vent	60	80	1.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

S. N.	Industry Name	Type of Plant	Capacity of Plant	Capacity of Power Plant	Type of fuel	Fuel Consumption	Point sources	Stack Connected to	Stack Height (m)	Temp (°C)	Diameter (m)	Velocity (m/s)	Volume (Nm³/hr)	Uncontrolled			Post ENCON measures Scenario		
														PM (kg/hr)	SO_2 (kg/hr)	NO_x (Kg/hr)	PM (kg/hr)	SO_2 (kg/hr)	NO_x (Kg/hr)
17	SMC Power Generation Ltd		DRI Kiln-2x300 TPD, CPP -33 MW, Induction furnace-7x12 T/H, Coal Washery-10,000 TPM, TMT Bar-1 LTPA, Rolling mill-1.8 LTPA, Iron ore crusher-24,000 TPM		Coal	Coal-120 T/day	1	AFBC	70	150	4.8	3.5	148500	14.9	184.2	89.1	4.46	14.85	14.85
							2	WHRB	65	150	4.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	TRL Krosaki Refractories Limited	Ceramics and Refractories	Silica Bricks-24,000 TPA, Basic Bricks-36,000 TPA, High Alumina Bricks-48,000 TPA, Dolomite Bricks-80,000 TPA, FCP-6,600 TPA, Monolithic-30,000 TPA, Special Monolothic-1,400 TPA, Other Castables-6,000 TPA, Tap Hole Clay-18,000 TPA, RH Sniorkel Prodcut-312 Numbers/Annum	NA	Coal, Furnace Oil, Pet coke	Coal-80 MT/Day, Pet coke-31 MT/Day, FO-60 KL/Day	1	Grinding	18	N/A	0.8	15.7	30500	N/A	N/A	N/A	N/A	N/A	N/A
							2	Grinding	18	N/A	0.8	14.1	25500	N/A	N/A	N/A	N/A	N/A	N/A
							3	Grinding	18	N/A	0.8	13.7	26600	N/A	N/A	N/A	N/A	N/A	N/A
							4	Grinding & Mixing	18	N/A	0.8	13.1	25600	N/A	N/A	N/A	N/A	N/A	N/A
							5	Grinding	18	N/A	1.0	14.6	41297	N/A	N/A	N/A	N/A	N/A	N/A
							6	Grinding	18	N/A	1.0	11.0	31114	N/A	N/A	N/A	N/A	N/A	N/A
							7	Grinding & Mixing	18	N/A	1.1	15.1	49819	N/A	N/A	N/A	N/A	N/A	N/A
							8	Grinding & Mixing	18	N/A	0.6	15.8	14014	N/A	N/A	N/A	N/A	N/A	N/A
							9	Grinding & Mixing	18	N/A	1.0	15.6	39823	N/A	N/A	N/A	N/A	N/A	N/A
							10	Grinding & Mixing	18	N/A	0.7	13.4	18572	N/A	N/A	N/A	N/A	N/A	N/A
							11	Mixing	19	N/A	0.3	16.7	4834	N/A	N/A	N/A	N/A	N/A	N/A
							12	Mixing	19	N/A	0.5	23.8	16817	N/A	N/A	N/A	N/A	N/A	N/A
							13	Mixing	19	N/A	0.5	21.2	16818	N/A	N/A	N/A	N/A	N/A	N/A
							14	Grinding	38	N/A	1.0	12.8	36206	N/A	N/A	N/A	N/A	N/A	N/A
							15	Grinding & Mixing	38	N/A	1.0	12.4	35074	N/A	N/A	N/A	N/A	N/A	N/A
							16	Grinding	38	N/A	1.0	12.2	34509	N/A	N/A	N/A	N/A	N/A	N/A
							17	Tunnel Kiln		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							18	Drier	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							19	Drier	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							20	Boiler	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							21	Boiler	11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							22	Tunnel Kiln		N/A	1.0	3.8	10760	N/A	N/A	N/A	N/A	N/A	N/A
							23	Tunnel Kiln		N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							24	Tunnel Kiln	11	N/A	0.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							25	Tunnel Kiln	13	N/A	0.8	17.3	32008	N/A	N/A	N/A	N/A	N/A	N/A
							26	Tunnel Kiln	13	N/A	0.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							27	Tunnel Kiln	14	N/A	0.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							28	Rotary Kiln	65	N/A	1.2	8.4	34214	N/A	N/A	N/A	N/A	N/A	N/A
							29	Rotary Kiln	65	N/A	1.2	8.6	34896	N/A	N/A	N/A	N/A	N/A	N/A
							30	Tunnel Kiln	45	N/A	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							31	Tunnel Kiln	45	N/A	1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							32	Tunnel Kiln	42	N/A	1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							33	Injector	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							34	Heat Chamber	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							35	Heater	42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							36	Tunnel Kiln	40	N/A	1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							37	Cooking Furnace	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							38	Baking Furnace	12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

S. N.	Industry Name	Type of Plant	Capacity of Plant	Capacity of Power Plant	Type of fuel	Fuel Consumption	Point sources	Stack Connected to	Stack Height (m)	Temp (°C)	Diameter (m)	Velocity (m/s)	Volume (Nm^3/hr)	Uncontrolled			Post ENCON measures Scenario		
														PM (kg/hr)	SO_2 (kg/hr)	NO_X (Kg/hr)	PM (kg/hr)	SO_2 (kg/hr)	NO_X (Kg/hr)
							39	Boiler	24	N/A	0.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							40	Mixing	24	N/A	0.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
							41	Mixing	24	N/A	0.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Annexure II

2. Uncontrolled Emission Scenario – Model Input and Output

SO_2

***** THE SUMMARY OF MODEL INPUT POINT SOURCES DATA*****

Source ID	Emission rate (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)
1	2.31E+02	196074.8	2406971.2	10	275	401	11.6	3.7
2	2.31E+02	196074.8	2406971.2	10	275	401	11.61	3.7
3	2.31E+02	196074.8	2406971.2	10	275	401	11.61	3.7
4	2.31E+02	196067	2406741	10	275	401	11.61	3.7
5	2.31E+02	196067	2406741	10	275	401	11.61	3.7
6	2.31E+02	196067	2406741	10	275	401	11.61	3.7
7	0.00E+00	195171	2406894.6	10	100	353	5.19	10.4
8	0.00E+00	194350.6	2406930.8	10	100	353	5.19	10.4
9	0.00E+00	195024.3	2406748.3	10	70	383	15.01	2.06
10	0.00E+00	195024.3	2406748.3	10	70	383	24.88	1.6
11	0.00E+00	179278.1	2385210.2	10	50	353	25.89	3.4
12	0.00E+00	179543.6	2385298.7	10	50	353	25.9	4.4
13	0.00E+00	179566.6	2385210.2	10	50	353	25.88	5.6
14	0.00E+00	179455.1	2384856.2	10	50	353	21.18	4.4
15	0.00E+00	179278.1	2385033.2	10	80	353	11.15	5.3
16	1.30E+02	179455.1	2385210.2	10	130	409	9.58	3.87
17	2.28E+02	179720.6	2385298.7	10	130	413	20.66	3.5
18	2.28E+02	178747.2	2385210.2	10	130	413	20.66	3.5
19	2.28E+02	179366.6	2384944.7	10	130	413	20.66	3.5
20	2.28E+02	179278.1	2385121.7	10	130	413	20.66	3.5
21	8.50E-01	179189.6	2385387.2	10	30	308	4.07	2
22	5.31E+00	179720.6	2384856.2	10	30	306	14.95	2.6
23	3.33E-01	179632.1	2385387.2	10	26.7	306	20.33	1.53
24	4.73E+00	191511	2410333	10	130	417	16.02	4
25	4.91E+00	191742	2410370	10	130	418	15.92	4
26	4.10E+00	191684	2410507	10	130	420.33	16.97	4

27	3.74E+00	191845	2409715	10	95	424.67	16.62	2.5
28	2.85E+00	191734	2409655	10	76	421	15.89	2
29	4.17E+00	191586.5	2409838.3	10	76	406.33	16.27	2
30	4.51E+00	191641.6	2409715.3	10	76	427.33	17.34	2
31	4.21E+00	191874.4	2409418.2	10	76	443	17.1	2
32	4.43E+00	191854.4	2409425.2	10	76	440.67	16.78	2
33	4.11E+00	191607.4	2409820.9	10	76	439	17.9	2
34	3.96E+00	191587	2409893.8	10	76	431	17.13	2
35	3.78E+00	191740	2409933.1	10	76	436.67	16.48	2
36	4.23E+00	191615	2410110.4	10	76	440.33	17.37	2
37	4.26E+00	191615.5	2410120.6	10	76	441	17.54	2
38	4.33E+00	191588.6	2410158.2	10	76	431.33	16.96	2
39	8.55E+00	192001.2	2410385.8	10	76	435	8.01	4.17
40	0.00E+00	191926	2409811.7	10	45	319.67	10.92	2.2
41	0.00E+00	192011	2409598.5	10	45	320.67	12.64	2.2
42	0.00E+00	191862.3	2409938.9	10	45	325	11.35	2.2
43	0.00E+00	191893	2410135	10	45	320	12.66	2.2
44	0.00E+00	191817.4	2408365.9	10	45	321.33	12.76	2.2
45	0.00E+00	192001.2	2410385.8	10	45	322.83	8.56	2.9
46	2.24E+00	191611.1	2409192.1	10	60	357.67	15	3
47	2.54E+00	191815.9	2408701.2	10	60	356	14.47	3
48	0.00E+00	191675	2408376.8	10	35	356.67	14.43	2.4
49	0.00E+00	191771.9	2408428.1	10	30	301.54	10.51	2.4
50	0.00E+00	191956.2	2408403.3	10	65	623.25	14.59	2.5
51	2.31E-01	192071.6	2408727.3	10	50	345	11.25	0.8
52	2.36E-01	191904.1	2408635.2	10	50	346.67	11.22	0.8
53	2.22E-01	191938	2408623	10	50	344.23	11.15	0.8
54	0.00E+00	192756.9	2408513.5	10	50	327	14.53	3
55	6.11E-01	192770.5	2408413.1	10	85	395.67	16.06	3

56	8.46E+00	192230.5	2408897.9	10	70	447	17.25	2.5
57	9.01E+00	192348.6	2408677.8	10	70	437	17.22	2.5
58	2.94E+01	191961.2	2408923.2	10	100	415.33	15.14	4
59	0.00E+00	192147	2408773.2	10	40	405.33	12.94	3
60	0.00E+00	192076.9	2408982.6	10	40	307.33	15.02	2.5
61	1.78E-01	191800.4	2408425.4	10	60	523	0	2
62	0.00E+00	193768	2404028	10	45	393	0	0.9
63	2.08E+01	193956	2404054	10	75	382	9.2	1.8
64	1.04E+02	193731.3	2400452.1	10	70	343	8.28	4.03
65	1.04E+02	193803.1	2400444.6	10	86	313	17.6	2.64
66	0.00E+00	193751	2400476	10	70	373	0	3.43
67	0.00E+00	193752	2399432	10	65	373	0	3
68	0.00E+00	193677	2400471.6	10	40	333	0	1.8
69	0.00E+00	193672.4	2400382.4	10	40	333	0	1.8
70	0.00E+00	193669.1	2400361	10	40	333	0	2
71	0.00E+00	193677	2400471.6	10	40	333	0	2
72	0.00E+00	193515.5	2400151.4	10	60	373	0	3
73	2.24E-01	192893	2402101	10	65	393	2.3	4.5
74	4.14E-01	192893	2402101	10	65	393	2.3	4.5
75	0.00E+00	192931.1	2402149.5	10	0	0	0	0
76	2.15E+03	174322.4	2400696.9	10	220	403	31	4.6
77	2.15E+03	174410.9	2400696.9	10	220	403	31	4.6
78	1.30E+01	188393.2	2425033.3	10	60	423	7.08	2.64
79	1.28E+02	188304.7	2424767.8	10	60	423	35.3	2.4
80	9.30E+02	193945.7	2415095	10	275	413	37.85	6.8
81	9.30E+02	194081	2414976	10	275	413	37.85	6.8
82	9.30E+02	194201	2415223	10	275	413	37.85	6.8
83	9.30E+02	194201	2415223	10	275	413	37.85	6.8
84	0.00E+00	195572	2413257	10	80	383	16.85	9.28

85	0.00E+00	195814.6	2413733.6	10	80	383	16.85	9.28
86	0.00E+00	195686	2413224	10	80	383	16.85	9.28
87	0.00E+00	195954	2413712	10	80	383	16.85	9.28
88	0.00E+00	193757	2414585	10	80	393	28.84	8.3
89	0.00E+00	193424.4	2414004.9	10	80	393	28.84	8.3
90	0.00E+00	194046	2414641	10	80	393	28.84	8.3
91	0.00E+00	193603	2414034	10	80	393	28.84	8.3
92	0.00E+00	193982.2	2414304.3	10	80	393	28.84	8.3
93	0.00E+00	193628	2413849	10	80	393	28.84	8.3
94	0.00E+00	194157	2414179.2	10	80	393	28.84	8.3
95	0.00E+00	193769.8	2413723.4	10	80	393	28.84	8.3
96	0.00E+00	194162.1	2413192.5	10	50	373	8.21	3.75
97	0.00E+00	194047.7	2413225.5	10	50	373	8.21	3.75
98	0.00E+00	194835.1	2415303.9	10	50	373	16.41	2.84
99	0.00E+00	194862.6	2415241.8	10	50	373	16.41	2.84
100	0.00E+00	193482.7	2415237.4	10	50	373	16.41	2.84
101	3.30E+02	195324.8	2412092.2	10	50	423	42.91	3.5
102	3.30E+02	195534.5	2411913.9	10	50	423	42.91	3.5
103	3.30E+02	193724.2	2413928.5	10	50	423	42.91	3.5
104	3.30E+02	193840.7	2413833.1	10	50	423	42.91	3.5
105	3.30E+02	194290.4	2413168.1	10	50	423	42.91	3.5
106	3.30E+02	195442.8	2413019.7	10	50	423	42.91	3.5
107	3.30E+02	194610.2	2413217.4	10	50	423	42.91	3.5
108	3.30E+02	194232.1	2413042.6	10	50	423	42.91	3.5
109	3.30E+02	194225.5	2413113.9	10	50	423	42.91	3.5
110	5.12E+01	188570.2	2412909.3	10	70	423	3.5	4.8
111	0.00E+00	188835.7	2412643.9	10	65	423	0	4.5

*** THE SUMMARY OF HIGHEST 24-HR RESULTS ***

GROUP ID	RANK HIGHEST VALUES	AVERAGE CONC MICROGRAM/M**3	DATE (YYMMDDHH)	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	TYPE (GRIDCART)	NETWORK GRID-ID
ALL	1ST HIGH VALUE IS	253.9349	19050224:	(192191.00, 2414300.11, 10.00, 10.00, 0.00)	GC	UCART1
	2ND HIGH VALUE IS	248.74179	19040224:	(192191.00, 2414300.11, 10.00, 10.00, 0.00)	GC	UCART1
	3RD HIGH VALUE IS	138.62169	19052824:	(192191.00, 2414300.11, 10.00, 10.00, 0.00)	GC	UCART1
	4TH HIGH VALUE IS	138.54695	19041924:	(192191.00, 2414300.11, 10.00, 10.00, 0.00)	GC	UCART1
	5TH HIGH VALUE IS	134.5642	19051424:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	6TH HIGH VALUE IS	133.32806	19052424:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	7TH HIGH VALUE IS	130.59873	19051824:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	8TH HIGH VALUE IS	128.51904	19053024:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	9TH HIGH VALUE IS	127.96215	19031924:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	10TH HIGH VALUE IS	124.07852	19041024:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	11TH HIGH VALUE IS	120.40873	19052724:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	12TH HIGH VALUE IS	118.97388	19051124:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	13TH HIGH VALUE IS	118.53247	19042124:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	14TH HIGH VALUE IS	118.02621	19052024:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	15TH HIGH VALUE IS	117.0917	19032824:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	16TH HIGH VALUE IS	115.85454	19041324:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	17TH HIGH VALUE IS	115.38462	19042924:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	18TH HIGH VALUE IS	115.22255	19032624:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	19TH HIGH VALUE IS	111.62205	19031324:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	20TH HIGH VALUE IS	111.22038	19051724:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	21ST HIGH VALUE IS	110.14901	19031224:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	22ND HIGH VALUE IS	109.17921	19051324:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	23RD HIGH VALUE IS	107.68938	19050824:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	24TH HIGH VALUE IS	107.65175	19042424:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1
	25TH HIGH VALUE IS	107.00213	19033024:	(175591.00, 2401020.11, 10.00, 10.00, 0.00)	GC	UCART1

NO_x

***** THE SUMMARY OF MODEL INPUT POINT SOURCES DATA*****

Source ID	Emission rate (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)
1	7.49E+01	196074.8	2406971.2	10	275	401	11.6	3.7
2	7.49E+01	196074.8	2406971.2	10	275	401	11.61	3.7
3	7.49E+01	196074.8	2406971.2	10	275	401	11.61	3.7
4	7.49E+01	196067	2406741	10	275	401	11.61	3.7
5	7.49E+01	196067	2406741	10	275	401	11.61	3.7
6	7.49E+01	196067	2406741	10	275	401	11.61	3.7
7	0.00E+00	195171	2406894.6	10	100	353	5.19	10.4
8	0.00E+00	194350.6	2406930.8	10	100	353	5.19	10.4
9	0.00E+00	195024.3	2406748.3	10	70	383	15.01	2.06
10	0.00E+00	195024.3	2406748.3	10	70	383	24.88	1.6
11	0.00E+00	179278.1	2385210.2	10	50	353	25.89	3.4
12	0.00E+00	179543.6	2385298.7	10	50	353	25.9	4.4
13	0.00E+00	179566.6	2385210.2	10	50	353	25.88	5.6
14	0.00E+00	179455.1	2384856.2	10	50	353	21.18	4.4
15	0.00E+00	179278.1	2385033.2	10	80	353	11.15	5.3
16	4.51E+01	179455.1	2385210.2	10	130	409	9.58	3.87
17	7.88E+01	179720.6	2385298.7	10	130	413	20.66	3.5
18	7.88E+01	178747.2	2385210.2	10	130	413	20.66	3.5
19	7.88E+01	179366.6	2384944.7	10	130	413	20.66	3.5
20	7.88E+01	179278.1	2385121.7	10	130	413	20.66	3.5
21	1.70E+00	179189.6	2385387.2	10	30	308	4.07	2
22	1.06E+01	179720.6	2384856.2	10	30	306	14.95	2.6
23	5.00E+00	179632.1	2385387.2	10	26.7	306	20.33	1.53
24	2.38E+00	191511	2410333	10	130	417	16.02	4

25	2.31E+00	191742	2410370	10	130	418	15.92	4
26	2.65E+00	191684	2410507	10	130	420.33	16.97	4
27	2.15E+00	191845	2409715	10	95	424.67	16.62	2.5
28	1.89E+00	191734	2409655	10	76	421	15.89	2
29	2.91E+00	191586.5	2409838.3	10	76	406.33	16.27	2
30	3.09E+00	191641.6	2409715.3	10	76	427.33	17.34	2
31	2.57E+00	191874.4	2409418.2	10	76	443	17.1	2
32	2.68E+00	191854.4	2409425.2	10	76	440.67	16.78	2
33	2.91E+00	191607.4	2409820.9	10	76	439	17.9	2
34	2.76E+00	191587	2409893.8	10	76	431	17.13	2
35	2.71E+00	191740	2409933.1	10	76	436.67	16.48	2
36	2.93E+00	191615	2410110.4	10	76	440.33	17.37	2
37	2.83E+00	191615.5	2410120.6	10	76	441	17.54	2
38	2.78E+00	191588.6	2410158.2	10	76	431.33	16.96	2
39	5.53E+00	192001.2	2410385.8	10	76	435	8.01	4.17
40	0.00E+00	191926	2409811.7	10	45	319.67	10.92	2.2
41	0.00E+00	192011	2409598.5	10	45	320.67	12.64	2.2
42	0.00E+00	191862.3	2409938.9	10	45	325	11.35	2.2
43	0.00E+00	191893	2410135	10	45	320	12.66	2.2
44	0.00E+00	191817.4	2408365.9	10	45	321.33	12.76	2.2
45	0.00E+00	192001.2	2410385.8	10	45	322.83	8.56	2.9
46	2.27E+00	191611.1	2409192.1	10	60	357.67	15	3
47	2.04E+00	191815.9	2408701.2	10	60	356	14.47	3
48	2.24E+00	191675	2408376.8	10	35	356.67	14.43	2.4
49	0.00E+00	191771.9	2408428.1	10	30	301.54	10.51	2.4
50	6.21E+00	191956.2	2408403.3	10	65	623.25	14.59	2.5
51	2.53E-01	192071.6	2408727.3	10	50	345	11.25	0.8
52	2.56E-01	191904.1	2408635.2	10	50	346.67	11.22	0.8
53	2.44E-01	191938	2408623	10	50	344.23	11.15	0.8

54	0.00E+00	192756.9	2408513.5	10	50	327	14.53	3
55	1.50E+00	192770.5	2408413.1	10	85	395.67	16.06	3
56	2.28E+00	192230.5	2408897.9	10	70	447	17.25	2.5
57	1.94E+00	192348.6	2408677.8	10	70	437	17.22	2.5
58	2.13E+00	191961.2	2408923.2	10	100	415.33	15.14	4
59	1.23E+00	192147	2408773.2	10	40	405.33	12.94	3
60	0.00E+00	192076.9	2408982.6	10	40	307.33	15.02	2.5
61	3.33E+00	191800.4	2408425.4	10	60	523	0	2
62	0.00E+00	193768	2404028	10	45	393	0	0.9
63	1.01E+01	193956	2404054	10	75	382	9.2	1.8
64	5.04E+01	193731.3	2400452.1	10	70	343	8.28	4.03
65	5.04E+01	193803.1	2400444.6	10	86	313	17.6	2.64
66	0.00E+00	193751	2400476	10	70	373	0	3.43
67	0.00E+00	193752	2399432	10	65	373	0	3
68	0.00E+00	193677	2400471.6	10	40	333	0	1.8
69	0.00E+00	193672.4	2400382.4	10	40	333	0	1.8
70	0.00E+00	193669.1	2400361	10	40	333	0	2
71	0.00E+00	193677	2400471.6	10	40	333	0	2
72	0.00E+00	193515.5	2400151.4	10	60	373	0	3
73	0.00E+00	192893	2402101	10	65	393	2.3	4.5
74	0.00E+00	192893	2402101	10	65	393	2.3	4.5
75	0.00E+00	192931.1	2402149.5	10	0	0	0	0
76	1.04E+03	174322.4	2400696.9	10	220	403	31	4.6
77	1.04E+03	174410.9	2400696.9	10	220	403	31	4.6
78	1.95E+00	188393.2	2425033.3	10	60	423	7.08	2.64
79	7.68E+01	188304.7	2424767.8	10	60	423	35.3	2.4
80	5.45E+02	193945.7	2415095	10	275	413	37.85	6.8
81	5.45E+02	194081	2414976.0	10	275	413	37.85	6.8
82	5.45E+02	194201	2415223	10	275	413	37.85	6.8

83	5.45E+02	194201	2415223	10	275	413	37.85	6.8
84	0.00E+00	195572	2413257	10	80	383	16.85	9.28
85	0.00E+00	195814.6	2413733.6	10	80	383	16.85	9.28
86	0.00E+00	195686	2413224	10	80	383	16.85	9.28
87	0.00E+00	195954	2413712	10	80	383	16.85	9.28
88	0.00E+00	193757	2414585	10	80	393	28.84	8.3
89	0.00E+00	193424.4	2414004.9	10	80	393	28.84	8.3
90	0.00E+00	194046	2414641	10	80	393	28.84	8.3
91	0.00E+00	193603	2414034	10	80	393	28.84	8.3
92	0.00E+00	193982.2	2414304.3	10	80	393	28.84	8.3
93	0.00E+00	193628	2413849	10	80	393	28.84	8.3
94	0.00E+00	194157	2414179.2	10	80	393	28.84	8.3
95	0.00E+00	193769.8	2413723.4	10	80	393	28.84	8.3
96	0.00E+00	194162.1	2413192.5	10	50	373	8.21	3.75
97	0.00E+00	194047.7	2413225.5	10	50	373	8.21	3.75
98	0.00E+00	194835.1	2415303.9	10	50	373	16.41	2.84
99	0.00E+00	194862.6	2415241.8	10	50	373	16.41	2.84
100	0.00E+00	193482.7	2415237.4	10	50	373	16.41	2.84
101	1.60E+02	195324.8	2412092.2	10	50	423	42.91	3.5
102	1.60E+02	195534.5	2411913.9	10	50	423	42.91	3.5
103	1.60E+02	193724.2	2413928.5	10	50	423	42.91	3.5
104	1.60E+02	193840.7	2413833.1	10	50	423	42.91	3.5
105	1.60E+02	194290.4	2413168.1	10	50	423	42.91	3.5
106	1.60E+02	195442.8	2413019.7	10	50	423	42.91	3.5
107	1.60E+02	194610.2	2413217.4	10	50	423	42.91	3.5
108	1.60E+02	194232.1	2413042.6	10	50	423	42.91	3.5
109	1.60E+02	194225.5	2413113.9	10	50	423	42.91	3.5
110	2.48E+01	188570.2	2412909.3	10	70	423	3.5	4.8
111	0.00E+00	188835.7	2412643.9	10	65	423	0	4.5

***** THE SUMMARY OF HIGHEST 24-HR RESULTS *****

GROUP ID	RANK HIGHEST VALUES	AVERAGE CONC MICROGRAM/M**3	DATE (YYMMDDHH)	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	TYPE (GRIDCART)	NETWORK GRID-ID
ALL	1ST HIGH VALUE IS	122.5871	19050224:	(192191.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	2ND HIGH VALUE IS	119.98893	19040224:	(192191.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	3RD HIGH VALUE IS	68.72896	19041924:	(192191.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	4TH HIGH VALUE IS	66.7743	19052824:	(192191.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	5TH HIGH VALUE IS	64.89403	19051424:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	6TH HIGH VALUE IS	64.49124	19052424:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	7TH HIGH VALUE IS	63.11705	19051824:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	8TH HIGH VALUE IS	62.24175	19031924:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	9TH HIGH VALUE IS	62.07435	19053024:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	10TH HIGH VALUE IS	60.05043	19041024:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	11TH HIGH VALUE IS	59.37819	19052024:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	12TH HIGH VALUE IS	59.14815	19041324:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	13TH HIGH VALUE IS	58.07855	19052724:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	14TH HIGH VALUE IS	57.55871	19051124:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	15TH HIGH VALUE IS	57.24197	19042924:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	16TH HIGH VALUE IS	56.99342	19042124:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	17TH HIGH VALUE IS	56.71035	19032824:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	18TH HIGH VALUE IS	55.21502	19032624:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	19TH HIGH VALUE IS	55.06428	19050824:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	20TH HIGH VALUE IS	54.07147	19031324:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	21ST HIGH VALUE IS	53.82553	19033024:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	22ND HIGH VALUE IS	53.27473	19051724:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	23RD HIGH VALUE IS	53.2049	19031224:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	24TH HIGH VALUE IS	52.87761	19051324:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1

	25TH HIGH VALUE IS	52.00833	19041424:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1

PM

*** THE SUMMARY OF MODEL INPUT POINT SOURCES DATA***

Source ID	Emission rate (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)
1	1.25E+01	196074.8	2406971.2	10	275	401	11.6	3.7
2	1.25E+01	196074.8	2406971.2	10	275	401	11.61	3.7
3	1.25E+01	196074.8	2406971.2	10	275	401	11.61	3.7
4	1.25E+01	196067	2406741	10	275	401	11.61	3.7
5	1.25E+01	196067	2406741	10	275	401	11.61	3.7
6	1.25E+01	196067	2406741	10	275	401	11.61	3.7
7	6.47E-02	195171	2406894.6	10	100	353	5.19	10.4
8	7.69E-02	194350.6	2406930.8	10	100	353	5.19	10.4
9	3.20E-02	195024.3	2406748.3	10	70	383	15.01	2.06
10	1.61E-01	195024.3	2406748.3	10	70	383	24.88	1.6
11	7.82E-01	179278.1	2385210.2	10	50	353	25.89	3.4
12	2.74E+00	179543.6	2385298.7	10	50	353	25.9	4.4
13	2.42E+00	179566.6	2385210.2	10	50	353	25.88	5.6
14	1.15E+00	179455.1	2384856.2	10	50	353	21.18	4.4
15	1.18E+00	179278.1	2385033.2	10	80	353	11.15	5.3
16	7.52E+00	179455.1	2385210.2	10	130	409	9.58	3.87
17	1.31E+01	179720.6	2385298.7	10	130	413	20.66	3.5
18	1.31E+01	178747.2	2385210.2	10	130	413	20.66	3.5
19	1.31E+01	179366.6	2384944.7	10	130	413	20.66	3.5
20	1.31E+01	179278.1	2385121.7	10	130	413	20.66	3.5
21	1.19E-01	179189.6	2385387.2	10	30	308	4.07	2
22	3.95E-01	179720.6	2384856.2	10	30	306	14.95	2.6

23	5.41E-01	179632.1	2385387.2	10	26.7	306	20.33	1.53
24	1.14E+00	191511	2410333	10	130	417	16.02	4
25	1.41E+00	191742	2410370	10	130	418	15.92	4
26	1.23E+00	191684	2410507	10	130	420.33	16.97	4
27	9.81E-01	191845	2409715	10	95	424.67	16.62	2.5
28	7.25E-01	191734	2409655	10	76	421	15.89	2
29	1.11E+00	191586.5	2409838.3	10	76	406.33	16.27	2
30	1.02E+00	191641.6	2409715.3	10	76	427.33	17.34	2
31	1.24E+00	191874.4	2409418.2	10	76	443	17.1	2
32	1.09E+00	191854.4	2409425.2	10	76	440.67	16.78	2
33	1.08E+00	191607.4	2409820.9	10	76	439	17.9	2
34	1.03E+00	191587	2409893.8	10	76	431	17.13	2
35	9.36E-01	191740	2409933.1	10	76	436.67	16.48	2
36	1.18E+00	191615	2410110.4	10	76	440.33	17.37	2
37	1.23E+00	191615.5	2410120.6	10	76	441	17.54	2
38	1.11E+00	191588.6	2410158.2	10	76	431.33	16.96	2
39	2.17E+00	192001.2	2410385.8	10	76	435	8.01	4.17
40	1.24E+00	191926	2409811.7	10	45	319.67	10.92	2.2
41	1.25E+00	192011	2409598.5	10	45	320.67	12.64	2.2
42	1.05E+00	191862.3	2409938.9	10	45	325	11.35	2.2
43	1.20E+00	191893	2410135	10	45	320	12.66	2.2
44	1.40E+00	191817.4	2408365.9	10	45	321.33	12.76	2.2
45	1.46E+00	192001.2	2410385.8	10	45	322.83	8.56	2.9
46	2.03E+00	191611.1	2409192.1	10	60	357.67	15	3
47	2.30E+00	191815.9	2408701.2	10	60	356	14.47	3
48	2.50E+00	191675	2408376.8	10	35	356.67	14.43	2.4
49	2.13E+00	191771.9	2408428.1	10	30	301.54	10.51	2.4
50	3.22E-01	191956.2	2408403.3	10	65	623.25	14.59	2.5
51	1.56E-01	192071.6	2408727.3	10	50	345	11.25	0.8

52	1.39E-01	191904.1	2408635.2	10	50	346.67	11.22	0.8
53	1.33E-01	191938	2408623	10	50	344.23	11.15	0.8
54	4.29E+00	192756.9	2408513.5	10	50	327	14.53	3
55	4.17E+00	192770.5	2408413.1	10	85	395.67	16.06	3
56	1.08E+00	192230.5	2408897.9	10	70	447	17.25	2.5
57	1.35E+00	192348.6	2408677.8	10	70	437	17.22	2.5
58	3.68E+00	191961.2	2408923.2	10	100	415.33	15.14	4
59	2.32E+00	192147	2408773.2	10	40	405.33	12.94	3
60	2.30E+00	192076.9	2408982.6	10	40	307.33	15.02	2.5
61	5.56E-01	191800.4	2408425.4	10	60	523	0	2
62	0.00E+00	193768	2404028	10	45	393	0	0.9
63	1.68E+00	193956	2404054	10	75	382	9.2	1.8
64	8.40E+00	193731.3	2400452.1	10	70	343	8.28	4.03
65	8.40E+00	193803.1	2400444.6	10	86	313	17.6	2.64
66	0.00E+00	193751	2400476	10	70	373	0	3.43
67	0.00E+00	193752	2399432	10	65	373	0	3
68	0.00E+00	193677	2400471.6	10	40	333	0	1.8
69	0.00E+00	193672.4	2400382.4	10	40	333	0	1.8
70	0.00E+00	193669.1	2400361	10	40	333	0	2
71	0.00E+00	193677	2400471.6	10	40	333	0	2
72	0.00E+00	193515.5	2400151.4	10	60	373	0	3
73	4.40E-01	192893	2402101	10	65	393	2.3	4.5
74	1.07E+00	192893	2402101	10	65	393	2.3	4.5
75	0.00E+00	192931.1	2402149.5	10	0	0	0	0
76	1.74E+02	174322.4	2400696.9	10	220	403	31	4.6
77	1.74E+02	174410.9	2400696.9	10	220	403	31	4.6
78	2.75E+00	188393.2	2425033.3	10	60	423	7.08	2.64
79	1.28E+01	188304.7	2424767.8	10	60	423	35.3	2.4
80	9.08E+01	193945.7	2415095	10	275	413	37.85	6.8

81	9.08E+01	194081	2414976.0	10	275	413	37.85	6.8
82	9.08E+01	194201	2415223	10	275	413	37.85	6.8
83	9.08E+01	194201	2415223	10	275	413	37.85	6.8
84	4.06E+01	195572	2413257	10	80	383	16.85	9.28
85	4.06E+01	195814.6	2413733.6	10	80	383	16.85	9.28
86	4.06E+01	195686	2413224	10	80	383	16.85	9.28
87	4.06E+01	195954	2413712	10	80	383	16.85	9.28
88	5.42E+01	193757	2414585	10	80	393	28.84	8.3
89	5.42E+01	193424.4	2414004.9	10	80	393	28.84	8.3
90	5.42E+01	194046	2414641	10	80	393	28.84	8.3
91	5.42E+01	193603	2414034	10	80	393	28.84	8.3
92	5.42E+01	193982.2	2414304.3	10	80	393	28.84	8.3
93	5.42E+01	193628	2413849	10	80	393	28.84	8.3
94	5.42E+01	194157	2414179.2	10	80	393	28.84	8.3
95	5.42E+01	193769.8	2413723.4	10	80	393	28.84	8.3
96	3.31E+00	194162.1	2413192.5	10	50	373	8.21	3.75
97	3.31E+00	194047.7	2413225.5	10	50	373	8.21	3.75
98	3.80E+00	194835.1	2415303.9	10	50	373	16.41	2.84
99	3.80E+00	194862.6	2415241.8	10	50	373	16.41	2.84
100	3.80E+00	193482.7	2415237.4	10	50	373	16.41	2.84
101	1.33E+01	195324.8	2412092.2	10	50	423	42.91	3.5
102	1.33E+01	195534.5	2411913.9	10	50	423	42.91	3.5
103	1.33E+01	193724.2	2413928.5	10	50	423	42.91	3.5
104	1.33E+01	193840.7	2413833.1	10	50	423	42.91	3.5
105	1.33E+01	194290.4	2413168.1	10	50	423	42.91	3.5
106	1.33E+01	195442.8	2413019.7	10	50	423	42.91	3.5
107	1.33E+01	194610.2	2413217.4	10	50	423	42.91	3.5
108	1.33E+01	194232.1	2413042.6	10	50	423	42.91	3.5
109	1.33E+01	194225.5	2413113.9	10	50	423	42.91	3.5

110	4.13E+00	188570.2	2412909.3	10	70	423	3.5	4.8
111	0.00E+00	188835.7	2412643.9	10	65	423	0	4.5

***** THE SUMMARY OF HIGHEST 24-HR RESULTS *****

GROUP ID	RANK HIGHEST VALUES	AVERAGE CONC MICROGRAM/M**3	DATE (YYMMDDHH)	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	TYPE (GRIDCART)	NETWORK GRID-ID
ALL	1ST HIGH VALUE IS	22.93504	19052424:	(197171.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	2ND HIGH VALUE IS	22.32004	19050224:	(192191.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	3RD HIGH VALUE IS	20.48591	19041924:	(192191.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	4TH HIGH VALUE IS	19.16157	19050924:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	5TH HIGH VALUE IS	19.13087	19041024:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	6TH HIGH VALUE IS	18.69499	19051724:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	7TH HIGH VALUE IS	18.66715	19041624:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	8TH HIGH VALUE IS	18.3619	19052724:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	9TH HIGH VALUE IS	17.57722	19050624:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	10TH HIGH VALUE IS	17.4496	19050824:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	11TH HIGH VALUE IS	17.30623	19051324:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	12TH HIGH VALUE IS	17.08403	19051424:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	13TH HIGH VALUE IS	17.06888	19032224:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	14TH HIGH VALUE IS	17.06789	19050724:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	15TH HIGH VALUE IS	16.84525	19051224:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	16TH HIGH VALUE IS	16.32655	19051124:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	17TH HIGH VALUE IS	16.19517	19053024:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	18TH HIGH VALUE IS	15.4795	19052524:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	19TH HIGH VALUE IS	15.32884	19040824:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	20TH HIGH VALUE IS	15.29028	19040624:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	21ST HIGH VALUE IS	15.08715	19051024:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1

	22ND HIGH VALUE IS	14.92949	19042824:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	23RD HIGH VALUE IS	14.77147	19031924:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	24TH HIGH VALUE IS	14.76397	19041524:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1
	25TH HIGH VALUE IS	14.72622	19042724:	(195511.00, 2414300.00, 10.00, 10.00, 0.00)	GC	UCART1

Annexure III

3. Post ENCON Envisaged Reduced Emission Scenario - Model Input and Output

SO_2

***** THE SUMMARY OF MODEL INPUT POINT SOURCES DATA*****

Source ID	Emission rate (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL.(M/SEC)	STACK DIAMETER (METERS)
1	1.25E+01	196075	2406971	10	275	401	11.6	3.7
2	1.25E+01	196075	2406971	10	275	401	11.61	3.7
3	1.25E+01	196075	2406971	10	275	401	11.61	3.7
4	1.25E+01	196067	2406741	10	275	401	11.61	3.7
5	1.25E+01	196067	2406741	10	275	401	11.61	3.7
6	1.25E+01	196067	2406741	10	275	401	11.61	3.7
7	0.00E+00	195171	2406895	10	100	353	5.19	10.4
8	0.00E+00	194351	2406931	10	100	353	5.19	10.4
9	0.00E+00	195024	2406748	10	70	383	15.01	2.06
10	0.00E+00	195024	2406748	10	70	383	24.88	1.6
11	0.00E+00	179278	2385210	10	50	353	25.89	3.4
12	0.00E+00	179544	2385299	10	50	353	25.9	4.4
13	0.00E+00	179567	2385210	10	50	353	25.88	5.6
14	0.00E+00	179455	2384856	10	50	353	21.18	4.4
15	0.00E+00	179278	2385033	10	80	353	11.15	5.3
16	7.52E+00	179455	2385210	10	130	409	9.58	3.87
17	1.31E+01	179721	2385299	10	130	413	20.66	3.5
18	1.31E+01	178747	2385210	10	130	413	20.66	3.5
19	1.31E+01	179367	2384945	10	130	413	20.66	3.5
20	1.31E+01	179278	2385122	10	130	413	20.66	3.5
21	6.80E-01	179190	2385387	10	30	308	4.07	2
22	4.25E+00	179721	2384856	10	30	306	14.95	2.6
23	2.67E-01	179632	2385387	10	26.7	306	20.33	1.53
24	3.35E+00	191511	2410333	10	130	417	16.02	4

25	3.32E+00	191742	2410370	10	130	418	15.92	4
26	3.41E+00	191684	2410507	10	130	420.33	16.97	4
27	2.92E+00	191845	2409715	10	95	424.67	16.62	2.5
28	2.49E+00	191734	2409655	10	76	421	15.89	2
29	2.92E+00	191587	2409838	10	76	406.33	16.27	2
30	3.16E+00	191642	2409715	10	76	427.33	17.34	2
31	2.95E+00	191874	2409418	10	76	443	17.1	2
32	3.10E+00	191854	2409425	10	76	440.67	16.78	2
33	2.88E+00	191607	2409821	10	76	439	17.9	2
34	2.77E+00	191587	2409894	10	76	431	17.13	2
35	2.64E+00	191740	2409933	10	76	436.67	16.48	2
36	2.96E+00	191615	2410110	10	76	440.33	17.37	2
37	2.98E+00	191616	2410121	10	76	441	17.54	2
38	3.03E+00	191589	2410158	10	76	431.33	16.96	2
39	5.99E+00	192001	2410386	10	76	435	8.01	4.17
40	0.00E+00	191926	2409812	10	45	319.67	10.92	2.2
41	0.00E+00	192011	2409599	10	45	320.67	12.64	2.2
42	0.00E+00	191862	2409939	10	45	325	11.35	2.2
43	0.00E+00	191893	2410135	10	45	320	12.66	2.2
44	0.00E+00	191817	2408366	10	45	321.33	12.76	2.2
45	0.00E+00	192001	2410386	10	45	322.83	8.56	2.9
46	1.57E+00	191611	2409192	10	60	357.67	15	3
47	1.78E+00	191816	2408701	10	60	356	14.47	3
48	0.00E+00	191675	2408377	10	35	356.67	14.43	2.4
49	0.00E+00	191772	2408428	10	30	301.54	10.51	2.4
50	0.00E+00	191956	2408403	10	65	623.25	14.59	2.5
51	1.61E-01	192072	2408727	10	50	345	11.25	0.8
52	1.65E-01	191904	2408635	10	50	346.67	11.22	0.8
53	1.56E-01	191938	2408623	10	50	344.23	11.15	0.8

54	0.00E+00	192757	2408514	10	50	327	14.53	3
55	4.28E-01	192771	2408413	10	85	395.67	16.06	3
56	5.92E+00	192231	2408898	10	70	447	17.25	2.5
57	6.30E+00	192349	2408678	10	70	437	17.22	2.5
58	2.06E+01	191961	2408923	10	100	415.33	15.14	4
59	0.00E+00	192147	2408773	10	40	405.33	12.94	3
60	0.00E+00	192077	2408983	10	40	307.33	15.02	2.5
61	1.24E-01	191800	2408425	10	60	523	0	2
62	0.00E+00	193768	2404028	10	45	393	0	0.9
63	1.68E+00	193956	2404054	10	75	382	9.2	1.8
64	8.40E+00	193731	2400452	10	70	343	8.28	4.03
65	8.40E+00	193803	2400445	10	86	313	17.6	2.64
66	0.00E+00	193751	2400476	10	70	373	0	3.43
67	0.00E+00	193752	2399432	10	65	373	0	3
68	0.00E+00	193677	2400472	10	40	333	0	1.8
69	0.00E+00	193672	2400382	10	40	333	0	1.8
70	0.00E+00	193669	2400361	10	40	333	0	2
71	0.00E+00	193677	2400472	10	40	333	0	2
72	0.00E+00	193516	2400151	10	60	373	0	3
73	1.57E-01	192893	2402101	10	65	393	2.3	4.5
74	2.90E-01	192893	2402101	10	65	393	2.3	4.5
75	0.00E+00	192931	2402150	10	0	0	0	0
76	1.74E+02	174322	2400697	10	220	403	31	4.6
77	1.74E+02	174411	2400697	10	220	403	31	4.6
78	9.10E+00	188393	2425033	10	60	423	7.08	2.64
79	1.03E+01	188305	2424768	10	60	423	35.3	2.4
80	9.08E+01	193946	2415095	10	275	413	37.85	6.8
81	9.08E+01	194081	2414976	10	275	413	37.85	6.8
82	9.08E+01	194201	2415223	10	275	413	37.85	6.8

83	9.08E+01	194201	2415223	10	275	413	37.85	6.8
84	0.00E+00	195572	2413257	10	80	383	16.85	9.28
85	0.00E+00	195815	2413734	10	80	383	16.85	9.28
86	0.00E+00	195686	2413224	10	80	383	16.85	9.28
87	0.00E+00	195954	2413712	10	80	383	16.85	9.28
88	0.00E+00	193757	2414585	10	80	393	28.84	8.3
89	0.00E+00	193424	2414005	10	80	393	28.84	8.3
90	0.00E+00	194046	2414641	10	80	393	28.84	8.3
91	0.00E+00	193603	2414034	10	80	393	28.84	8.3
92	0.00E+00	193982	2414304	10	80	393	28.84	8.3
93	0.00E+00	193628	2413849	10	80	393	28.84	8.3
94	0.00E+00	194157	2414179	10	80	393	28.84	8.3
95	0.00E+00	193770	2413723	10	80	393	28.84	8.3
96	0.00E+00	194162	2413193	10	50	373	8.21	3.75
97	0.00E+00	194048	2413226	10	50	373	8.21	3.75
98	0.00E+00	194835	2415304	10	50	373	16.41	2.84
99	0.00E+00	194863	2415242	10	50	373	16.41	2.84
100	0.00E+00	193483	2415237	10	50	373	16.41	2.84
101	2.66E+01	195325	2412092	10	50	423	42.91	3.5
102	2.66E+01	195535	2411914	10	50	423	42.91	3.5
103	2.66E+01	193724	2413929	10	50	423	42.91	3.5
104	2.66E+01	193841	2413833	10	50	423	42.91	3.5
105	2.66E+01	194290	2413168	10	50	423	42.91	3.5
106	2.66E+01	195443	2413020	10	50	423	42.91	3.5
107	2.66E+01	194610	2413217	10	50	423	42.91	3.5
108	2.66E+01	194232	2413043	10	50	423	42.91	3.5
109	2.66E+01	194226	2413114	10	50	423	42.91	3.5
110	4.13E+00	188570	2412909	10	70	423	3.5	4.8
111	0.00E+00	188836	2412644	10	65	423	0	4.5

*** THE SUMMARY OF HIGHEST 24-HR RESULTS ***

GROUP ID	RANK HIGHEST VALUES	AVERAGE CONC MICROGRAM/M**3	DATE (YYMMDDHH)	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	TYPE (GRIDCART)	NETWORK GRID-ID
ALL	1ST HIGH VALUE IS	20.24695	19050224:	(192201.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	2ND HIGH VALUE IS	19.65277	19040224:	(192201.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	3RD HIGH VALUE IS	12.62944	19051824:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	4TH HIGH VALUE IS	11.64559	19052824:	(192201.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	5TH HIGH VALUE IS	11.31665	19052724:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	6TH HIGH VALUE IS	11.08726	19042824:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	7TH HIGH VALUE IS	10.95254	19051524:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	8TH HIGH VALUE IS	10.84327	19052524:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	9TH HIGH VALUE IS	10.59484	19050824:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	10TH HIGH VALUE IS	10.48959	19041624:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	11TH HIGH VALUE IS	10.46257	19032524:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	12TH HIGH VALUE IS	10.24211	19050524:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	13TH HIGH VALUE IS	10.12609	19051324:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	14TH HIGH VALUE IS	10.11633	19051024:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	15TH HIGH VALUE IS	9.90451	19042224:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	16TH HIGH VALUE IS	9.72806	19032924:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	17TH HIGH VALUE IS	9.6801	19030224:	(195561.00, 2412730.00, 10.00, 10.00, 0.00)	GC	UCART1
	18TH HIGH VALUE IS	9.32922	19032624:	(175401.00, 2400970.00, 10.00, 10.00, 0.00)	GC	UCART1
	19TH HIGH VALUE IS	9.24216	19051124:	(175401.00, 2400970.00, 10.00, 10.00, 0.00)	GC	UCART1
	20TH HIGH VALUE IS	9.1499	19030224:	(175401.00, 2400970.00, 10.00, 10.00, 0.00)	GC	UCART1
	21ST HIGH VALUE IS	8.96382	19042424:	(175401.00, 2400970.00, 10.00, 10.00, 0.00)	GC	UCART1
	22ND HIGH VALUE IS	8.93324	19040424:	(175401.00, 2400970.00, 10.00, 10.00, 0.00)	GC	UCART1
	23RD HIGH VALUE IS	8.9325	19051324:	(175401.00, 2400970.00, 10.00, 10.00, 0.00)	GC	UCART1

	24TH HIGH VALUE IS	8.7667	19050424:	(175401.00, 2400970.00, 10.00, 10.00, 0.00)	GC	UCART1
	25TH HIGH VALUE IS	8.75723	19041424:	(175401.00, 2400970.00, 10.00, 10.00, 0.00)	GC	UCART1

NO_x

***** THE SUMMARY OF MODEL INPUT POINT SOURCES DATA*****

Source ID	Emission rate (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL.(M/SEC)	STACK DIAMETER (METERS)
1	1.25E+01	196074.8	2406971.2	10	275	401	11.6	3.7
2	1.25E+01	196074.8	2406971.2	10	275	401	11.61	3.7
3	1.25E+01	196074.8	2406971.2	10	275	401	11.61	3.7
4	1.25E+01	196067	2406741	10	275	401	11.61	3.7
5	1.25E+01	196067	2406741	10	275	401	11.61	3.7
6	1.25E+01	196067	2406741	10	275	401	11.61	3.7
7	0.00E+00	195171	2406894.6	10	100	353	5.19	10.4
8	0.00E+00	194350.6	2406930.8	10	100	353	5.19	10.4
9	0.00E+00	195024.3	2406748.3	10	70	383	15.01	2.06
10	0.00E+00	195024.3	2406748.3	10	70	383	24.88	1.6
11	0.00E+00	179278.1	2385210.2	10	50	353	25.89	3.4
12	0.00E+00	179543.6	2385298.7	10	50	353	25.9	4.4
13	0.00E+00	179566.6	2385210.2	10	50	353	25.88	5.6
14	0.00E+00	179455.1	2384856.2	10	50	353	21.18	4.4
15	0.00E+00	179278.1	2385033.2	10	80	353	11.15	5.3
16	7.52E+00	179455.1	2385210.2	10	130	409	9.58	3.87
17	1.31E+01	179720.6	2385298.7	10	130	413	20.66	3.5
18	1.31E+01	178747.2	2385210.2	10	130	413	20.66	3.5
19	1.31E+01	179366.6	2384944.7	10	130	413	20.66	3.5
20	1.31E+01	179278.1	2385121.7	10	130	413	20.66	3.5
21	1.36E+00	179189.6	2385387.2	10	30	308	4.07	2
22	8.50E+00	179720.6	2384856.2	10	30	306	14.95	2.6

23	4.00E+00	179632.1	2385387.2	10	26.7	306	20.33	1.53
24	3.35E+00	191511	2410333	10	130	417	16.02	4
25	2.31E+00	191742	2410370	10	130	418	15.92	4
26	2.65E+00	191684	2410507	10	130	420.33	16.97	4
27	2.15E+00	191845	2409715	10	95	424.67	16.62	2.5
28	1.89E+00	191734	2409655	10	76	421	15.89	2
29	2.03E+00	191586.5	2409838.3	10	76	406.33	16.27	2
30	2.17E+00	191641.6	2409715.3	10	76	427.33	17.34	2
31	1.80E+00	191874.4	2409418.2	10	76	443	17.1	2
32	1.87E+00	191854.4	2409425.2	10	76	440.67	16.78	2
33	2.04E+00	191607.4	2409820.9	10	76	439	17.9	2
34	1.93E+00	191587	2409893.8	10	76	431	17.13	2
35	1.89E+00	191740	2409933.1	10	76	436.67	16.48	2
36	2.05E+00	191615	2410110.4	10	76	440.33	17.37	2
37	1.98E+00	191615.5	2410120.6	10	76	441	17.54	2
38	1.94E+00	191588.6	2410158.2	10	76	431.33	16.96	2
39	3.87E+00	192001.2	2410385.8	10	76	435	8.01	4.17
40	0.00E+00	191926	2409811.7	10	45	319.67	10.92	2.2
41	0.00E+00	192011	2409598.5	10	45	320.67	12.64	2.2
42	0.00E+00	191862.3	2409938.9	10	45	325	11.35	2.2
43	0.00E+00	191893	2410135	10	45	320	12.66	2.2
44	0.00E+00	191817.4	2408365.9	10	45	321.33	12.76	2.2
45	0.00E+00	192001.2	2410385.8	10	45	322.83	8.56	2.9
46	1.59E+00	191611.1	2409192.1	10	60	357.67	15	3
47	1.43E+00	191815.9	2408701.2	10	60	356	14.47	3
48	1.57E+00	191675	2408376.8	10	35	356.67	14.43	2.4
49	0.00E+00	191771.9	2408428.1	10	30	301.54	10.51	2.4
50	4.35E+00	191956.2	2408403.3	10	65	623.25	14.59	2.5
51	1.77E-01	192071.6	2408727.3	10	50	345	11.25	0.8

52	1.79E-01	191904.1	2408635.2	10	50	346.67	11.22	0.8
53	1.71E-01	191938	2408623	10	50	344.23	11.15	0.8
54	0.00E+00	192756.9	2408513.5	10	50	327	14.53	3
55	1.05E+00	192770.5	2408413.1	10	85	395.67	16.06	3
56	1.59E+00	192230.5	2408897.9	10	70	447	17.25	2.5
57	1.36E+00	192348.6	2408677.8	10	70	437	17.22	2.5
58	1.49E+00	191961.2	2408923.2	10	100	415.33	15.14	4
59	8.61E-01	192147	2408773.2	10	40	405.33	12.94	3
60	0.00E+00	192076.9	2408982.6	10	40	307.33	15.02	2.5
61	2.33E+00	191800.4	2408425.4	10	60	523	0	2
62	0.00E+00	193768	2404028	10	45	393	0	0.9
63	1.68E+00	193956	2404054	10	75	382	9.2	1.8
64	8.40E+00	193731.3	2400452.1	10	70	343	8.28	4.03
65	8.40E+00	193803.1	2400444.6	10	86	313	17.6	2.64
66	0.00E+00	193751	2400476	10	70	373	0	3.43
67	0.00E+00	193752	2399432	10	65	373	0	3
68	0.00E+00	193677	2400471.6	10	40	333	0	1.8
69	0.00E+00	193672.4	2400382.4	10	40	333	0	1.8
70	0.00E+00	193669.1	2400361	10	40	333	0	2
71	0.00E+00	193677	2400471.6	10	40	333	0	2
72	0.00E+00	193515.5	2400151.4	10	60	373	0	3
73	0.00E+00	192893	2402101	10	65	393	2.3	4.5
74	0.00E+00	192893	2402101	10	65	393	2.3	4.5
75	0.00E+00	192931.1	2402149.5	10	0	0	0	0
76	1.74E+02	174322.4	2400696.9	10	220	403	31	4.6
77	1.74E+02	174410.9	2400696.9	10	220	403	31	4.6
78	1.37E+00	188393.2	2425033.3	10	60	423	7.08	2.64
79	1.03E+01	188304.7	2424767.8	10	60	423	35.3	2.4
80	9.08E+01	193945.7	2415095	10	275	413	37.85	6.8

81	9.08E+01	194081	2414976	10	275	413	37.85	6.8
82	9.08E+01	194201	2415223	10	275	413	37.85	6.8
83	9.08E+01	194201	2415223	10	275	413	37.85	6.8
84	0.00E+00	195572	2413257	10	80	383	16.85	9.28
85	0.00E+00	195814.6	2413733.6	10	80	383	16.85	9.28
86	0.00E+00	195686	2413224	10	80	383	16.85	9.28
87	0.00E+00	195954	2413712	10	80	383	16.85	9.28
88	0.00E+00	193757	2414585	10	80	393	28.84	8.3
89	0.00E+00	193424.4	2414004.9	10	80	393	28.84	8.3
90	0.00E+00	194046	2414641	10	80	393	28.84	8.3
91	0.00E+00	193603	2414034	10	80	393	28.84	8.3
92	0.00E+00	193982.2	2414304.3	10	80	393	28.84	8.3
93	0.00E+00	193628	2413849	10	80	393	28.84	8.3
94	0.00E+00	194157	2414179.2	10	80	393	28.84	8.3
95	0.00E+00	193769.8	2413723.4	10	80	393	28.84	8.3
96	0.00E+00	194162.1	2413192.5	10	50	373	8.21	3.75
97	0.00E+00	194047.7	2413225.5	10	50	373	8.21	3.75
98	0.00E+00	194835.1	2415303.9	10	50	373	16.41	2.84
99	0.00E+00	194862.6	2415241.8	10	50	373	16.41	2.84
100	0.00E+00	193482.7	2415237.4	10	50	373	16.41	2.84
101	2.66E+01	195324.8	2412092.2	10	50	423	42.91	3.5
102	2.66E+01	195534.5	2411913.9	10	50	423	42.91	3.5
103	2.66E+01	193724.2	2413928.5	10	50	423	42.91	3.5
104	2.66E+01	193840.7	2413833.1	10	50	423	42.91	3.5
105	2.66E+01	194290.4	2413168.1	10	50	423	42.91	3.5
106	2.66E+01	195442.8	2413019.7	10	50	423	42.91	3.5
107	2.66E+01	194610.2	2413217.4	10	50	423	42.91	3.5
108	2.66E+01	194232.1	2413042.6	10	50	423	42.91	3.5
109	2.66E+01	194225.5	2413113.9	10	50	423	42.91	3.5

110	4.13E+00	188570.2	2412909.3	10	70	423	3.5	4.8
111	0.00E+00	188835.7	2412643.9	10	65	423	0	4.5

NOx

***** THE SUMMARY OF HIGHEST 24-HR RESULTS *****

GROUP ID	RANK HIGHEST VALUES	AVERAGE CONC MICROGRAM/M**3	DATE (YYMMDDHH)	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	TYPE (GRIDCART)	NETWORK GRID-ID
ALL	1ST HIGH VALUE IS	26.86223	19052424:	(180571.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	2ND HIGH VALUE IS	23.70963	19052124:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	3RD HIGH VALUE IS	23.51512	19050124:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	4TH HIGH VALUE IS	18.62235	19052924:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	5TH HIGH VALUE IS	17.82287	19042624:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	6TH HIGH VALUE IS	17.45805	19042724:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	7TH HIGH VALUE IS	17.38841c	19051524:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	8TH HIGH VALUE IS	14.51067	19051624:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	9TH HIGH VALUE IS	12.70491	19050724:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	10TH HIGH VALUE IS	11.46826	19040524:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	11TH HIGH VALUE IS	11.228	19033124:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	12TH HIGH VALUE IS	11.22527	19052224:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	13TH HIGH VALUE IS	10.96247	19050524:	(178911.00, 2386080.00, 10.00, 10.00, 0.00)	GC	UCART1
	14TH HIGH VALUE IS	10.75747	19052424:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	15TH HIGH VALUE IS	10.67985	19041424:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	16TH HIGH VALUE IS	10.63411	19051824:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	17TH HIGH VALUE IS	10.18165	19032824:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	18TH HIGH VALUE IS	10.03505	19041024:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	19TH HIGH VALUE IS	9.80817	19052724:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	20TH HIGH VALUE IS	9.63846	19051124:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	21ST HIGH VALUE IS	9.55401	19042124:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	22ND HIGH VALUE IS	9.48511	19031324:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1

	23RD HIGH VALUE IS	9.41018	19040424:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	24TH HIGH VALUE IS	9.32359	19032624:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1
	25TH HIGH VALUE IS	9.0824	19051724:	(175591.00, 2401020.00, 10.00, 10.00, 0.00)	GC	UCART1

PM

***** THE SUMMARY OF MODEL INPUT POINT SOURCES DATA*****

Source ID	Emission rate (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL.(M/SEC)	STACK DIAMETER (METERS)
1	3.74E+00	196074.8	2406971.2	10	275	401	11.6	3.7
2	3.74E+00	196074.8	2406971.2	10	275	401	11.61	3.7
3	3.74E+00	196074.8	2406971.2	10	275	401	11.61	3.7
4	3.74E+00	196067	2406741	10	275	401	11.61	3.7
5	3.74E+00	196067	2406741	10	275	401	11.61	3.7
6	3.74E+00	196067	2406741	10	275	401	11.61	3.7
7	6.47E-02	195171	2406894.6	10	100	353	5.19	10.4
8	7.69E-02	194350.6	2406930.8	10	100	353	5.19	10.4
9	3.20E-02	195024.3	2406748.3	10	70	383	15.01	2.06
10	1.61E-01	195024.3	2406748.3	10	70	383	24.88	1.6
11	7.82E-01	179278.1	2385210.2	10	50	353	25.89	3.4
12	2.74E+00	179543.6	2385298.7	10	50	353	25.9	4.4
13	2.42E+00	179566.6	2385210.2	10	50	353	25.88	5.6
14	1.15E+00	179455.1	2384856.2	10	50	353	21.18	4.4
15	1.18E+00	179278.1	2385033.2	10	80	353	11.15	5.3
16	2.26E+00	179455.1	2385210.2	10	130	409	9.58	3.87
17	3.94E+00	179720.6	2385298.7	10	130	413	20.66	3.5
18	3.94E+00	178747.2	2385210.2	10	130	413	20.66	3.5
19	3.94E+00	179366.6	2384944.7	10	130	413	20.66	3.5
20	3.94E+00	179278.1	2385121.7	10	130	413	20.66	3.5

21	1.19E-01	179189.6	2385387.2	10	30	308	4.07	2
22	3.95E-01	179720.6	2384856.2	10	30	306	14.95	2.6
23	5.41E-01	179632.1	2385387.2	10	26.7	306	20.33	1.53
24	1.00E+00	191511	2410333	10	130	417	16.02	4
25	9.96E-01	191742	2410370	10	130	418	15.92	4
26	1.02E+00	191684	2410507	10	130	420.33	16.97	4
27	8.76E-01	191845	2409715	10	95	424.67	16.62	2.5
28	7.46E-01	191734	2409655	10	76	421	15.89	2
29	7.78E-01	191586.5	2409838.3	10	76	406.33	16.27	2
30	7.16E-01	191641.6	2409715.3	10	76	427.33	17.34	2
31	8.69E-01	191874.4	2409418.2	10	76	443	17.1	2
32	7.66E-01	191854.4	2409425.2	10	76	440.67	16.78	2
33	7.58E-01	191607.4	2409820.9	10	76	439	17.9	2
34	7.23E-01	191587	2409893.8	10	76	431	17.13	2
35	6.55E-01	191740	2409933.1	10	76	436.67	16.48	2
36	8.23E-01	191615	2410110.4	10	76	440.33	17.37	2
37	8.63E-01	191615.5	2410120.6	10	76	441	17.54	2
38	7.76E-01	191588.6	2410158.2	10	76	431.33	16.96	2
39	1.52E+00	192001.2	2410385.8	10	76	435	8.01	4.17
40	8.67E-01	191926	2409811.7	10	45	319.67	10.92	2.2
41	8.75E-01	192011	0 2409598.5	10	45	320.67	12.64	2.2
42	7.33E-01	191862.3	2409938.9	10	45	325	11.35	2.2
43	8.40E-01	191893	2410135	10	45	320	12.66	2.2
44	9.80E-01	191817.4	2408365.9	10	45	321.33	12.76	2.2
45	1.02E+00	192001.2	2410385.8	10	45	322.83	8.56	2.9
46	1.42E+00	191611.1	2409192.1	10	60	357.67	15	3
47	1.61E+00	191815.9	2408701.2	10	60	356	14.47	3
48	1.75E+00	191675	2408376.8	10	35	356.67	14.43	2.4
49	1.49E+00	191771.9	2408428.1	10	30	301.54	10.51	2.4

50	2.26E-01	191956.2	2408403.3	10	65	623.25	14.59	2.5
51	1.09E-01	192071.6	2408727.3	10	50	345	11.25	0.8
52	9.72E-02	191904.1	2408635.2	10	50	346.67	11.22	0.8
53	9.33E-02	191938	2408623	10	50	344.23	11.15	0.8
54	3.00E+00	192756.9	2408513.5	10	50	327	14.53	3
55	2.92E+00	192770.5	2408413.1	10	85	395.67	16.06	3
56	7.54E-01	192230.5	2408897.9	10	70	447	17.25	2.5
57	9.45E-01	192348.6	2408677.8	10	70	437	17.22	2.5
58	2.58E+00	191961.2	2408923.2	10	100	415.33	15.14	4
59	1.62E+00	192147	2408773.2	10	40	405.33	12.94	3
60	1.61E+00	192076.9	2408982.6	10	40	307.33	15.02	2.5
61	3.89E-01	191800.4	2408425.4	10	60	523	0	2
62	0.00E+00	193768	2404028	10	45	393	0	0.9
63	5.04E-01	193956	2404054	10	75	382	9.2	1.8
64	2.52E+00	193731.3	2400452.1	10	70	343	8.28	4.03
65	2.52E+00	193803.1	2400444.6	10	86	313	17.6	2.64
66	0.00E+00	193751	2400476	10	70	373	0	3.43
67	0.00E+00	193752	2399432	10	65	373	0	3
68	0.00E+00	193677	2400471.6	10	40	333	0	1.8
69	0.00E+00	193672.4	2400382.4	10	40	333	0	1.8
70	0.00E+00	193669.1	2400361	10	40	333	0	2
71	0.00E+00	193677	2400471.6	10	40	333	0	2
72	0.00E+00	193515.5	2400151.4	10	60	373	0	3
73	3.08E-01	192893	2402101	10	65	393	2.3	4.5
74	7.46E-01	192893	2402101	10	65	393	2.3	4.5
75	0.00E+00	192931.1	2402149.5	10	0	0	0	0
76	5.21E+01	174322.4	2400696.9	10	220	403	31	4.6
77	5.21E+01	174410.9	2400696.9	10	220	403	31	4.6
78	1.93E+00	188393.2	2425033.3	10	60	423	7.08	2.64

79	3.09E+00	188304.7	2424767.8	10	60	423	35.3	2.4
80	2.72E+01	193945.7	2415095	10	275	413	37.85	6.8
81	2.72E+01	194081	2414976.0	10	275	413	37.85	6.8
82	2.72E+01	194201	2415223	10	275	413	37.85	6.8
83	2.72E+01	194201	2415223	10	275	413	37.85	6.8
84	2.44E+01	195572	2413257	10	80	383	16.85	9.28
85	2.44E+01	195814.6	2413733.6	10	80	383	16.85	9.28
86	2.44E+01	195686	2413224	10	80	383	16.85	9.28
87	2.44E+01	195954	2413712	10	80	383	16.85	9.28
88	3.25E+01	193757	2414585	10	80	393	28.84	8.3
89	3.25E+01	193424.4	2414004.9	10	80	393	28.84	8.3
90	3.25E+01	194046	2414641	10	80	393	28.84	8.3
91	3.25E+01	193603	2414034	10	80	393	28.84	8.3
92	3.25E+01	193982.2	2414304.3	10	80	393	28.84	8.3
93	3.25E+01	193628	2413849	10	80	393	28.84	8.3
94	3.25E+01	194157	2414179.2	10	80	393	28.84	8.3
95	3.25E+01	193769.8	2413723.4	10	80	393	28.84	8.3
96	1.99E+00	194162.1	2413192.5	10	50	373	8.21	3.75
97	1.99E+00	194047.7	2413225.5	10	50	373	8.21	3.75
98	2.28E+00	194835.1	2415303.9	10	50	373	16.41	2.84
99	2.28E+00	194862.6	2415241.8	10	50	373	16.41	2.84
100	2.28E+00	193482.7	2415237.4	10	50	373	16.41	2.84
101	7.99E+00	195324.8	2412092.2	10	50	423	42.91	3.5
102	7.99E+00	195534.5	2411913.9	10	50	423	42.91	3.5
103	7.99E+00	193724.2	2413928.5	10	50	423	42.91	3.5
104	7.99E+00	193840.7	2413833.1	10	50	423	42.91	3.5
105	7.99E+00	194290.4	2413168.1	10	50	423	42.91	3.5
106	7.99E+00	195442.8	2413019.7	10	50	423	42.91	3.5
107	7.99E+00	194610.2	2413217.4	10	50	423	42.91	3.5

108	7.99E+00	194232.1	2413042.6	10	50	423	42.91	3.5
109	7.99E+00	194225.5	2413113.9	10	50	423	42.91	3.5
110	1.24E+00	188570.2	2412909.3	10	70	423	3.5	4.8
111	0.00E+00	188835.7	2412643.9	10	65	423	0	4.5

PM

***** THE SUMMARY OF HIGHEST 24-HR RESULTS *****

GROUP ID	RANK HIGHEST VALUES	AVERAGE CONC MICROGRAM/M**3	DATE (YYMMDDHH)	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	TYPE (GRIDCART)	NETWORK GRID-ID
ALL	1ST HIGH VALUE IS	14.13078	19050224:	(192201.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	2ND HIGH VALUE IS	14.02865	19040224:	(192201.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	3RD HIGH VALUE IS	11.50187	19041924:	(192201.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	4TH HIGH VALUE IS	10.66405	19051724:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	5TH HIGH VALUE IS	10.2744	19050924:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	6TH HIGH VALUE IS	9.97163	19050724:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	7TH HIGH VALUE IS	9.94122	19052924:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	8TH HIGH VALUE IS	9.92653	19041624:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	9TH HIGH VALUE IS	9.80891	19051224:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	10TH HIGH VALUE IS	9.69979	19051424:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	11TH HIGH VALUE IS	9.6173	19032224:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	12TH HIGH VALUE IS	9.51501	19053024:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	13TH HIGH VALUE IS	9.4504	19051124:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	14TH HIGH VALUE IS	9.32523	19052724:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	15TH HIGH VALUE IS	9.30692	19051324:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	16TH HIGH VALUE IS	9.16655	19050824:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	17TH HIGH VALUE IS	8.8458	19050624:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	18TH HIGH VALUE IS	8.81075	19041524:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	19TH HIGH VALUE IS	8.77511	19052324:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	20TH HIGH VALUE IS	8.54205	19040824:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1

	21ST HIGH VALUE IS	8.49776	19040624:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	22ND HIGH VALUE IS	8.44779	19031924:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	23RD HIGH VALUE IS	8.23218	19042724:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	24TH HIGH VALUE IS	8.19327	19032624:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1
	25TH HIGH VALUE IS	8.11687	19053124:	(195561.00, 2414410.00, 10.00, 10.00, 0.00)	GC	UCART1

Annexure IV

Best Available Technologies in Iron and Steel Plants for Efficiency Improvement and Emission Reduction of SOx, NO_x, PM, CO in Jharsuguda

RAW MATERIAL STORAGE AREA EMISSION CONTROL

Most of the Indian plants have open storage of major raw materials including iron ore, coal, and coke. Uncovered and unsystematic storage of raw materials is susceptible to heavy material loss and dust emission during high winds.

Systematic and covered storage paved and impermeable storage surface area (wherever applicable) and appropriate drainage system minimise the material loss, dust emission and leaching problems.

Use of large stackers and reclaimers instead of smaller loading machines (shovels, backhoe loader, etc.) reduces dust emission in raw material storage area. Similarly, paved floors with interceptor catch and proper drainage help to control surface run-off and leaching of raw materials to ground water. Green belt around the raw material storage areas also help significantly in preventing dust emission in ambient environment.

Indian best Practice: Tata Steel Jamshedpur uses tarpaulin sheet to cover raw material stockpiles. The plant also stores pulverized injection grade coal under a shed to control the emission and moisture content. JSW Steel Vijayanagar Works has installed wind curtains to minimise the material dust getting air borne.

Global best Practice: Raw material storage areas in EU steel plants are provided with boundary enclosures over stockpiles2. Raw materials are stored in covered storage yard. Open stockpiles are stored perpendicular to the direction of prevailing wind to reduce the volume of raw material exposed to the wind.

The drop heights are small during stacking and transfer of raw materials. Storage areas are provided with impermeable paving, interceptor catch, and proper drainage systems are made for runoff control for leachable raw materials. Thick green cover of trees is provided around the raw material storage and handling area.

EMISSION CONTROL DURING RAW MATERIAL TRANSFER

The unloaded raw materials are transferred to preparation areas (crusher/screener and base mix yard) before finally sending to the particular process units. The material is transported mainly using open or closed conveyor belts and vehicles (dumpers).

Transfer through closed conveyors is preferred over other alternatives. Maximum use of covered conveyor is deemed best in order to control dust emission and material loss. Enclosed transfer points and smaller dropping heights are also put in place to prevent dust emissions from covered conveyors.

Indian best Practice: SAIL Rourkela, Essar Steel, Hazira and Tata Steel, Jamshedpur use entirely covered conveyors for raw material transfer within the plant.

Global best Practice: The global best practice is to install 100 per cent covered conveyors. Lesser drop heights are ensured during raw material transfers3. Building enclosures and dust suppression systems are installed for every transfer point. The roads are properly paved to reduce the dust emission from vehicle movement. Plants undertake regular spillage cleaning using vacuum system and maintain good housekeeping.

COKE MAKING PLANT

Till 2009-10, India however operated 45 by-product coke oven batteries with aggregate capacity of 22.98 million tonnes per annum (MTPA) gross coke. The primary purpose of using by-product technology is for the cheap and 'rich in energy' coke oven gas available as heating fuel.

BYPRODUCT COKE PLANT

In an integrated steel making plant with by-product recovery coke oven units, the coke plant is the most highly polluting section. It is a major source of air, water, and hazardous wastes pollution in the steel industry. The best available technology (BAT) for by-product coke oven focuses on design and technology, operational improvement and pollution monitoring and control. The by-product coke making facility may include the following into best practices:

CARBONIZATION CHAMBER HEIGHT AND COAL HOLDING CAPACITY

Higher capacity of the coke oven chamber is an important parameter for by-product recovery type ovens. As larger amount of coal is held in an oven, it significantly reduces the number of pushing per day and hence emissions per tonne of coke produced. Besides, it also reduces space, machinery, and handling operations for per tonne of coke produced.

Higher oven chamber height maximizes the battery capacity. For example, the annual output of two 4.5 m tall top-charged batteries is equivalent to a 7m tall top charged battery. In India, chamber height for coke ovens are found in the range of found 4.5 m-7.0 m.

Indian best Practice: The tallest carbonization chamber height for coke oven in India (till 2010-11) was found at 7.0 m. The integrated steel plants such as Vizag steel (battery#1 to battery#4), Neelachal Ispat, SAIL Bhilai (battery#9, #10) have installed 7.0m height coke ovens for coke making. Nearly 31.6 tonnes of coking coal (dry basis) can be charged at a time in a 7.0m tall coke oven.

Global best Practice: The Duisburg-Schwelgern (Germany) coke plant of ThyssenKrupp Steel AG integrated steel plant has the tallest oven with 8.3 m batteries. The plant has a capacity of 2.5 million tonne metallurgical grade coke per annum. These ovens have the capacity to hold nearly 70 tonnes of coking coal (dry basis) per oven charging.

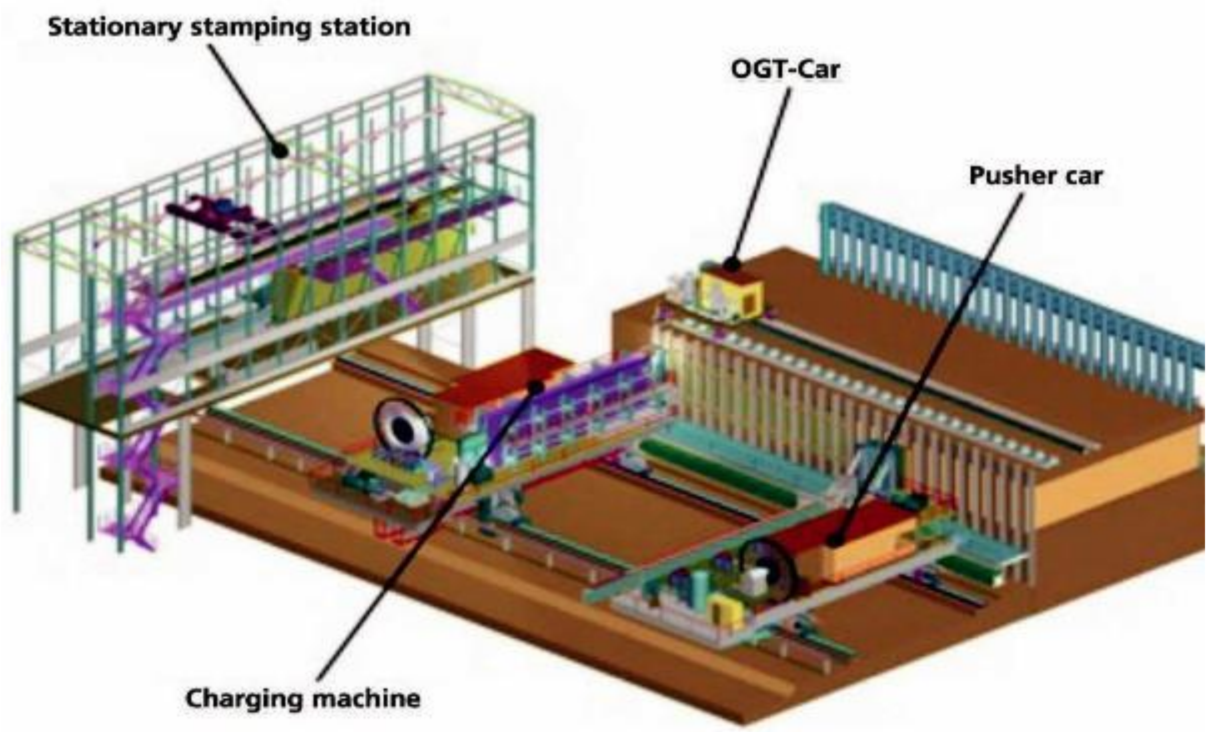
STAMP CHARGING (APPLICABLE FOR BOTH RECOVERY AND NON-RECOVERY TYPE COKE OVENS)

The stamp charging has significant advantages over conventional top charging of coking coal into coke ovens. It can produce high quality coke from low quality coking coal. The compactness of the stamp charge is normally 20-50 per cent higher than conventional charging. While the top-charging facility produces coal compactness of 765 kg/m^3 only, the stamp charging technology gives compactness of 1150 kg/m^3. By using stamp charging, more charge can be fed at a time in the oven compared to the top charging process. Therefore, the stamp charging also reduces door leakage and charging and pushing emissions. It enables better and efficient coke oven operation as well.

Indian best Practice: Stamp charging facility has been installed in some integrated steel plants in India such as Tata Steel (in battery#8 and battery-#9) and JSW Steel (battery#3A #3B, #3C and #3D).

Global best Practice: Stamp charging facility for coke oven has now been adopted widely across the globe. Example - Tangshan Jiahua (BCCW) Coking & Chemical Company, China has stamp charged battery for 6.25 m tall batteries with 46 ovens per battery.

Diagrammatic Representation of Stamp Charged Coke Oven Battery



Source: Coking plant technology, FLSmidth http://www.flsmidth.com/en-US/Products/Product+Index/All+Products/Coking+Plant+Technology/ Coking+Plant+Technology/Stamping+Technology (as viewed on 26 October 2012)

COKE DRY QUENCHING (CDQ) (APPLICABLE FOR BOTH RECOVERY AND NON-RECOVERY TYPE COKE OVENS)

Coke making process involves quenching of red-hot coke produced from coke oven. In case of wet quenching, significant quantity of water is lost during quenching. Besides, wastewater is also generated, and heat is lost in the environment. Dry quenching method saves water (around 0.5-1.0 m^3/tonne of gross coke), reduces water pollution as well gives opportunity for waste heat recovery of around 0.286 GCal/tonne gross coke. Stable coke quality and energy efficiency of the process are key driving forces for this technology.

Indian best Practice: As of 2009-10, only two integrated plants in India had installed CDQ facilities - Vizag steel (for all four batteries) and Neelachal Ispat Nigam Limited (for one battery).

Global best Practice: Many plants across the world have installed CDQ facilities. By March 2008, the number of CDQ plants (chambers) in operation was: 104 in East Asia, 12 in Central Asia, 5 in South America and 21 in Europe. In Europe, five are in Hungary, three in Finland, four in Poland, four in Romania and five are in Turkey.

HIGH PRESSURE AMMONIA LIQUOR ASPIRATION SYSTEM (HPLA)

During charging of coal in coke ovens high sooty emission is released. A localized vacuum is created by injecting high pressure ammonia liquor in a jet spray system in the gas collecting mains pipe to collect the gas. This helps not only to collect the high calorific value coke oven gas but also reduces charging emission by around 60per cent.

Charging Gas Cleaning (CGC) system is installed with stamp charge batteries which do not use HPLA system, but the gas is collected cleaned and burnt. However, in this process, significant amount of coke oven gas is lost. Therefore, HPLA with charging gas transfer system (CGT) is preferred for stamp charged batteries. This checks the pollution issue and increases coke oven gas yield. CGT is considered best practice for stamp charging coke oven plants.

Indian best Practices: HPLA systems are installed in a few integrated steel plants in India such as Neelachal Ispat (one battery), Tata Steel Jamshedpur (for battery#8 and #9), Vizag Steel for battery#4, and few SAIL plants – SAIL Rourkela (battery #1, #4 and #5), SAIL Bhilai (battery #3,#4,#5, #6 and #10), Bokaro Steel (battery #5), etc.

Global best Practice: Many coke plants across the world have installed HPLA system, example - Duisburg-Schwelgern (Germany) coke plant of ThyssenKrupp SteelAG integrated steel plant.

SELF SEALING DOORS

Positive pressure generated during coking process in the coke oven forces the off gas to leak through the doors. The leakage could be huge if sealing of doors is not complete. The self-sealing doors manage to maintain the lower pressure in the oven and enables formation of tar gasket along the doors for self-sealing. It helps to minimize the emissions during the coking cycle.

Indian best Practice: Self- sealing doors are applied in many coke oven plants in India such as – Vizag steel (battery#4), SAIL-Rourkela (battery##1 and #4), Tata Steel (battery#5, #6, #7, #8 and #9) etc.

Global best Practice: The integrated steel plants such as Corus, Ijmuiden (The Netherlands), Hüttenwerke Krupp Mannesmann, Duisburg-Huckingen (Germany), BHP Steel (Australia), ArcelorMittal Fos-sur-Mer and Dunkirk (France) etc. have installed self-sealing doors in the coke oven.

STATIONARY LAND BASED PUSHING EMISSION CONTROL

After completing the coking cycle, the red hot coke is pushed out from the oven into an open container. The high diffuse emission generated during this process is arrested using a suction hood installed at the container car. The gas is later collected in a pipe and cleaned in a bag filter before release in the environment.

The installation of the stationary land-based pushing emission control system in new and renovated (rebuilt) batteries has been mandated in India by the MoEF as per the GSR 46 (E) notification.

Indian best Practice: Vizag Steel (battery # 4), Tata Steel (battery # 8, # 9) and JSW Steel (all four batteries) etc. have installed this clean technology.

Global best Practice: Many steel plants across Europe such as ArcelorMittal- Ghent, (Belgium) and Dunkirk, Fos-sur-Mer, Seremange (France), Mannesmann Hüttenwerke Krupp, Duisburg-Huckingen (Germany), Corus, IJmuiden (The Netherlands) have installed stationary land pushing emission control system.

WET OXIDATIVE DESULPHURIZATION OF COKE OVEN GAS

Sulphur is present in raw coke oven gas as hydrogen sulphide (H2S) in the concentration of 1,800-4,000 mg/Nm^3 in Indian coke plants. To minimise sulphur dioxide (SO2) emissions during burning of the coke oven gas, the H2S content has to be minimized. A standard of 800 mg/Nm^3 of sulphur concentration in coke oven gas (after by-product recovery unit) has been stipulated by the MoEF as per the GSR 46 (E) notification. Conventionally, sulphur is removed by absorbing H2S with ammonia scrubbing.

There are number of wet oxidative desulphurization process in use such as Stretford, Takahax, Thylox, Perox etc. based on the chemicals used for scrubbing and regeneration of the sulphur.

Indian best Practice: JSW Steel Vijayanagar has installed wet desulphurization process for coke oven gas to achieve post cleaning H2S concentration of less than 200 mg/Nm^3.

Global best Practice: Many plants across the globe such as ArcelorMittal, Hamilton (Canada) and Lorraine (France), POSCO (Korea) have installed Stretford process, Nippon Steel plants (Japan) have installed Takahax process.

VARIABLE PRESSURE REGULATION TECHNOLOGY

Higher pressure build-up during charging of coal in coke ovens results in leakage through doors and lids – causing high diffuse emissions and loss of the valuable coke oven gas. The pressure build-up peaks (up to 35 mm water column) during charging and remains slightly positive (10-15 mm water column) for a large part of the coking duration of 14-28 hours.

In the conventional manual method, a fixed high- and low-pressure regulation is used for pressure control. Through the advanced variable pressure regulation technology, the coke oven pressure is lowered to just above atmospheric pressure during charging. This enables drastic reduction of all diffuse emissions (charging, doors, lids and gas off-take joints). The dust, PAH emissions and coke particulate emissions are also reduced drastically using this technology.

Indian best Practice: None of the Indian plants have so far installed the variable oven pressure control technology for charging emissions control.

Global best Practice: This pressure regulation system has been operating since 2003 at the new coke plant in Duisburg, Duisburg-Schwelgern (Germany), thereafter at several coke ovens plants in Brazil, China, and South-Korea, etc.

HIGH COKE OVEN GAS COLLECTION RATE

Coke oven gas is rich in calorific value (3800 to 4200 kCal/Nm^3) and is used as an important fuel for high temperature heating applications in the different units of steel mills. It can also be mixed with other lean calorific value waste gases so that the leaner waste gas can also be used suitably. The coke oven gas collection rate reflects the extent to which the waste energy is recovered from the coke oven battery.

Indian best Practices: Among Indian integrated steel plants, Vizag Steel was observed to have the highest coke oven gas recovery rate at 340 Nm^3/tonne dry coal charged. Vizag Steel uses low ash Australian coking coal with ash content of 10per cent and volatile matter of 26.1per cent.

Global best Practice: The best practice in EU integrated steel plants is coke oven gas recovery rate of around 388 Nm^3/tonne dry coal charged using the same Australian grade coking coal.

LOW SPECIFIC THERMAL ENERGY FOR BATTERY

The coke battery refractory walls are heated up to 1350°C by using waste gas fuels (e.g. coke oven gas, blast furnace gas or a mixture of both). The waste fuel gas is used to heat the bricks underneath each oven. The specific thermal energy consumption per tonne of gross coke produced indicates the overall energy and operational efficiency of the battery.

If the refractory walls of the oven chambers have cracks and deformations, then additional amount of under-firing will be required for heating the brick walls.

Indian best Practices: SAIL Bhilai plant battery #5 was found having the lowest specific thermal energy consumption among Indian plants at of 726 kcal/kg gross coke.

Global best Practice: At Kawasaki Steel, Mizushima (Japan) battery #4 was reported to have the lowest specific thermal energy consumption at 650 kcal/kg of gross coke.

HIGH GROSS COKE YIELD

The amount of gross coke produced per tonne of dry coal charged is an important parameter. It shows whether coal charged in the oven is efficiently being converted into coke or being over burnt (over coking) in the coking process which may lead to the energy loss. Some Indian plants also add pet coke to enhance the coke yield as well as to improve the strength of coke output.

Advanced control technologies including infrared sensors and computer diagnostics need to be installed to minimise over coking. Non-recovery type coke ovens have lesser coke yield compared to the by-product recovery type.

Indian best Practices: SAIL Burnpur was found having the highest gross coke yield of around 76per cent. The reason was the high use of imported coal to indigenous coal (60:40) resulted in high gross coke yield. The indigenous coal is used from Chasnalla (Jharkhand), Jitpur and Ramnagore area and imported coal from Australia. However, productivity of this coke oven plant (0.558 t gross coke/m^3 inner volume) and BF-coke to gross coke ratio (89per cent) was found low compared to the other similar plants in India.

For the non-recovery type coke ovens highest coke yield was 72.9 per cent at Bhushan Power and Steel, Sambalpur.

Global best Practice: Among the EU integrated steel plants, the gross coke yield was found as high as 81per cent for Australian grade coking coal21. For the non-recovery type coke ovens, the global best practice has been considered at 76per cent.

HIGH BF (MET) COKE PRODUCTION EFFICIENCY

The coke obtained after quenching is screened and crushed to obtain different size fractions. BF-grade coke of size between 25-70 mm is the desired product for the blast furnace operations. The other small and powdered coke is deemed as waste and used in sinter plants, partly added in the blast furnace, sold or even recycled back in the coking process. Higher the BF-grade coke produced, better the operations of the coke plant. By-product plants in India have typical BF coke production efficiency of 79-84 percent.

Indian best Practice: JSW Steel, Vijayanagar was found having the best BF coke production of 91.9per cent in India. The Coking coal is mainly imported from Australia and South Africa with some quantity from USA and China.
Non-recovery type coke ovens had relatively high BF grade coke production efficiency. Green Rating project found Jindal Steel and Power Limited (JSPL), Raigarh and Bhushan Power and Steel, Sambalpur with the BF coke production efficiency as high as 90 to 92 percent.

Global best Practice: The highest BF grade coke efficiency, globally, was considered as 92 percent.

BENZO(A)PYRENE MONITORING

In coke ovens, the emissions during the entire charging and coking cycle primarily arise out of the volatile hydrocarbons present in the coal mass. The hydrocarbons in coal are typically around 25 per cent by weight and vary slightly across plants depending on the coal blend. The off gas collected or released from charging and coking operations predominantly appear in the form of polycyclic aromatic hydrocarbon (PAH) compounds due to partial burning. PAHs are persistent organic compounds released during incomplete combustion of fossil fuels, as done during the coke making process. Prolonged human exposure to emissions of PAH group of compounds is known to lead to cancer. Thus, the health of workers in by-product coke oven battery area is a major concern. To monitor the extent of emissions of PAH group of compounds, the concentration of benzo(a) pyrene compound is measured and used as an indicator for the entire PAH family. The other organic compound measured in coke ovens is benzene.

As per the European Integrated Pollution Prevention Control (IPPC) document, the average daily value for the emission rate was estimated to be in the range of 5 – 35 mg BaP/tonne of coke.

Indian best Practice: Vizag Steel has reported the purchase of B(a)P emissions monitoring equipment in March 2011, thus becoming the only Indian plant to have in-house monitoring facility. The frequency of monitoring should be as frequent as possible, at least once in a month. The B(a)P norms in ambient air in India is notified at 1 ng/m^3 as per National Ambient Air Quality (NAAQ) 2009 standards.

Global best Practice: In Australia, the PAH emission concentration is measured every six days using Gas Chromatography-Mass Spectrometry (GCMS) as per 'Other Approved Method 1 means measurement of PAH using a certified extraction and analysis procedure based on US-EPA method 8270, and reporting results as speciated PAH, including benzo(a)pyrene'.

The threshold limit of B(a)P is 1 ng/m^3 for ambient standards in Australia. As per Australian EPA, where levels of B(a)P exceed 1 ng/m^3 an assessment to determine the likely reason for the elevated PAH level must be made of:

- Weather data (including provision of a wind rose showing wind speed and direction for the period of the monitoring);
- Operating conditions and;
- Other relevant factors.

Reporting: For each monitoring site graphical presentation should include the 12-month averages for PAH and benzo(a) pyrene for the current licensing (consent) year plus the preceding years (where such data exists). This graph must include a trendline and a line showing relevant guideline criteria for benzo(a)pyrene.

SPECIFIC WASTEWATER INFLUENT TO ETP

Moisture in charge coal, which is evaporated in ovens and condensed in the gas collecting mains, is the main source of wastewater in a by-product recovery plant. The excess wastewater generated in the process is sent to an effluent treatment plant for treatment followed by recycling or discharge. Higher moisture content in coal (with higher quantity required for stamp charge preparation) may lead to higher wastewater pollution load. Overall, if moisture content in charge coal is in the range of 8-15 per cent, this leads to wastewater generation of 0.1 to 0.17 m^3/tonne of coke.

Indian best Practices: Among Indian plants Vizag Steel (0.2 m^3/tonne of gross coke) and Tata Steel (Tata Steel-0.27 m^3/tonne gross coke) had the lowest wastewater generation to ETP. Vizag Steel is equipped with top charging facility whereas Tata Steel has stamp charging facility.

Global best Practice: The best practice of wastewater influent sent to treatment plants is in EU coke oven units at 0.1 m^3/tonne of gross coke.

Indian best Practices: Many of the Indian coke oven plants such as from Vizag Steel, Tata Steel, JSW steel, SAIL Rourkela etc. have installed biological wastewater treatment system with nitrification-denitrification system. Tata Steel has biological treatment system with pre nitrification system which removes extra ammonia from the effluent. However, most of the plants found failed to comply the coke oven wastewater pollutant concentration norms.

HIGH SPECIFIC CRUDE TAR COLLECTION

Wastewater generated from coke oven plant contains tar. As it is relatively hard to degrade, it is removed by gravity separation, as much as possible, before it enters the effluent treatment plant. The specific crude tar collection rate gives a good indication of how well the tar has been removed by gravity separation prior to the overflow flushing liquor entering the ETP.

Indian best Practices: Among the Indian steel plants, Neelachal Ispat which uses 100 percent imported Australian grade coking coal, reported the highest crude tar collection at 42 kg/tonne of gross coke from the coke plant.

Global best Practice: The EU coke oven plants using the same Australian grade coking coal have recovered as high as 48 kg of crude tar per tonne of gross coke.

NON-RECOVERY COKE OVENS

Worldwide, the use of non-recovery coke oven technology is rising, both in integrated steel plants and by merchant coke producers. By 2010, almost one-third26 of the coke oven output of US and 8per cent of total coke production in China27 was from non-recovery type. However, the EU member states have not initiated the use of non-recovery coke oven technology as of 2009-1028. In India, non-recovery coke oven technology accounted for more than a fourth of the 32 MTPA coke production capacity in 2009-10.

Non recovery type coke ovens are considered cleaner than by-product recovery type, as the off gas generated from the process (high in calorific value) is burnt completely and used for steam and subsequent power generation. This way no pollutants are generated from treatment of coke oven gas and subsequent recovery of by-products. Therefore, as mentioned earlier, the USEPA since mid-1990s has effectively banned greenfield by-product recovery coke ovens and only non-recovery coke oven technology is being promoted as a clean technology for coke making. Stamp charging, higher coal holding capacity and coke dry quenching (CDQ) are considered as the best practices for non-recovery type coke ovens as well. The former two technologies are already adopted in Indian plants such as Visa Steel, JSPL, Raigarh and Bhushan Power and Steel, Sambalpur. None of the non-recovery coke oven plants in India have installed CDQ yet.

EQUIVALENT WASTE HEAT POWER GENERATION IN NON-RECOVERY COKE OVENS

The heat from the hot flue gases generated in the non-recovery coke making process is used for power generation. The waste gas is burnt to heat the oven chambers and the hot flue gas is sent to a gas fired boiler to generate steam and subsequently power. The steam and power is further used in various units of the plant to maximise energy savings.

Indian best Practice: Visa Steel Kalinganagar has reported the highest equivalent waste heat power generation at 341 kWh/tonne gross coke.

Global best Practice: The global best practice has been reported at 500 kWh/tonne gross coke in the standalone 1.6 MTPA non-recovery coke oven facility of Tata Steel, Haldia, West Bengal, India.

SINTER PLANT

The sintering process involves fusion of iron ore particles at a temperature just below the melting point of iron. The fuel used for the fusion process is coke dust, also called coke breeze. The fused mass of iron ore particles appears as blocks of size ranging from 5 to 50 mm.

The sinter plant is also called the scavenging unit of a steel mill as a wide range of wastes can be mixed with fresh raw material in sinter making. The design and technology, operational performance improvement and air emission control are important aspects to be considered for BAT in sinter plants.

LARGER SINTER MACHINE SURFACE AREA

Sinter machines with larger surface area enable installation of all energy conservation technologies such as sinter cooler waste heat recovery and thus help in minimising specific energy consumption of sintering process. The specific energy consumption of a sinter machine with larger surface area retrofitted with all the relevant waste energy recovery devices is 40-50per cent less than the conventional smaller sized sinter machines.

The average sinter machine size in India, in 2009-10, was 195 m^2 reaction area whereas the average sinter machine size reported in Japan was 342 m^2 (2005 data) and 234 m^2 in the European Union's 27-nation block (2009 data).

Indian best Practice: In the year 2010-11, JSW Steel Vijayanagar has installed India's largest sinter machine of 496 m^2 reaction area for its sinter plant #3. This machine can produce 5.75 MTPA of sinter.

Global best Practice: The world's largest sinter machine from Outotech has the size of 600 m^2. This can produce as high as 6.5 MTPA sinter.

SINTER COOLER WASTE HEAT RECOVERY

The hot screened sinter needs to be cooled before it is dispatched to the blast furnace section. A part of the waste energy recovered can be used in annealing hood. The hot air generated can also be supplied to the ignition hood burner of sinter strand, thereby minimising the waste fuel gas (BF gas, coke oven gas) consumption for ignition purposes. To further enhance recovery, steam can be generated for use in process or power generation. The annealing hood and pre-heated air together can gainfully use only 20per cent of the waste energy available.

Further, steam generation can help in energy recovery of up to 30per cent of the waste energy available.

Indian best Practice: A number of sintering plants in India such as at SAIL Rourkela (sinter plant #2), Tata Steel (sinter plant #2, #3 and #4), JSW Steel Vijayanagar (sinter plant #1, #2), Ispat Industries etc. have installed partial waste heat recovery system of annealing hood and preheating ignition hood. However, significant amount of heat is still wasted, and hence further heat recovery is possible for applications such as steam generation.

Global best Practice: In Philippine Sinter Corporation plant of Japanese steelmaker JFE Steel (Philippines), for a sinter strand of 495 m^2 and which produces 5.5 MTPA of sinter, 18 MW of waste heat power is generated from sinter cooler waste heat recovery. The power plant accounts for 73 per cent of the sinter plant's electrical energy demand.

SINTER EXHAUST GAS LOW TEMPERATURE RECOVERY

The sinter exhaust gas carries low temperature heat which is diluted with fresh air and released to atmosphere. This sensible heat of the waste gases can be recovered through a heat recovery boiler before being passed to the electrostatic precipitators (ESP) and stack.

Indian best Practices: None of the Indian plants have installed low temperature waste heat recovery.

Global best Practice: Sinter plants in Japan have installed this technology. In 1995, it was reported that nearly 43per cent Japanese sinter machines had installed low temperature gas heat recovery from stack exhaust gas.

SELECTIVE WASTE GAS RECYCLING

Hot waste exhaust gas from wind boxes is collected and re-circulated back to the sinter bed to minimize the solid fuel energy required in the bed. An enclosed hood is provided on the top of the sinter bed to maintain sinter bed temperature. This can reduce the coke breeze consumption by 10-15per cent and reduces exhaust gas flow by 50per cent and corresponding air pollution as well.

Indian best Practices: Till 2009-10, none of the Indian sinter plants had installed selective waste gas recycling (SWGR) technology. However, one upcoming sinter plant of JSPL Patratu, Jharkhand (430 m^2 reaction area) has proposed to install this technology.

Global best Practice: The technology has been installed in five plants in Japan (including Tobata sinter plant #3, Yawata Works, Nippon Steel Corporation) and one steel plant in Europe Corus IJmuiden (The Netherlands).

HIGH SINTER PRODUCTIVITY

Higher productivity of a sinter plant per square metre of strand surface area enables lower energy consumption per tonne of sinter produced. Apart from the operational techniques and performance, the factors which affect sinter machine productivity are the raw material quality, rate of unusable powdered sinter fines produced, the consistency of blend of raw materials prior to charging, the dimensions of sinter bed, waste heat recovery and the effectiveness of suction under the strand.

Indian best Practice: Tata Steel Jamshedpur sinter plant #3 and #4 and JSW Steel Vijayanagar Sinter plant#2 (each of 204 m^2 grate area) had the highest productivity of 1.50 tonne sinter/m^2/hour.

Global best Practice: The global best sinter strand productivity is reported at 1.80 tonne sinter/m^2/hour.

LOW SPECIFIC COKE BREEZE CONSUMPTION

Coke breeze generated from coke making process is used as fuel and a fusion source in sinter making. It is a major source of thermal energy for sinter plant. Coke consumption largely depends on raw material quality and waste energy recovery measures in sinter plant. Coke is the dominant fuel source in sinter plants accounting for 85-90 per cent of thermal energy input, with the remainder coming from waste gas fuel. Higher the coke breeze consumption, higher the specific energy consumption of the sintering process.

Indian best Practice: Sinter plant #1 of JSW Steel Vijayanagar has reported the lowest coke breeze consumption of 55.5 kg/tonne sinter in India. This sinter machine is equipped with waste heat recovery and uses preheated air in the strand's ignition hood. The coking coal used is low ash coal imported mainly from Australia while the iron ore fines is from the nearby Bellary mines.

Global best Practice: Sinter plants in EU have achieved coke breeze consumption of as low as 39 kg/tonne sinter (in year 2004, as surveyed by European Blast Furnace committee).

LOW SPECIFIC THERMAL ENERGY CONSUMPTION

Coke breeze accounts for bulk of the energy consumption in sinter plants accounting for close to 90 per cent of thermal energy input, with the remainder coming from waste gas fuel. The specific thermal energy consumption depends on the operational techniques, quality of raw material feed and extent of waste energy recovery recycled back to the sinter machine.

Indian best Practices: Lowest specific thermal energy consumption of 0.40 GCal/tonne sinter was observed at JSW Steel Vijaynagar Sinter Plant #1.

Global best Practice: EU sinter plants have reported the best thermal energy efficiency at 0.30 GCal/tonne sinter in plants accompanied by technologies such as waste gas recycling, sinter cooler waste heat recovery, etc.

HIGH SOLID WASTE RECYCLING IN SINTER PLANT

Different solid wastes from blast furnace and steel melting process stages are recycled through the sinter plant by mixing with the fresh raw material feed. It may include metallurgical wastes, dust captured from air pollution equipment's and small quantity of slag from steel melting.

Indian best Practice: Ispat Industries, Raigad was found having highest waste recycling in sinter plant at 122 kg/tonne sinter in India. It recycles gas cleaning plant and flue dust from blast furnace, electric arc furnace and gas based sponge iron units (69.5 kg/tonne product sinter), mill scale (35.2 kg/tonne product sinter) and electric arc furnace slag (17.2 kg/tonne product sinter).

Global best Practice: The global best practice also corresponds to the Indian best practice of Ispat Industries, Raigad at 122 kg/ tonne sinter.

ADVANCE SINTER PLANT DUST EMISSION CONTROL

Reddish dust emission from a sinter plant is one of the largest air pollution sources in a steel industry which largely comes from sinter crusher area, raw material and lime proportioning area and other sinter shed areas. ESP is the most common dust abatement device used at sinter plant. Wet ESP is also used in some plants.

For good performance, ESP is used with pulse energisation technique in which high voltage pulse is repeated at up to 200pulses/seconds frequency. This performs efficiently even with high resistivity dust. Use of Moving Electrode Electrostatic Precipitator (MEEP) is another method which can counter insulating effect of dust layer at plates and removes highly adhesive dust effectively. In this technique group of ESP plats move on a caterpillar track and rotating brushes keeps the plates clean. Electrostatic space cleaner is also used with ESP which enlarges the gap between the plates and allows higher voltage for higher dust control efficiency. Use of various programmable logics and use of up to five fields with ESP, efficiency of ESP can be improved. Use of alkali in ESP and waste gas re-circulation system also has additional advantages.

These techniques give 95-99 per cent of dust emission reduction at sinter plant. A MEEP can reduce dust emission to 25-30 mg/Nm^3. With energisation technique, ESP can reduce the dust emission to 43 to 77 mg/Nm^3. With electrostatic space cleaner dust emission control is reported less than 40 mg/Nm^3.

Indian best Practice: Sinter plants in India are majorly equipped with dry type dust control systems with space de-dusting system. However, it has been observed high dust emission from most of these sinter plants. Sinter plant installed at Ispat Industries Limited which uses BF gas and natural gas for ignition hood and carry waste gas recirculation for preheating, dust emission was found comparatively low.

Global best Practice: ArcelorMittal, Ghent (Belgium) using ESP equipped with micro-pulse discrimination have achieved emission reduction to 20 – 42.7 mg/Nm^3. Energy pulse superimposition has been installed at many sinter plants such as Gwangyang Works, Posco (South Korea), Thyssen Krupp Stahl, Duisburg (Germany), ArcelorMittal, Dunkirk and Fos sur Mer (France) and Ghent (Belgium) etc.

A MEEP has been installed at Riva, Taranto (Italy) and ArcelorMittal, Eisenhüttenstadt (Germany). An electrostatic space cleaner super (ESCS) has been installed at the sinter plant of Nippon Steel Corporation, Yawata Works in Japan.

CONTROL OF DIOXINS AND FURANS

Sinter plants are a major source of polychlorinated dibenzop- dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), formally known as dioxins and furans, respectively.

PCDDs and PCDFs are listed among the 12 most persistent organic pollutants (POPs) under the Stockholm Convention due to their environmental persistence and their high accumulation ability in biological tissues.

A whole range of measures such as use of activated carbon in flue gas stream, minimising chlorine content in the feed and use of fabric filters with catalytic oxidations systems need to be adopted to minimise dioxin-furan emissions.

Indian best Practice: None of the Indian plants have adopted any measure to reduce dioxin-furan emissions.

Global best Practice: Sinter plants in EU such as ArcelorMittal, Ghent (Belgium), Thyssen Krupp Stahl in Duisburg (Germany) and Hüttenwerke Krupp Mannesmann, Duisburg (Germany) use activated carbon system45. Further, plants such as ArcelorMittal Bremen (Germany) and Voestalpine Stahl GmbH, Donawitz (Austria) use the bag filter system in combination with reduction and oxidation agents.

BLAST FURNACE

Blast furnace (BF) process accounted for more than 90per cent of iron making in the world in 2011. In India, BF process contributed to about 65 per cent of iron making; with the remaining 35 per cent accounted by the Direct Reduced Iron (DRI) route.

In the BF process, agglomerated ore in the form of sinter (or pellet) along with lump ore are the major raw material feed. Coke is added that acts as a reducing agent as well as energy source.

Improvements in design and technology, operations, pollution control systems, waste management and health and safety are the focus areas of best practice in BF process.

LARGE WORKING VOLUME FURNACE

Larger working volumes of blast furnace shell enables the installation of clean technologies such as pulverised coal injection, high top pressure and higher hot blast temperature, thus minimizing coke consumption. The consumption of coke in large blast furnaces can be reduced by up to 50per cent in large volume blast furnaces, thus also reducing coke demand and hence, environmental impacts in the upstream coke making.

Indian best Practice: In 2010-11, the largest size blast furnace was installed at JSW Steel Vijayanagar BF #3 and #4. Each blast furnace has working volume of 3445 m^3 with hot metal capacity of 2.8 MTPA. These BFs are installed with clean technologies such as pulverized coal injection, bell less top, high top pressure etc.

Global best Practice: Blast furnace in Japan such as Nippon Steel Oita Works is reported to have the largest working volume at 5000 m^3 with unit capacity of 5.0 MTPA hot metal.

BELL LESS TOP

In this design, the charge material from hopper passes through two valves – gate valve and sealing valve operating alternatively, before entering the rotating feeder system. Thus, a two-valve mechanism is used instead of the conventional double-bell system. This enables uniform distribution of materials, maintaining uniform temperature and reaction zones and minimising coke consumption.

Indian best Practice: Of the 43 blast furnaces considered till 2009-10 and for which data was available, 29 had bell-less design type for charging.

Global best Practice: The bell less charging is a common practice in advanced countries – for example, 40 of the 49 BFs in Western Europe have installed this technology.

PULVERISED COAL INJECTION (PCI)

High grade coal (such as anthracite) is powdered and injected through tuyeres at the bottom of the blast furnace. Oxygen supplied in the hot blast tuyeres enables faster burning of this coal. This alternate fuel injection system reduces coke consumption in the blast furnace. Around 0.85-0.95 kg metallurgical coke production is avoided for every kilogram of pulverised coal injected into the blast furnace. Higher the PCI, lower the coke consumption and better is the energy efficiency.

Indian best Practice: Tata Steel Blast Furnace #H had highest PCI rate at 135 kg/tonne hot metal (thm) in 2009-10. The furnace has a working volume of 3230 m^3.

Global best Practice: PCI is a common technology adopted in blast furnaces globally. The highest PCI rate of 255 kg/thm has been achieved by Corus, Ijmuiden #6 (The Netherlands). However, depending on the carrying capacity of the coal and thermochemical condition of furnace, maximum theoretical PCI of 270 kg/thm can be achieved. To maintain the combustion for high PCI, oxygen enrichment is provided in the furnace.

HIGH TOP PRESSURE AND TOP PRESSURE RECOVERY TURBINE (TRT)

While the raw material charge in a blast furnace descends by gravity in the reactor shell, the hot blast air is forced upwards. The counter-current direction of hot blast air is important to speed up the interaction of the reductant gases (carbon monoxide) with the iron burden to enable faster removal of the oxides from the ore. Hence, high top pressure needs to be maintained to enhance the productivity and minimize coke and hence, energy consumption.
High top pressure (above 1.5bar g) blast furnaces also provide an ideal opportunity for recovering energy from the large volumes of pressurised top gas. As per International Energy Agency (IEA, 2007), a top-pressure recovery turbine (TRT) can be used to generate electricity from this high top pressure. A TRT can produce 15 – 40 kWh/thm.

Indian best Practice: The furnaces equipped with TRT technology in India are Vizag Steel (BF # 1 and # 2 – each with 12 MW generator capacity), Tata Steel (BF # G – 8.0 MW and

BF # H – 13.5 MW), JSW Steel (BF # 3 – 12.4 MW) and Ispat Industries (BF # 1 – 5.5 MW). The Indian best practice for power generation was 23 kWh/ tonne steel in Vizag Steel in 2009-10.

Global best Practice: Several blast furnaces in the world run at high top pressure for improved efficiency. High top pressure of these furnaces is around 3.0 bar (g).

TRTs are widely used in Japan and Europe. In China, 66 blast furnaces representing nearly half the total production capacity were equipped with TRT in 2004. Japanese BFs have achieved as high as 40-60kWh/thm power from top pressure.

DRY GAS CLEANING

In wet gas cleaning around 0.4-8 m^3/thm of fresh water is used. This also leads to extensive waste water generation to treatment plants. Presently, the latest technology that is used for gas cleaning has 100 per cent dry gas cleaning approach, minimising wastewater generation and freshwater consumption.

Indian best Practice: Bhushan Power and Steel, Sambalpur is the only plant in India equipped with dry gas cleaning technology with its blast furnace. This is for a BF of 860 m^3 working volume bell-less type blast furnace with 3 internal type hot blast stoves, PCI facility and 1.5 bar (g) design top pressure.

Global best Practice: Dry gas cleaning for BF gas is common among Chinese and Japanese blast furnaces.

CAST HOUSE SLAG GRANULATION

For ensuring that all the slag that is generated has cement-making properties, it has to be rapidly quenched with a high pressure jet of water at the blast furnace cast house itself so that it breaks down into tiny granules. This is known as cast house slag granulation.

Indian best Practice: Out of the 43 BFs in India, till 2009-10, 33 had installed cast house slag granulation system.

Global best Practice: Blast furnace of EU plants such as Thyssen AG, Duisburg (Germany) and Corus plants at Port Talbot and Scunthorpe have installed cast house slag granulation with fume emission control.

WASTE HEAT RECOVERY FROM HOT BLAST STOVES

The waste flue gases (exhaust) from the hot blast stoves are released to the atmosphere at around 350°C. This waste heat can be utilised for preheating the incoming cold blast (combustion air). It can also be used for heating the waste gas fuel itself before it is used for burning. Energy savings is estimated up to 0.07 GCal/thm.

Indian best Practice: Many Indian BFs - Tata Steel (BF #G, #H), Ispat Industries, Jindal Steel and Power (BF#2), Jai Balaji, Durgapur have installed waste heat recovery from hot blast stoves.

Global best Practice: Many blast furnaces across the world have adopted waste heat recovery from hot blast stoves. Plants such as ThyssenKrupp Steel AG, Duisburg (Germany), Blast Furnace # 7 of Corus, Ijmuiden (The Netherlands), ArcelorMittal, Ghent (Belgium) and ArcelorMittal, Gijón, (Spain), Voestalpine Stahl GmbH, Linz and Donawitz (Austria) have installed energy saving system from hot blast stove exhaust.

BLAST FURNACE PRODUCTIVITY

The productivity of a blast furnace is defined as tonnes of hot metal produced per m^3 working volume per day. Higher the productivity of a blast furnace, lower the coke consumption and higher the energy efficiency. Productivity of a blast furnace depends on a number of factors such as raw material quality, high top pressure, oxygen injection and hot blast temperature.

Indian best Practice: Among medium and large sized BFs in India, Tata Steel BF #H has the highest productivity at 2.6 thm/ m^3 working volume/ day. Amongst mini blast furnaces, BF #1 and #2 of Jai Balaji, Durgapur plant have achieved high productivity of 3.4 thm/m^3 working volume/day.

Global best Practice: Corus IJmuiden BF#6 has achieved the productivity as high as 4.0 thm/m^3 working volume/day. This BF has the working volume of 2328 m^3, having all the clean technologies installed and highest PCI of 255 kg/thm.

HIGH AGGLOMERATED IRON ORE RATIO IN IRON BURDEN

Agglomerated ore has advantages of higher bed permeability, higher porosity and self-fluxing burden – all of which enable faster reaction of iron ore with reactant gases. With high ratio of agglomerated iron ore in the form of sinter and pellet in iron ore charge in the blast furnace, higher productivity can be achieved.

Indian best Practice: The highest ratio of agglomerated ore in blast furnace iron burden was reported at Ispat Industries, Raigad, Maharashtra at 86 per cent (sinter 1146 kg/thm + pellets 302 kg/ thm with total burden of 1717 kg/ thm).

Global best Practice: It is reported that agglomerated iron ore ratio in the charge of blast furnace can be achieved as high as 90per cent at Corus Ijmuiden with equal use of pellets and sinter.

COKE RATE IN BLAST FURNACE

Coke is the source of energy as well as reducing agent for blast furnace operation. Lower the coke consumption lower is the energy consumption. The coke is not only a costly concern for the plant but it also puts major environmental impact during production at coke oven. Therefore, lesser coke consumption not only saves cost and increases energy efficiency but also lowers the environmental impact from the plant.

Indian best Practice: Lowest specific coke consumption has been achieved by Ispat Industries at 394 kg/thm. The same furnace has the highest rate of substitute fuel - pulverized coal injection in India, at 126 kg/thm.

However, the gross thermal specific energy consumption was found lowest at Jindal Steel and Power, Raigarh at 4.22Gcal/thm. This is a 1462m^3 working volume blast furnace with 3 internal type of hot blast stoves. The specific coke consumption is 410kg/thm and PCI of 130kg/thm.

Global best Practice: The lowest coke consumption has been achieved at 250kg/thm58 whereas the lowest gross specific thermal energy consumption has been achieved at 4.0Gcal/thm.

LOW BLAST FURNACE GAS GENERATION

The blast furnace gas is generated as waste gas during blast furnace iron making process. It has the calorific value of around 700 to 900 kCal/ m^3. The lower the BF-gas generated the lower would be the energy released as waste during blast furnace operations.

Indian best Ppractice: Blast furnace #G of Tata Steel, Jamshedpur has lowest BF gas generation at 1200 Nm^3/thm. This is a BF with working volume of 2308 m^3, bell-less design with 4 external type hot blast stoves.

Global best Practice: The global lowest BF gas generation rate has also been noted to that of Indian BF at 1200 Nm^3/thm.

HIGH HOT BLAST TEMPERATURE

Higher the hot blast temperature, lower will be coke consumption in the blast furnace. It also leads to lower specific energy consumption in blast furnace operations.

Indian best Practice: Blast furnace #H of Tata Steel, Jamshedpur has achieved the hot blast temperature of 1,188°C. The blast furnace #G of the Tata Steel has shown lowest hot blast volume requirement at 920m^3/thm.

Global best Practice: Blast furnace at Nippon Steel (Japan) has achieved the highest hot blast temperature of 1300°C. The global best for the lowest volume of hot blast achieved so far is 900m^3/thm.

LOW SLAG GENERATION RATE

The impurities in blast furnace operation are collected as slag. Higher the blast furnace slag generation rate, higher will be the energy required for heating up the slag in the blast furnace to molten metal temperature, leading to higher coke and energy consumption.

The blast furnace slag generation rate primarily depends on the quality of iron burden and the ash content in coke or pulverised coal.

Indian best Practice: Among small BFs in India, Visa Steel has been found having lowest slag generation rate of 210kg/thm in a 250 m^3 blast furnace. The iron burden consists of 100per cent lump ore sourced from Orissa Mineral Corporation with 63.49 per cent Fe, very low Silica (0.48per cent) and alumina (0.57per cent) content. No pulverized coal injection is adopted here.

Among medium and large BFs, Neelachal Ispat has the lowest slag rate at 273 kg/ thm. The company has a BF of 1670 m^3 working volume which is currently purchasing iron ore from Daitari/Banspani mines of Orissa Mining Corporation and 100per cent coking coal from Australia.

Global best Practice: European blast furnace have achieved slag rate as low as 150 kg/thm. These plants use high quality iron ore and have major proportion of agglomerated iron in the iron burden.

LOW SPECIFIC IRON ORE CONSUMPTION

Specific iron ore consumption depends on the ore quality grade which is determined by its ferrous content and the impurities. The impurities mainly are alumina and silica content. Indian blast furnaces normally use iron ore fines with high alumina at 3.0-3.5per cent when compared to less than 2.0 per cent globally.

Indian best Practice: Lowest specific iron ore consumption in India was observed at Vizag Steel at 1.53 tonne/tcs. The blast furnace uses 75per cent agglomerated iron ore as iron burden. Iron ore lump and fines are sourced from NMDC, Bailadila, Chhattisgarh. Sinter used in process has 55.4per cent Fe, 6.5per cent Silica and 2.32per cent Alumina whereas lump ore contains 66.69 per cent Fe, 1.6per cent Silica and 0.94per cent Alumina.

Global best Practice: European blast furnaces have achieved the lowest iron ore consumption of 1.4 tonne/tcs.

SPECIFIC EQUIVALENT COKING COAL CONSUMPTION

Coke consumption in blast furnace and the coke making efficiency on a plant boundary level is easily reflected in the specific equivalent coking coal consumption per tonne of crude steel in an integrated steel plant. This single indicator gives a clear measure of how efficiently the plant is managing its energy use.

Indian best Practice: Lowest equivalent coking coal consumption of 656 kg/tcs was reported at Ispat Industries. The plant also has lowest specific coke consumption of 394 kg/thm. On the other hand, the plant uses maximum substitute fuel of pulverized coal injection at 126kg/thm.

Global best Practice: The global best for plant level coke consumption is as low as 250 kg/tcs.

CAST HOUSE DEDUSTING SYSTEM

When the blast furnace tap hole is opened intermittently for tapping the molten iron, a huge amount of fumes and graphite dust particles are released. Further, as the molten iron travels along the open sand pathways to the insulated vessel (ladle), huge fumes and dust emissions are again released.

Hence, to ensure proper working conditions for the blast furnace workers and minimise heat loss, the fumes, dust and graphite particles need to be collected through properly designed suction hoods and bag filter/ ESP system.

Indian best Practice: Of the 43 BFs surveyed in India, only 12 had installed cast house dedusting system.

Global best Practice: As per the European Union IPPC document, cast house dedusting system has been installed at Blast furnace #7, Corus, IJmuiden (The Netherlands); blast furnaces #5, #6 and #A, Voestalpine, Linz (Austria); blast furnace Thyssen Krupp Stahl AG, Duisburg-Schwelgern (Germany); ArcelorMittal, Drbrowa Górnicza (Poland); SSAB (Sweden) and Rivagroup, Taranto (Italy)66. The dedusting system is for tap holes, runners, skimmers, and torpedo ladle charging points.

Cast house dedusting at Bhushan Power and Steel, Sambalpur, Odisha

ADVANCED CARBON-MONOXIDE MONITORING SYSTEM FOR GAS LEAKAGE DETECTION

The BF-gas and other waste gas fuels are found to leak from the gas scrubbing area, blast furnace top, hot blast stove area and other areas in the blast furnace operations. The BF-gas contains around 26 per cent carbon monoxide and hence is extremely lethal. The leakage of BF-gas has been reported to be a major cause of fatalities in steel plants, it was observed that employees were not carrying portable carbon monoxide meters (an indicator and proxy for gas leakage measurement) in the blast furnace area of many plants. Further, many online carbon monoxide monitors installed in different locations were not found working. More attention is required for gas leakage tracking and accessibility of monitors for plant personnel, including contract workers.

Indian best Practice: The alarm level for BF-gas leakage detection was found normally kept at 30-50 ppm carbon monoxide.

Global best Practice: The global best practice is exposure to carbon-monoxide of less than 5 ppm in 8-hour shift as per standards in advanced countries and with nil gas leak accidents.

BF GAS CLEANING AND METALLURGICAL WASTEWATER TREATMENT

Blast furnace gas after coarse dust separation is directed to gas scrubbing using scrubber or wet ESP. Scrubbing water, reddish in colour, contains higher concentration of carbon particles and heavy metals such as iron, lead and zinc. Whereas coarse dust is reused in sinter plant, sludge from wet gas cleaning, settled at settling tank, is difficult to reuse because of having high lead (0.8-2.0per cent) and zinc content (1-10per cent). The low zinc sludge is separated from high zinc sludge and is reused in sinter whereas high zinc sludge is stored and disposed off. Sedimentation process at settling tank is improved by using flocculation agents such as anionic polyelectrolytes, mixed polymers or activated silicic acids. Overflow of the sedimentation step is generally cooled and used back in gas scrubbing.

Use of low quality ore may generate high impurity off gas resulting in higher impurities such as alumina, silica, salt content and alkali compounds in scrubbing water which may result in increase in water requirement for scrubbing, reduction in GCP efficiency and recyclability of treated water. Higher cyanide concentration in scrubbing water is observed especially during starting or restarting phase of blast furnace.

Overflow from the scrubbing water circuit ranges 0.1 – 3.5 m^3/thm whereas the gross water requirement for off gas cleaning ranges 0.4 – 8 m^3/thm depending on the raw material quality and water availability.

Indian best Practice: Indian blast furnaces such as at Ispat Industries, Jindal Steel and Power Limited and Jai Balaji, can recycle 100 per cent of treated GCP wastewater. GCP sludge generated is entirely reused in sinter plants. However, in many other blast furnaces in India, it is found that metallurgical wastewater being released as overflow to the drains. Due to inefficient filtering and dewatering equipment's and their poor maintenance, the recycling was poor and contaminated wastewater was being discharged into the environment.

Global best Practice: BF gas treatment is widely applied at blast furnaces around the world which can achieve the residual dust concentration of 1 – 10 mg/Nm^3. Low pressure drop (0.07-0.14 bar) and high efficiency gas cleaning system is preferred in modern plants. The older scrubber at the blast furnace however can also be replaced with the modern one but in consideration with the top gas pressure turbine.

Corus, IJmuiden (The Netherlands); Thyssen Krupp Stahl AG, Duisburg (Germany) have installed hydrocyclonage to separate zinc rich sludge (20-40per cent by weight) as overflow and separate it for stockpile/landfill.

For cyanide treatment at ArcelorMittal, Bremen, formaldehyde is added to scrubbing water before sedimentation process to produce glyconitrile which is oxidized by adding hydrogen peroxide solution to form glycol to lower the environmental impact.

COREX PLANT

The COREX process uses a Melter-gasifier which gasifiers non-coking coal to produce reducing gas which is used in reduction shaft for reduction of iron ore (lumps and pellets) for making direct reduced iron (DRI). The process is called smelting. The hot gases produced in the Melter-gasifier are further used to melt the hot DRI produced from reducing shaft.

The improvised form of COREX process is FINEX which can use iron ore fines directly. In India, JSW Steel, Vijayanagar has been using COREX technology till 2011, however few other steel plants such as Essar Steel, Hazira are adopting the COREX technology as well. The market penetration of COREX technology is limited and it has certain shortcomings as well. The major limitations include:

- The limited unit-wise capacity of the COREX module (maximum 1.0-1.5 MTPA hot metal per module)
- High oxygen requirement (almost 10 times the requirement in BF)
- Frequent breakdowns which affect production
- Strictly controlled charge quality requirement for smooth operations.

The best practices for COREX process operations have been reported for lower off-gas generation, minimised solid fuel and hence gross energy consumption, lower oxygen consumption and lower COREX slag generation rate.

The other clean technologies of BF such as cast house slag granulation, cast house dedusting, low slag generation, lower coal and coke consumption etc. are also applicable to COREX process.

BASIC OXYGEN FURNACE

This is the most popular primary steel making process in the world which utilises oxygen for steel making. This process, named the basic oxygen furnace or BOF process (also Linz Donawitz or LD process) enables production of high-quality steel in a batch cycle of less than 60 minutes duration. As of 2010, this accounted for 70 percent of steel making route in the world80. In India basic oxygen furnace route accounted for 46per cent of steel making in 2010-11, with the rest being accounted by electric arc or induction furnaces.

The process requires continuous supply of hot molten iron from BFs which is mixed with coolant materials (steel scrap, iron ore lumps etc.) and lime agents. The molten iron is supplied with pure oxygen to achieve the higher temperature required for steel making which can be further purified to achieve desired quality. Steel slag generated from steel making is one of the biggest problems besides the air and water pollution issues.

The process has major pollution issues in India like secondary emissions, metallurgical wastewater discharge and slag disposal. Hence, there is significant potential of adopting best practices in BOF steel making in India.

LARGER SIZE CONVERTER

The converter size or unit capacity is defined as tonne of liquid steel produced per batch cycle and is a key design feature for steel melting shops (SMS). Larger converters enable installation of waste energy gas recovery systems and advanced pollution control equipment's. The converter size in Indian plants was found in the range of 66 to 300 tonnes /heat.

Indian best Practice: SAIL Bokaro SMS #2 unit has the largest size converter of 300 tonne/heat. This has the capacity to produce 2.16 MTPA of liquid steel. The converter is equipped with combination oxygen blown facility and operates at 26 heats per day.

Global best Practice: The largest LD converter was found at 375 tonne/ heat at ILVA Spa (Italy).

DOGHOUSE FOR EMISSION CONTROL

Huge amounts of fugitive emissions are released during oxygen lancing and when coolant materials such as iron ore and scrap are fed to the converter during each blowing cycle. To address the pollution problem, a total housing or enclosure system for each converter vessel is available and it captures the entire emissions from the enclosure. This technology is called doghouse. The dust-laden doghouse air is cleaned in bag filter or electrostatic precipitator (ESP) before being released to the atmosphere.

Indian best Ppractice: Tata Steel (SMS#2) and JSW Steel (SMS# 1 and SMS #2) are the two integrated steel plants in India which have installed doghouse technology for fugitive emission control in SMS area.

Global best Practice: Installation of doghouse is common in BOF units of steel plants in EU and advanced countries.

COMBINATION BLOWN CONVERTER

Oxygen blowing is required for faster reaction in LD converters. In conventional converters supersonic oxygen jet lancing is done from the top which has low penetration in depth at the same time bottom oxygen blowing has issues of intense heat generation and effect on refractory life. The new technology- Combination blown system can blow oxygen from the bottom which maximizes oxygen interaction with hot metal and speeds up the reaction without compromising the refractory life and intense heat issue. Oxygen injection can also be supplied through Multi holes oxygen lancing into molten bath. This in ensures further speed up of reaction and better interaction of oxygen with molten metal.

Indian best Practice: Most of the Indian steel plants have installed multi hole lancing facilities for oxygen enrichment. Integrated steel plants such as Vizag Steel, JSW Steel, Tata Steel (SMS#2) etc. have installed combination blown converters for steel making.

Global best Practice: Combination blown converters are preferred and widely installed in steel plants in advanced countries.

SUB-LANCE

Using sub-lance technology, metallurgical samples from the converter can be withdrawn and check for its desired qualities without tilting the converter and within 90 seconds. Sub-lance system along with dynamic process control minimises oxygen re-blows and increase the lancing precision85. Emissions to air are also reduced as it is not necessary to tilt the BOF.

Indian best Ppractice: None of the Indian steel plants have installed the sub-lance system to the converters.

Global best Practice: Steel plants in European Union member states have adopted sub-lance technology for its converters. As per Vortrefflich (2010), more than 30 steel shops in China have installed over 90 sub-lance systems producing in excess of 200 Million Tonne of liquid steel per year.

SEMI-DRY GAS CLEANING

Off gas scrubbing at BOF may require 0.5 to 1.0 m^3/ tcs water. Using semi-dry technique of gas cleaning system water demand can be reduced by nearly 50per cent, thereby, reduces effluent generation as well. Dust removal efficiency of particles >1µm of this technology is up to 99%.

Indian best Practice: None of the Indian steel makers have adopted this process for off gas cleaning in India.

Global best Practice: This has been adopted in many steel making plants in Europe.

NUMBER OF HEATS PER DAY

The tap-to-tap time reflects the entire time duration required for completion of one batch of oxidation cycle in a converter to achieve the desired steel quality output. Faster the tap-to-tap time, lower the energy loss and faster is the batch cycle of steel melting. Tap-to-tap time of Indian converters was found in the range of 40 to 99 minutes/cycle.

Lower tap-to tap time also ensures higher number of heats per day. Higher the number of heats (batch cycles) per day, higher will be the overall efficiency of BOF plant operations. The higher heats per day ensure proper scheduling of the upstream blast furnace operations and hence lower energy losses at the blast furnace unit. Number of heats per day in Indian plants was found in the range of 14 to 34.

Indian best Practice: LD converter #1 of capacity 150 tonne/heat at Tata Steel has the lowest tap to tap time of 40 minutes. The same converter, therefore, has highest number of heats of 34 heats/day.

Global best Practice: Baosteel (China) has achieved lowest tap to time of 34 minutes. Average tapping temperature remains 1610-1700 DegC88. Mittal Steel Sparrows Point plant (USA) has achieved highest tap to tap time of 40heats/day with its 295tonne/heat converters.

LOW SPECIFIC OXYGEN CONSUMPTION

Lower the oxygen consumed for steelmaking in BOF operations, lower the energy that is required for oxygen supply. This leads to improved energy efficiency of the BOF process operations.

Apart from hot metal quality, the specific oxygen consumption depends on the stirring and homogenisation of the bath. Higher stirring helps in increased oxygen interaction and ensures early completion of the steelmaking cycle. Oxygen consumption in LD converters in Indian plants was found in the range of 47 to 65 Nm^3/tonne of liquid steel (tls).

Indian best Ppractice: SMS#2 of Tata Steel Jamshedpur consumes lowest oxygen at 47 Nm^3/tls for its 160 tonne/heat converter.

Global best Practice: The lowest oxygen consumption of 47 Nm^3/tls at Tata Steel Jamshedpur also corresponds to the global best.

HIGHER LD GAS COLLECTION & REUSE

The off gas from BOF process is rich in energy at 1800 kCal/m^3 and can be used for reheating and power generation purposes in a steel plant. Nearly 2-4per cent of the energy required in steel plant is supplied by LD gas. Higher LD gas collection and reuse enables better energy efficiency and lower air emission. LD gas collection and reuse in Indian steel plants was found in the range of 0 to 107 Nm^3/tcs.

Indian best Practice: JSW Steel has achieved highest LD gas collection at 107 Nm^3/tcs from SMS#1 which has 3 x 130 tonne/heat capacity converter.

Global best Practice: The highest LD gas collection and reuse has been reported at 130 Nm^3 /tcs.

LOW LD SLAG GENERATION

The impurities in molten bath in the BOF process are collectively separated and removed as slag. Lower the slag generation rate, higher will be BOF process efficiency and lower solid wastes generation. LD slag generation rate was found in the range of 96-180kg/tcs.

Indian best Practice: Vizag Steel in India has achieved the lowest LD slag generation of 96 kg/tcs with its 150 tonne/heat capacity converters. The charge consists of hot metal of 1005 kg/ tonne liquid steel, scrap of 83.4kg/tonne liquid steel and fluxes of 18.6 kg/tonne liquid steel. Global best practice: European steel plants have achieved LD slag generation as low as 85 kg/tcs.

LD SLAG REUSE

Recycle and reuse of LD slag is a complex issue for the steel industry. It contains lime or calcium oxide (48-55 per cent), ferrous oxide (18-22 per cent), silica (10-15 per cent) and traces of alumina, other metal oxides, phosphorus, and heavy metals. Due to high iron oxide content LD slag is not used in cement making but some quantities are used as liming agent in the sintering process where its limiting factor is phosphorous content which in high quantity affects the sinter chemistry.

Road and rail making ballast are the main sources of LD slag reuse. However, it is also used as component of cement raw mix, seashore protection, pavement bases, storage yard, heavy vehicles parking loads etc. The hazardous components of LD slag and their impacts on environment are yet to be explored.

Indian best Practice: Ispat Industries, Raigad have started metal recovery from the LD slag. JSW Steel states that around 20 per cent LD slag is gainfully reused in process i.e. around 14 per cent through metal recovery and 6 per cent using a lime agent is sinter plant# 2. Essar steel has started using the LD slag in heavy vehicle parking spaces, ceramic tiles making, filling low lying area and boundary wall of the compound.

Global best Practice: In Europe, considerable amount of LD slag is also used as fertilizer (nearly 3per cent) and lime agent for agriculture due to its high lime (CaO) content. Use of LD slag reuse as sulphur containing soil conditioner has also been reported.

In EU plants, nearly 45per cent LD slag is reported to be use in road construction, 17per cent as interim storage, 14per cent internal recycling, 11per cent final deposit and remaining in hydraulic engineering, fertilizer, cement production and other uses.

SPECIFIC ENERGY CONSUMPTION

Each steel plant produces different types of downstream steel products to cater to its individual customer segments, with each product requiring varying degrees of energy use. Further, some plants purchase intermediate products such as coke, etc. Hence, comparing the total specific energy of one plant with another does not allow for consistent assessment. Therefore, for consistent measurement and reporting of best practice for energy use in steel plants should be based on primary energy assessments till crude steel making alone. Natural gas-based plants had lowest specific energy consumption. In coal-based processes, conventional BF-BOF process had better specific energy consumption pattern than coal DRI-Electric furnace based steel making route.

Indian best Practice: Among DRI based plants, Ispat Industries, Raigad was observed as the best energy efficient plant with specific primary energy consumption at 5.4 GCal/tcs. Ispat Industries is a 3.6 MTPA integrated steel plant with gas DRI process, blast furnace and electric arc furnace.

Among coal based BF-BOF integrated steel plants, Tata Steel, Jamshepdur had achieved the best specific energy consumption at 6.2 GCal/tcs. Tata Steel, Jamshedpur is a 6.8MTPA capacity steel plant (2009-10) with 7 BFs of total 7.3 MTPA hot metal capacity, 4 sinter plants (8MTPA), 9 coke ovens (total 2.3 MTPA gross coke), 2 SMS shops (total 6.8MTPA) and a captive power plant (757 MW).

Global best Practice: The global best achievable specific energy consumption for a coal-based BF-BOF plant is reported at around 4.5 GCal/tcs for a Netherlands and France based plant.

CARBON EMISSION INTENSITY

The iron and steel sector is the third highest emitter of carbon emissions after the thermal power and cement sectors in India. Carbon emission intensity is higher in coal based processes. The sector emitted around 135 million tonnes of carbon dioxide (CO_2) in 2008-09, with average emission intensity at 2.4 tonne CO_2/tcs.

Carbon emissions intensity has close relation to specific primary energy consumption, varying only due to the type of major fuel used (coal or natural gas). Indian grid is dominated by coal based power plants and hence, in case plants import power, the emission factor of power continues to remain high at 0.85 kg CO_2/kWh. Within coal, the emission factor for CO_2 expressed as tonne CO_2/GCal of energy supplied varies depending on the net calorific value and total carbon content of the fuel. While coking coal has an emission factor of 0.44 tonne CO_2/GCal, the non-coking coal sourced from India has an emission factor of 0.38 tonne CO_2/GCal.

Indian best Practice: Among integrated steel plants, the carbon emission intensity has been observed lowest at 1.4 tonne CO_2/tcs at Essar Steel Hazira which is natural gas based DRI-EAF plant.

For an integrated coal-based BF-BOF based integrated steel plants, 2.7 tonne CO_2/tcs is the lowest carbon emission intensity which is at Tata Steel, Jamshedpur.

Global best Practice: For carbon emissions intensity of primary steel making, the global best practice corresponds to the Indian best practice, i.e. Essar Steel, Hazira at 1.4 tonne CO_2/ tcs. The plant is a natural based DRI - EAF based integrated steel plant with power sourced from a natural gas based combined cycle power plant.

Reducing Air Pollution in India's Industrial Cluster through Smart Energy Management

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