NEDO Project Formation Research on High-efficiency CCT

Joint Feasibility Study
Replacement of Badarpur Thermal Power Station to the latest USC with Comprehensive Environmental Measures

Part 1 – Results of Feasibility Study

June 14, 2016

Scope Complex, NTPC Limited

Study Team

JPOWER, Kyushu Electric Power, JCOAL

Contents

A) Design Parameters

Generator Output : 2 x 660MW

Boiler Specification

- Fuel Type : Domestic Coal
- Design GCV : 13,500～19,000 kJ/kg
- Start-up Fuel : Light Diesel Oil only
- Number of Mills: 8
- Minimum Turndown: 30% (of BMCR)

Steam Condition at Steam Turbine Inlet

- Main Steam Pressure : 26.48 MPa(a)
- Main Steam Temperature : 600 degree C
- Reheat Steam Temperature : 600 degree C

B) Environmental Regulation

As per Environmental (Protection) Act 1986 revised on 7/12/2015

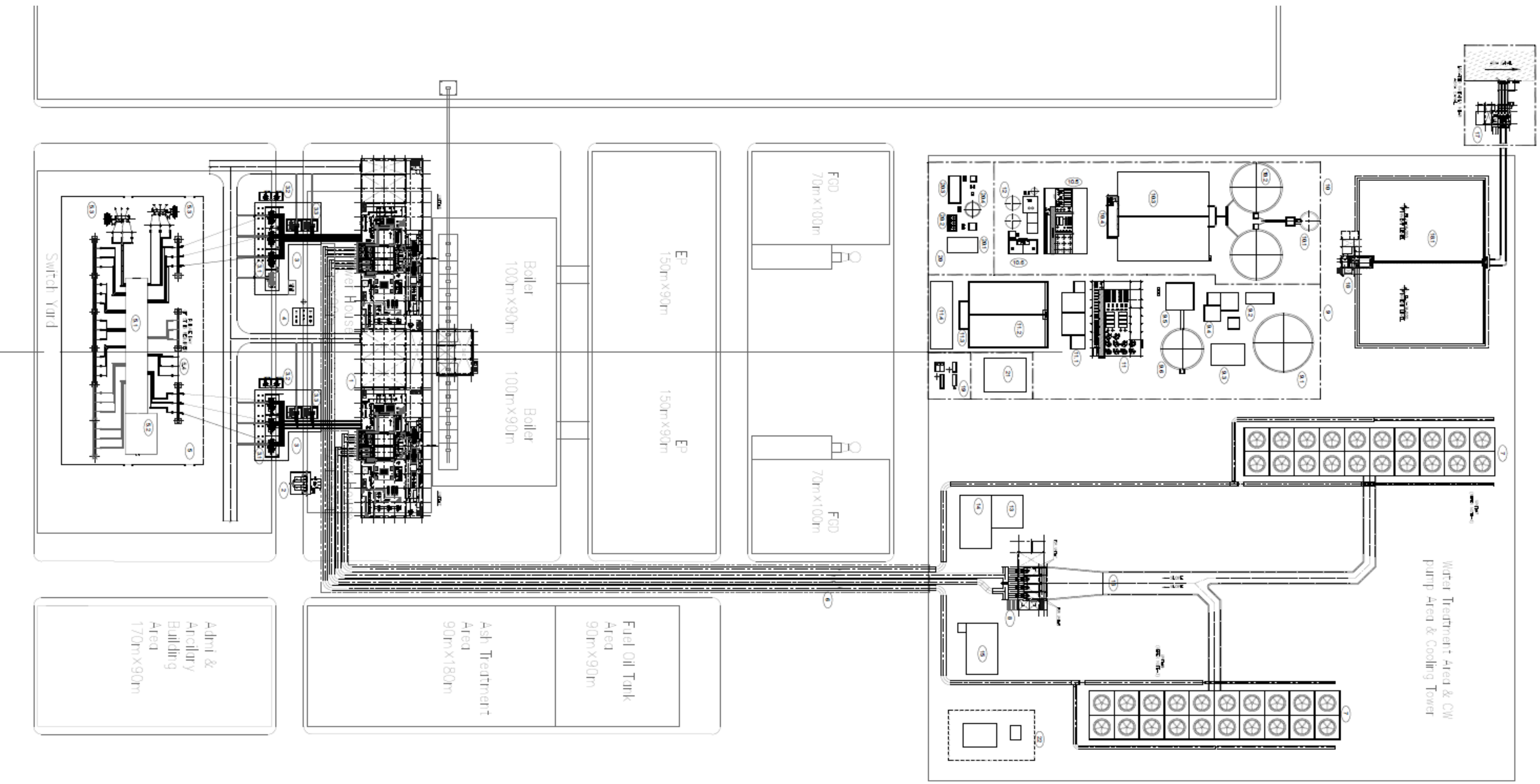
- Water Consumption : < 2.5 m^3/MWh
  (Zero Effluent Discharge Mandatory)
- Flue Gas SPM Density : < 30 mg/Nm^3
- Flue Gas SO_2 Density* : < 100 mg/Nm^3 (approx. 35ppm)
- Flue Gas NOx Density* : < 100 mg/Nm^3 (approx. 49ppm)
- Flue Gas Mercury Density*: < 0.03 mg/Nm^3 (approx. 3 ppb)

*each density limit as on 6% O2 conversion

Other requirements

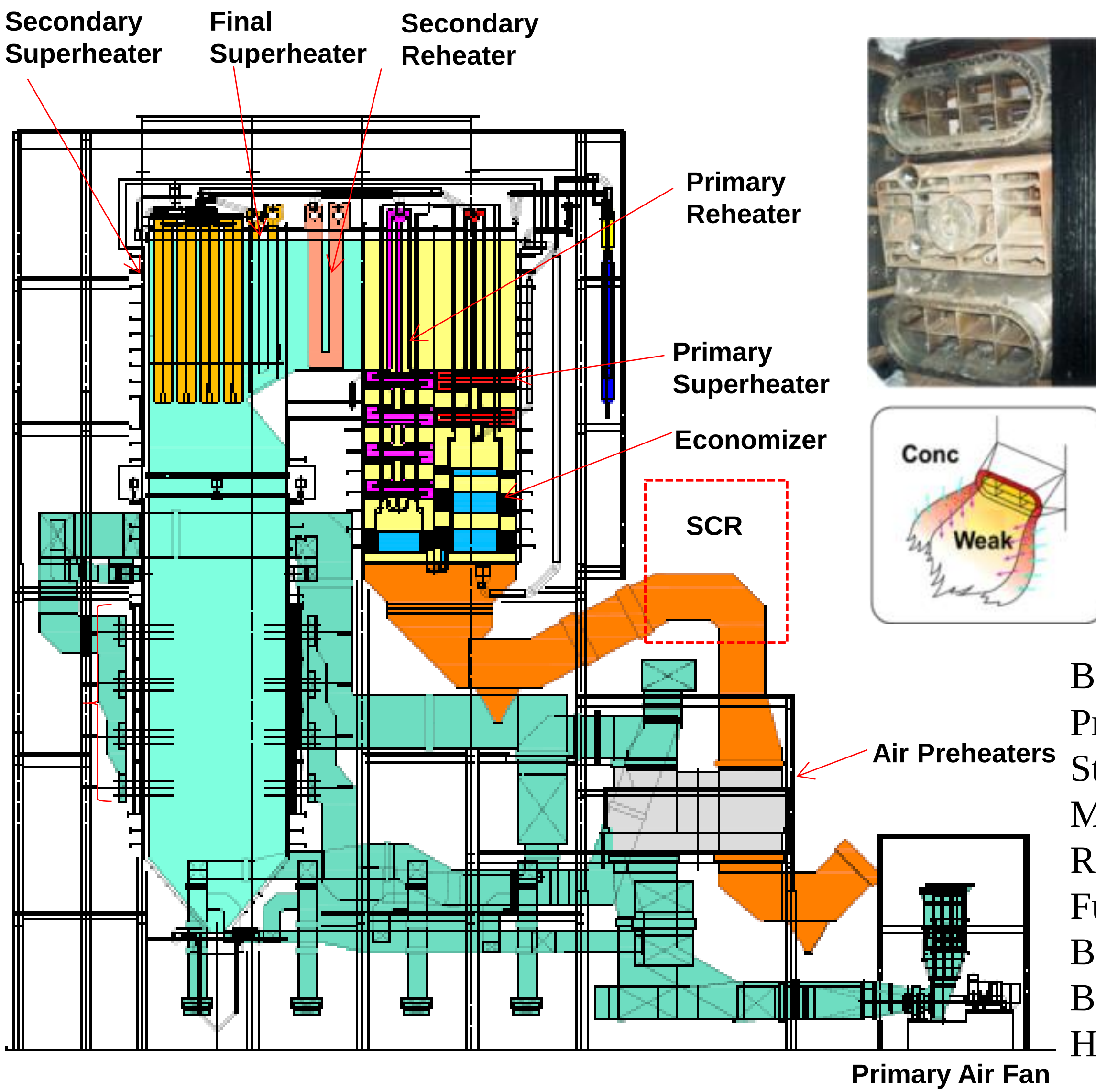
- Stack Height : 150 m（based on existing limit)

C) Plot Plan

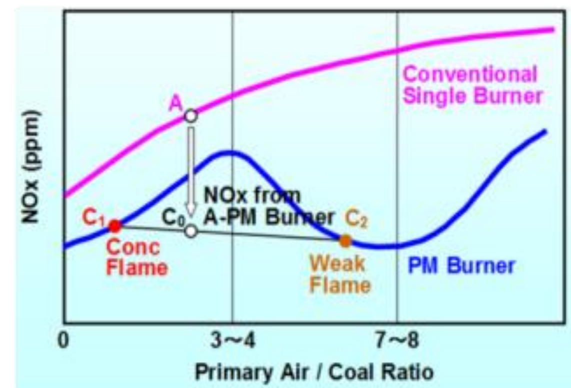


Switch Yard
Boiler
100m×90m
EP
150m×90m
FGD
70m×100m
Admin & Ancillary Building Area
170m×90m
Ash Treatment Area
90m×180m
Fuel Oil Tank Area
90m×90m
Water Treatment Area & CW pump Area & Cooling Tower

D) Boiler – Steam Generator



- Divide Combustion Flame into Concentrate and Weak Flames



BMCR: 1,970.432 t/h
Primary Fuel: Coal
Start-up Fuel: LDO only
MST Control: FW-fuel rate & 2-stg spray
RST Control : Gas damper & spray
Furnace: Vertical rifle tube structure
Burner layout: Corner (tangential) firing
Burner type : Low NOx Burner
House Load Op.: supported

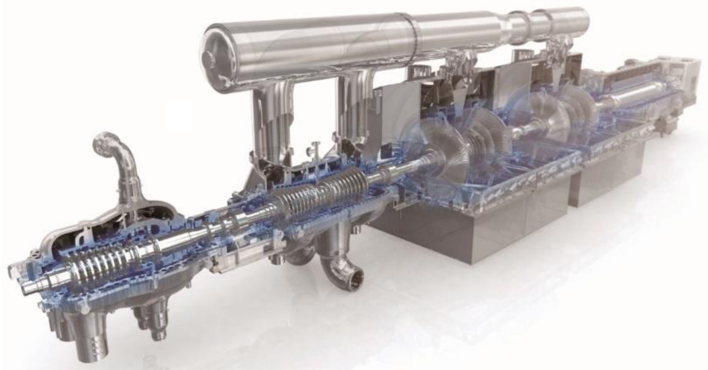
USC Variable-pressure One-through Boiler (radiation reheat outdoor)

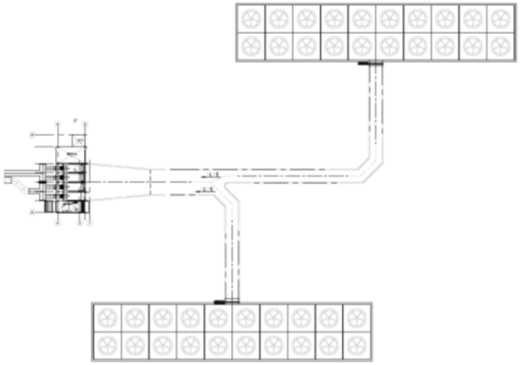
E) Turbine and Cooling Tower

Feature

New Turbine will be provided with

- 1 × HPT, 1 × IPT, 2 × LPTs configuration
- Advanced flow pattern nozzles and blades
- Long last stage blade
- Leakage Reduction and Control





Feature

New Cooling system will be provided with

- Induced draft cooling tower
- Back to back, double row configuration
- Clarified cooling water

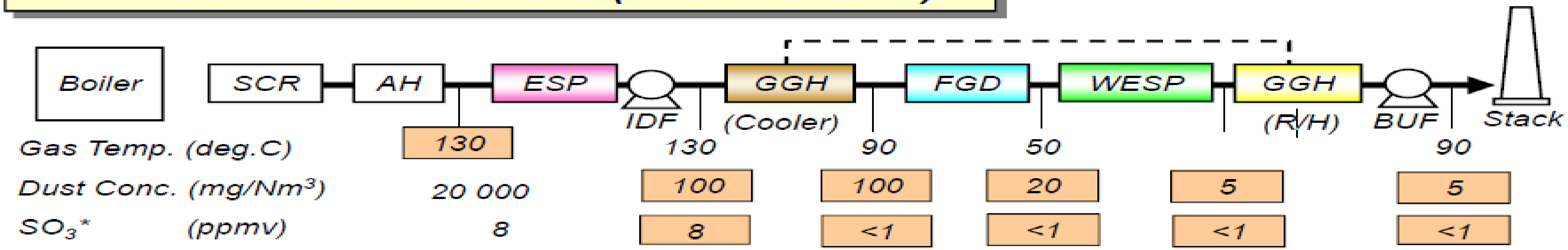
Feature

New Plant water system will be designed to meet the new regulation of water consumption less than “2.5m3/MWh” and “Zero waste water discharged”

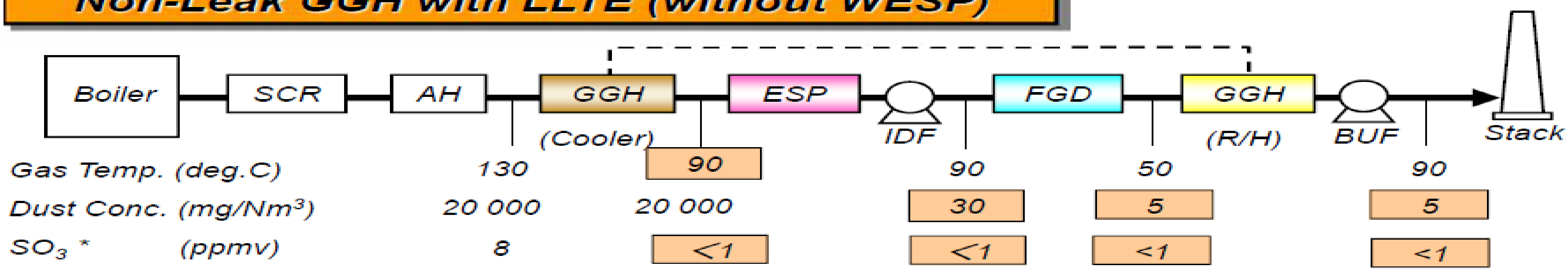
*The word “Waste water” does not contain rainwater.

F) Flue Gas Treatment (GGH)

Non-Leak GGH with LTE (with Wet ESP)



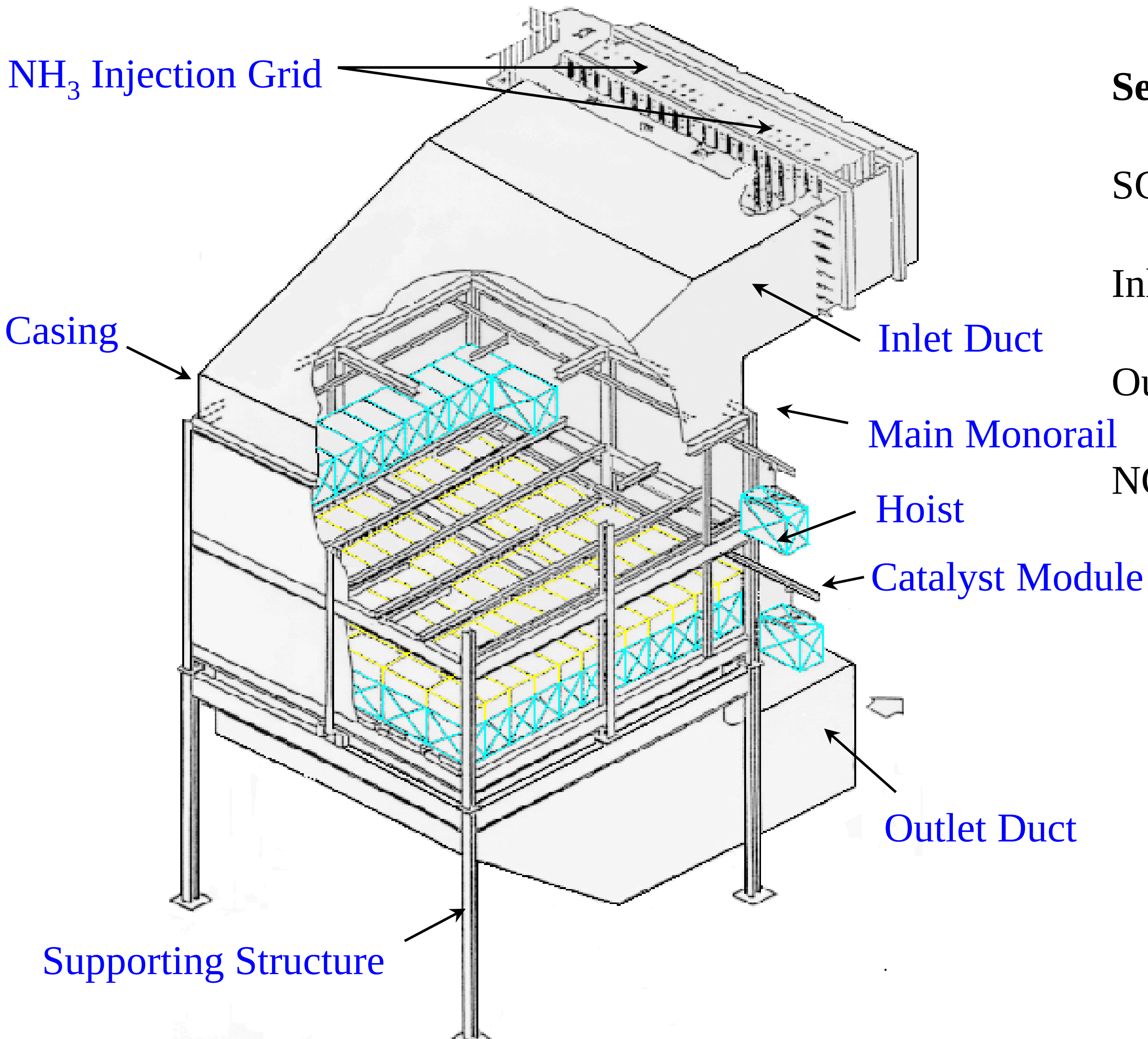
Non-Leak GGH with LLTE (without WESP)



* SO_3 concentration in gaseous phase

	LLTE	LTE
ESP	·Lower Dust Electric Resistance ·High Efficiency / Smaller ESP	·Higher Dust Electric Resistance ·Bigger ESP ·Outlet Dust should be kept 100-200 mg/Nm³ (due to SO_3)
FGD	·No limit to inlet dust conc. ·Outlet dust can be 10 mg/Nm3	·Inlet dust to be 100-200 mg/Nm³
GGH	·No corrosion potential due to SO_3 ·Less corrosion potential to down stream equipment	·Dust deposition / plugging

F) Flue Gas Treatment (DeNOx System)



Selective Catalyst Reduction System

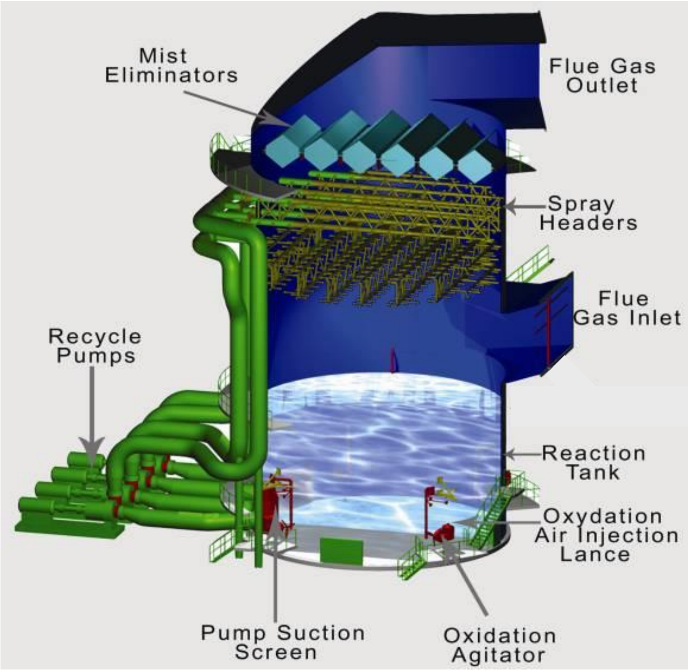
SCR Inlet Gas Flow: 2,091,600 Nm3/h

Inlet NOx : 327 ppmvd@6%O2

Outlet NOx : 44 ppmvd@6%O2

NOx Removal: 86.5%

F) Flue Gas Treatment (DeSOx System)



DeSOx System

DeSOx Inlet Gas Flow: 2,044,000 m3N/h

Inlet NOx : 611 ppmvd@6%O2

Outlet NOx : 35 ppmvd@6%O2

SOx Removal: 94.3 %

G) CHP (1/3)

Unloading/Receiving Conveyors

- **Receiving Conveyor two (2) lines x 100 % capacity**
- **Conveyor capacity : 1,850 t/h (1,800 mm, 2m/s)**
- **Tandem Wagon Tripper two (2) lines x 100% capacity**

Coal Storage Yard

- **Number of piles 4 piles (45 m x 500 m x 4 piles)**
- **Coal staking height : 10 m**
- **Indoor type (shed)**
- **Coal storage capacity : 507,680 tons (29 days@100%PLF)**
- **Stacker/Reclaimer 1,850 tons x 2 numbers**

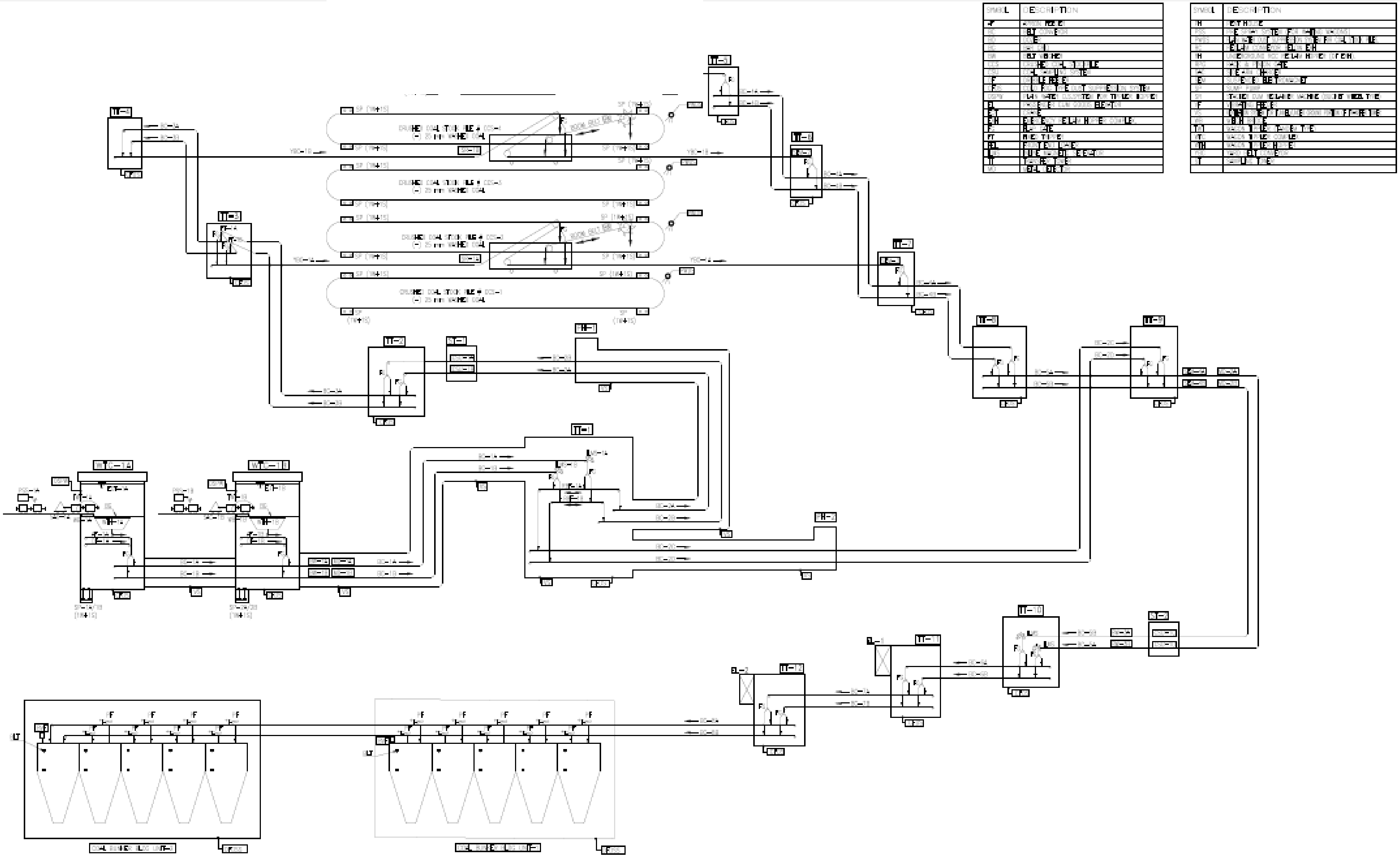
Discharging/Bunkering Conveyor

- **Discharging Conveyor : two (2) lines x 100% capacity**
- **Conveyor capacity : 1,850 t/h (1,800 mm, 2m/s)**
- **Coal bunkering by five (5) numbers of Plow Scrapers x 2 lines**

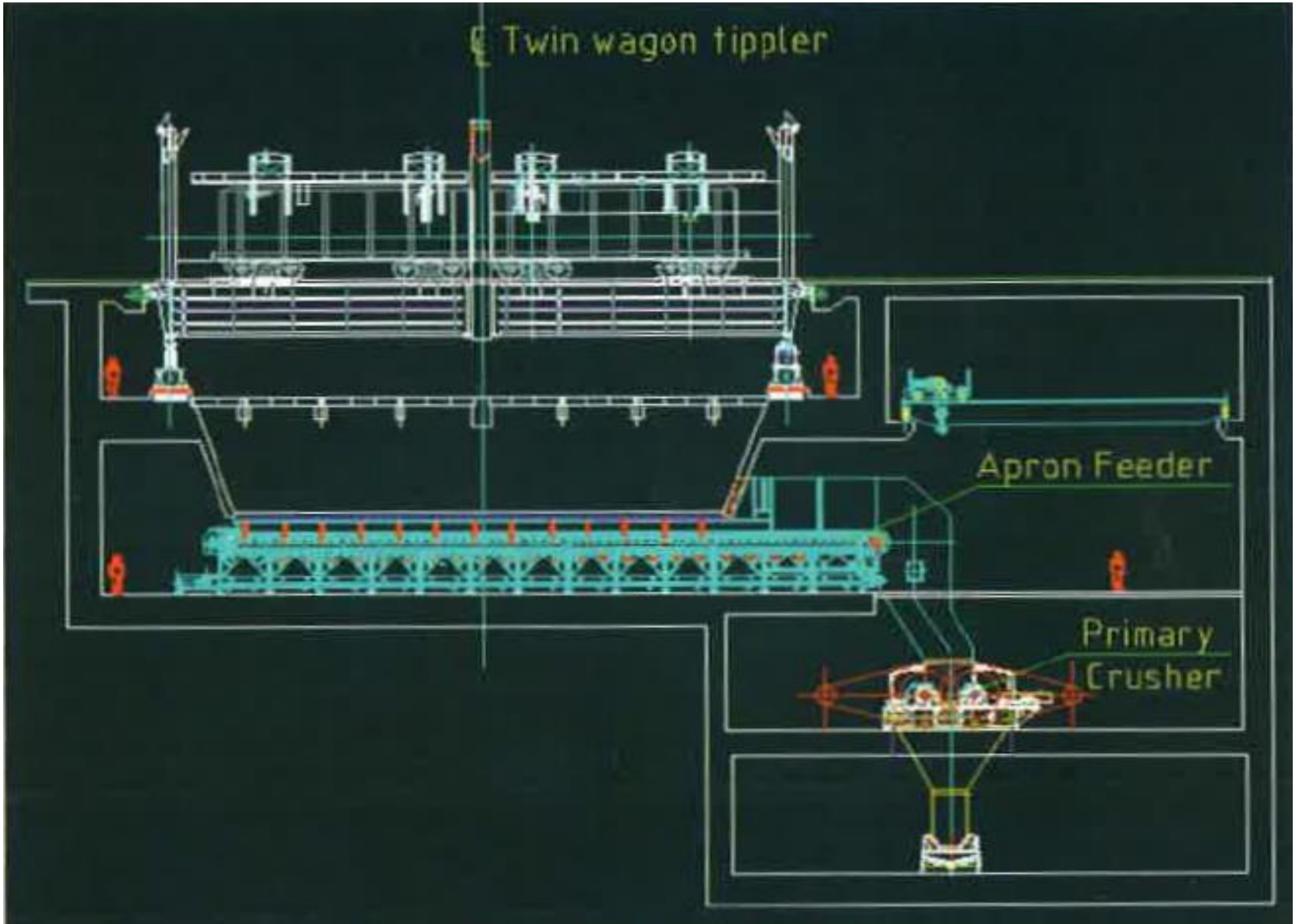
Bypass system (Direct bunkering system)

- **Direct bunkering from tandem wagon tripper to Bunkers (1,850 t/h x 2 lines)**

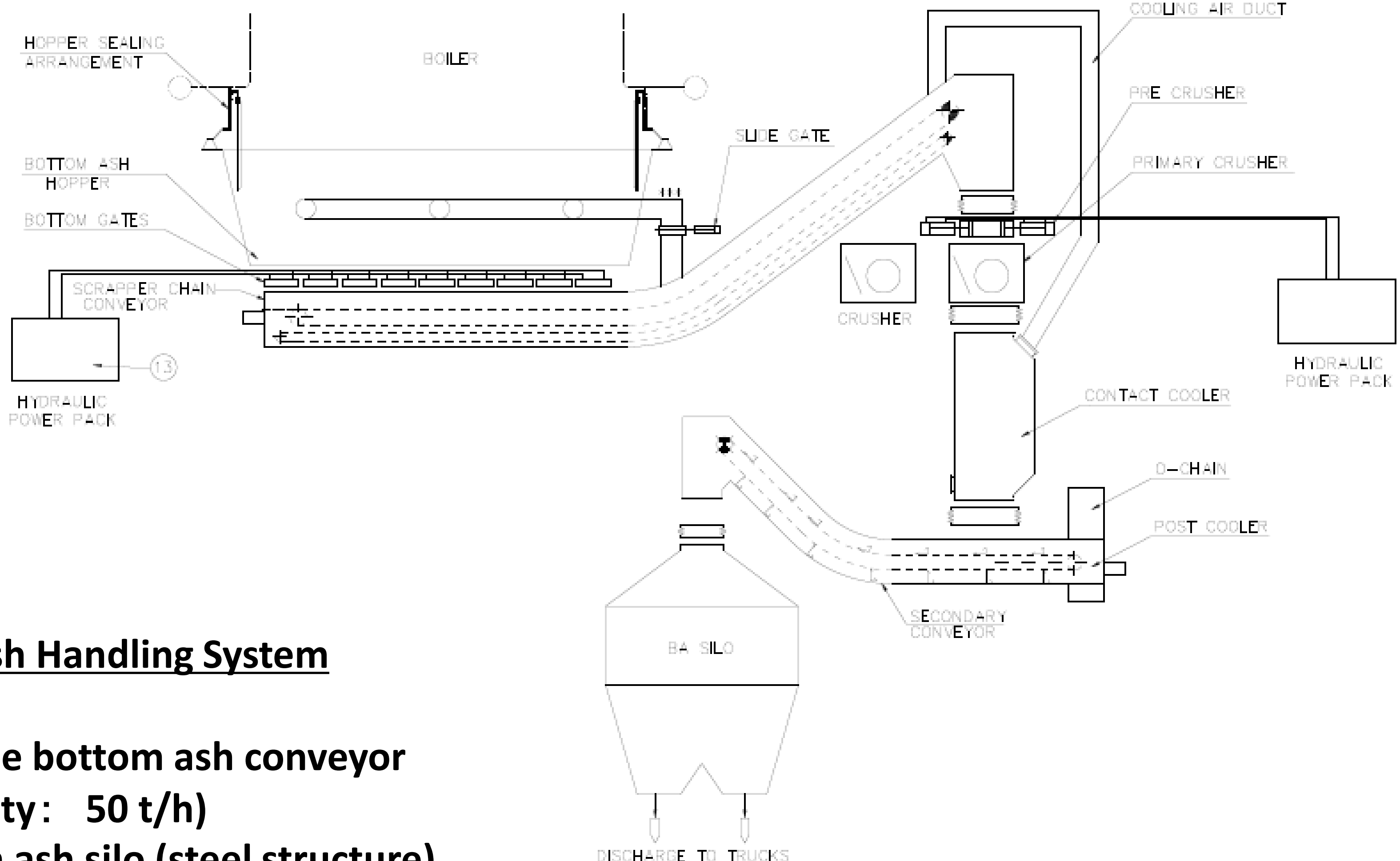
G) CHP (2/3)



G) CHP (3/3)



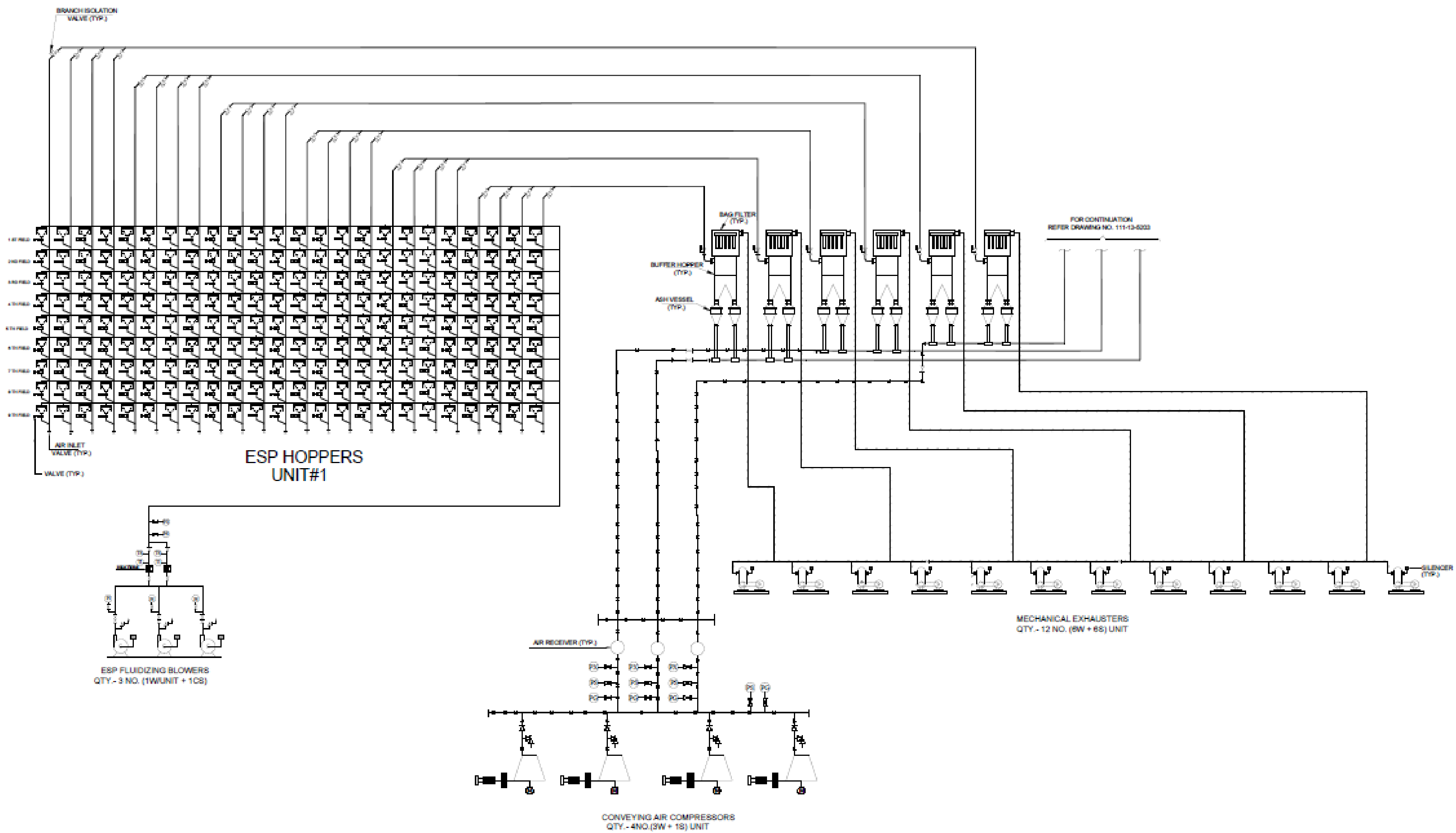
H) Ash Handling System (1/3)



Bottom Ash Handling System

- **Dry type bottom ash conveyor (capacity :   50 t/h)**
- **Bottom ash silo (steel structure) 100 tons x 1 silo**

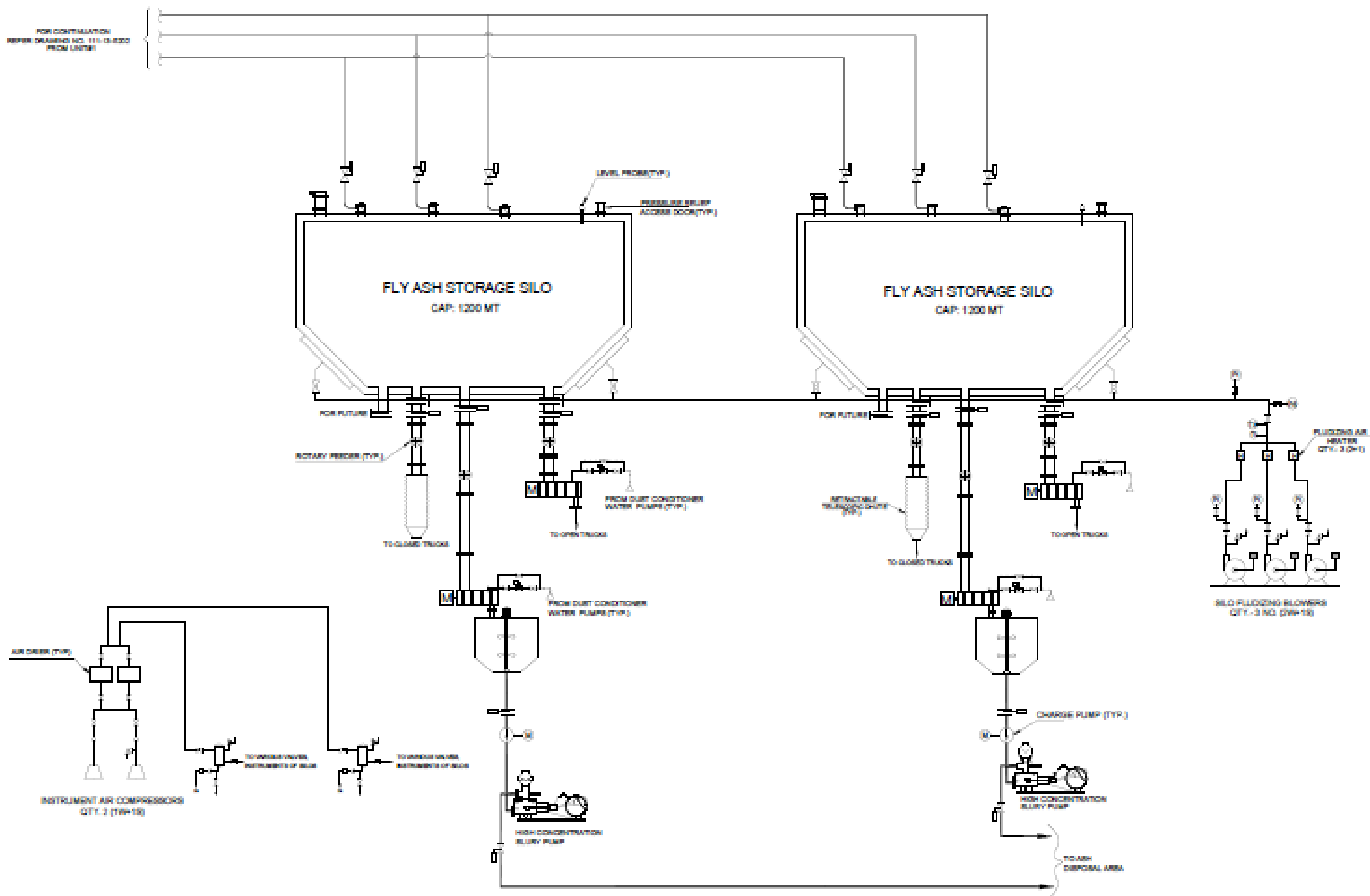
H) Ash Handling System (2/3)



Fly ash transportation system

- **Fly ash（EP+AH) by Vacuum Compressors (3 operation + 1 standby)**

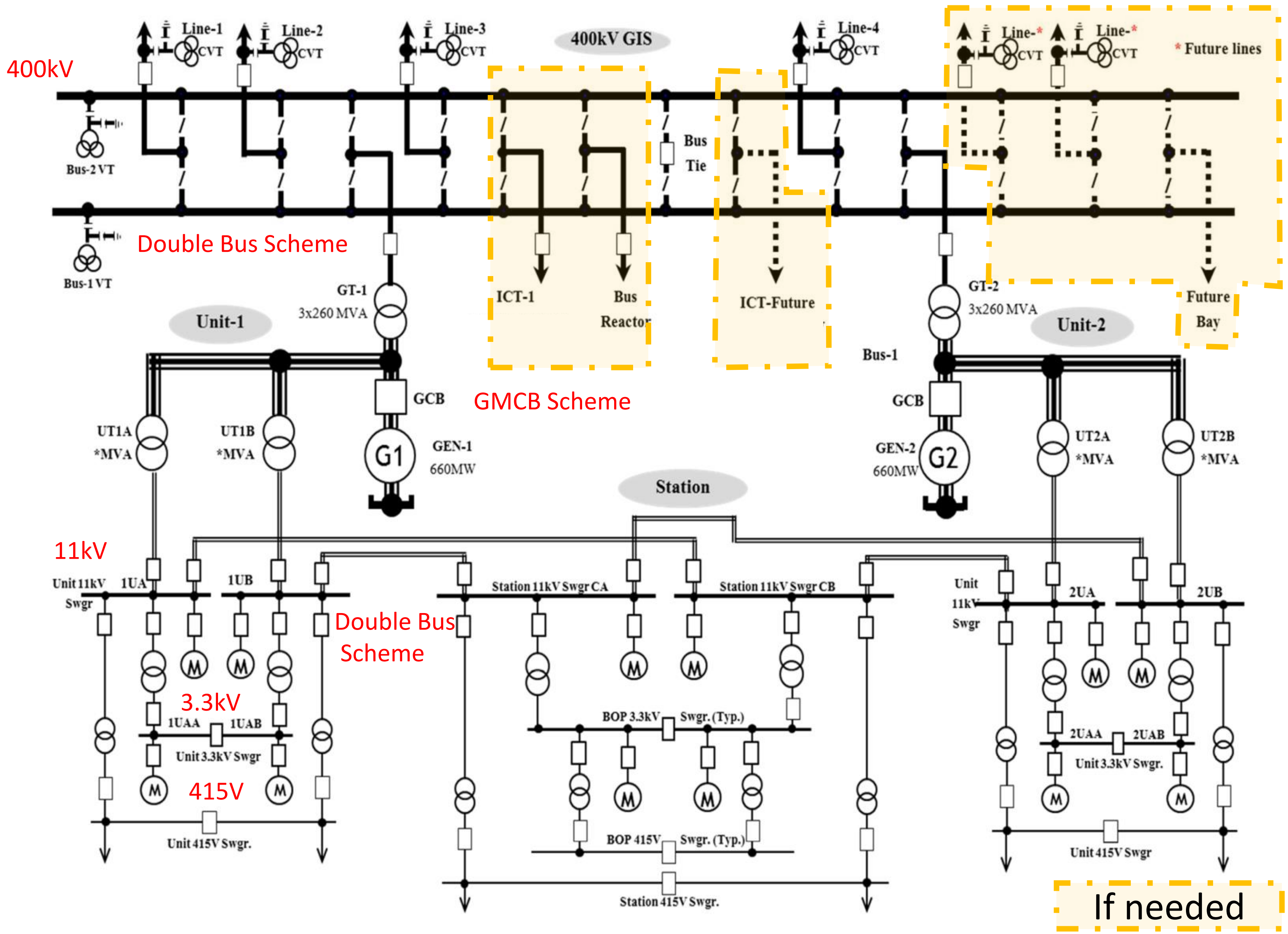
H) Ash Handling System (3/3)



<u>Fly ash silo & Slurry ash disposal System</u>

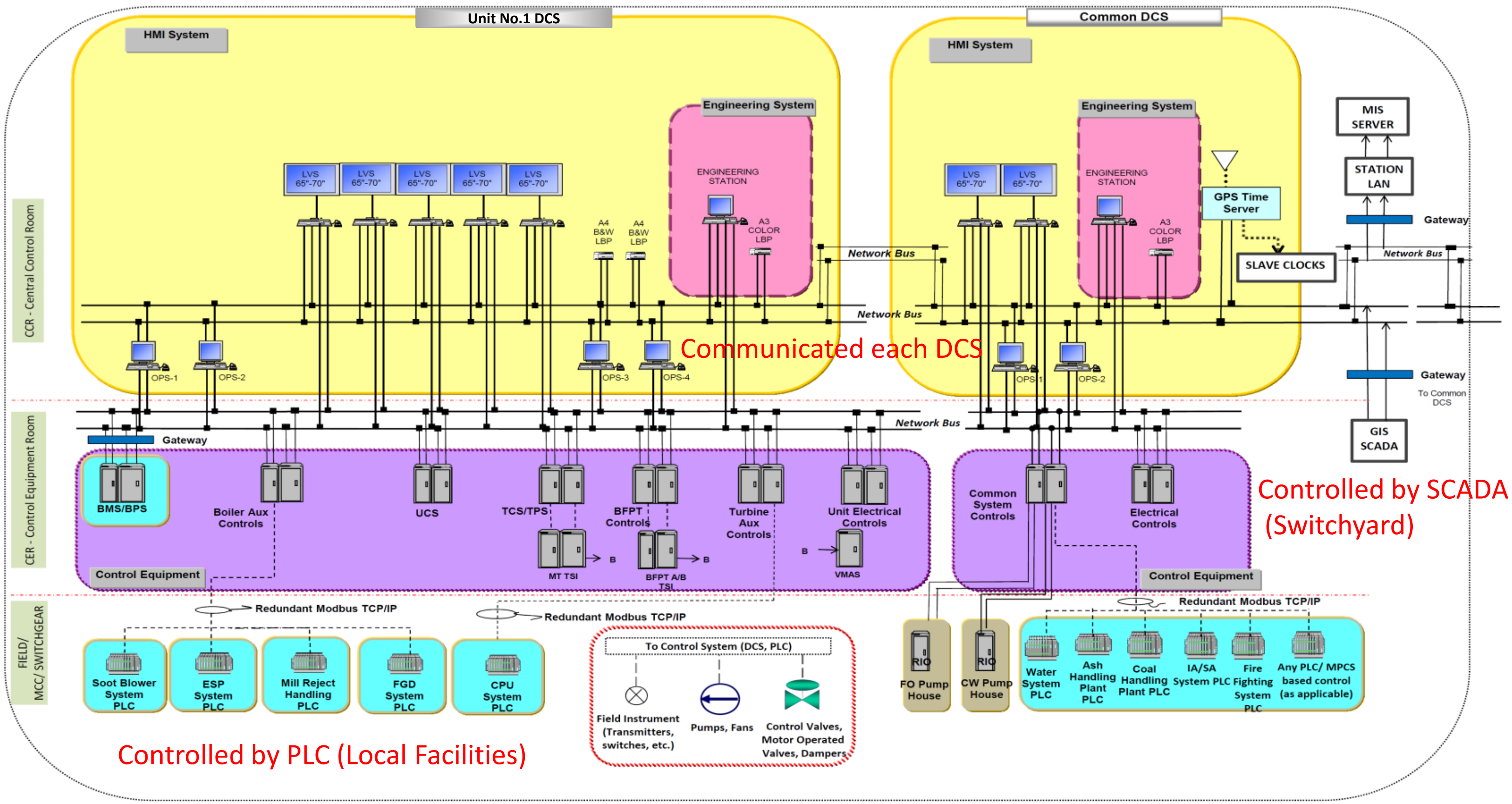
- **Fly ash silo (RCC type) x 2 Silos (capacity： 1,200 MT/24 hrs x 2)**
- **Silo fluidizing blowers (2 operation + 1 standby)**
- **High Concentration Slurry Pumps: two (2) pumps x 100% capacity**

I) Electrical System



J) C&I System

Installed DCS each Unit (Total 3 units incl. common.)



Unit & BOP DCS Description
UCS: Unit Coordination & Boiler Modulating Control System
TCS: Turbine Control System
TPS: Turbine Protection System
MPCS: Manufacturer's Proprietory Control System
GPS : Global Positioning System
R I/O: Remote Input/Output Cubicle

System Description
TSI: Turbine Supervisory Instrumentation

HMI Description
LVS : Large Video Screen
OPS: Operator Station
Color LBP: Color Laser Beam Printer
B/W LBP: Black & white Laser Beam Printer
A-Network: Administration Network

- Central Control Room
- Engineering Room
- Equipment Room
- Local Control Room
- By Others

K) O&M Plan

Operation

- Operation for new plant will be highly automated.
- Need to consider the difference of control method between drum boiler and once through boiler.
- Requirement for the quality of feed water treatment will become higher for once through boiler. (practice in Japan ; conductivity < 20 μS/m, SiO_2 < 20 ppb)

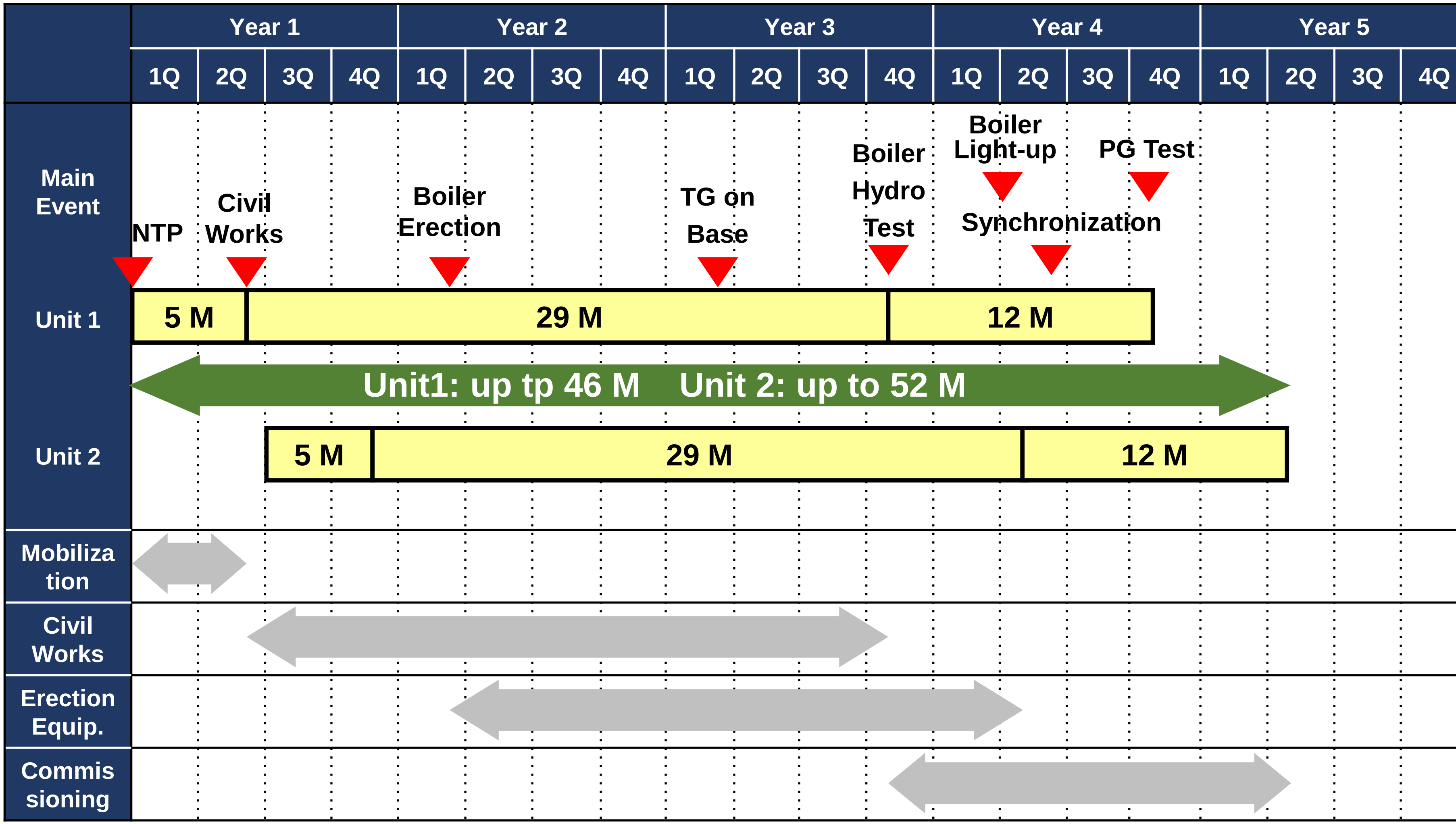
Maintenance Plan – Inspection in USC plant

Inspection Class	Duration	Frequency	Remark
Class A	56 days	Every 4 years	Overhaul (Boiler and Turbine) removing turbine rotor every 8 years
Class B	42 days	Every 2 years	Overhaul (Boiler)
Class C	14 days	Every year	Visual Inspection

Organization – Number of employees in USC plant

	Badarpur TPS (for reference)	USC Plant in Japan
Operation	(Main Plant) 65 + local operators	(Main Plant) 40 + Fuel Gas Desulfurization (FGD) plant operators 10
Maintenance	Over 100 + contractor	30 + contractor
Others	EEMG, MPD, FM, Chem., Civil, R&M	18 + contractor

L) Construction Schedule (indicative)

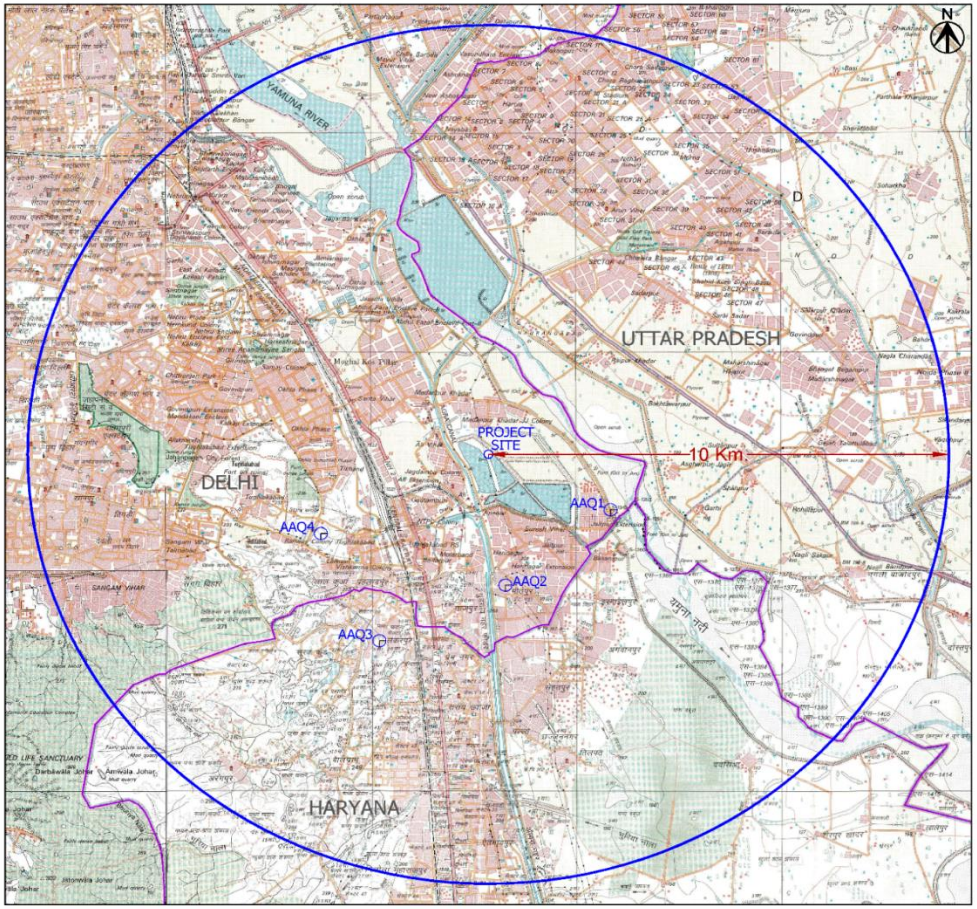


2. Environmental Analysis (1/5)

Project site is selected inside Delhi for new power plant with 2 x 660MW USC (ultra super critical) coal fired units as shown in below study area base map. Also, actual air quality value surrounding area (at monitoring location) is summarized in the table.

(Value in µg/m³)

Sampling Location		PM10	SO2	NOx
JAITPUR (AAQ1)	Minimum	56	8.1	11.5
	Maximum	305	13.5	32.1
	Average	122.6	9.8	15.7
MITHAPUR (AAQ2)	Minimum	61	8.2	12.2
	Maximum	314	13.8	32.4
	Average	135	10.2	16.3
TUGHLAKABAD RAILWAY COLONY (AAQ3)	Minimum	58	8.2	12.4
	Maximum	327	14.7	34.9
	Average	127.5	10.4	16.5
LAKADPUR (AAQ4)	Minimum	60	8.4	12.5
	Maximum	324	14.5	34.7
	Average	127.6	10.6	16.7

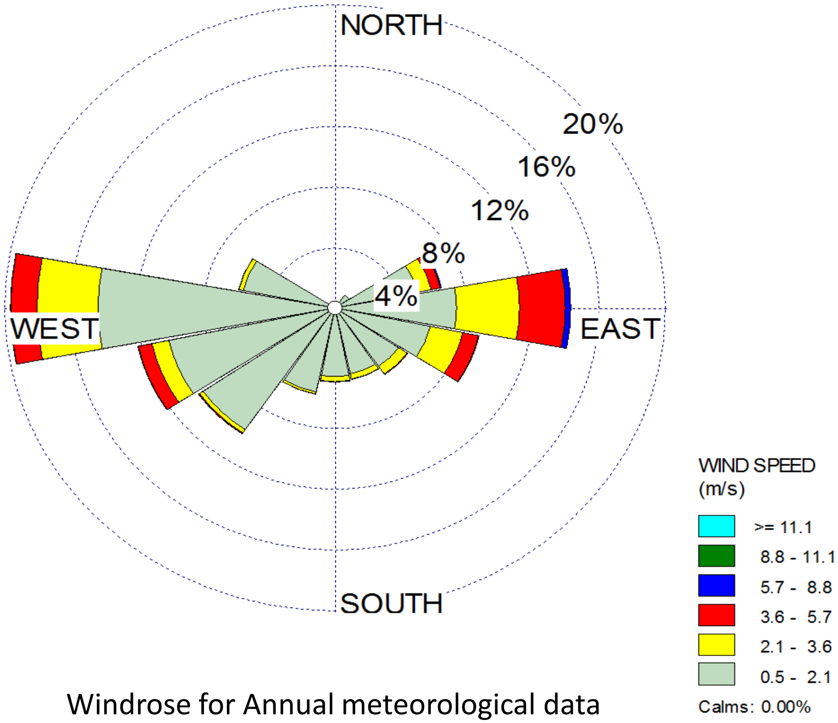


2. Environmental Analysis (2/5)

Air pollution from newly installed coal fired thermal power plant (2 x 660MW) is shown bellow simulated by Gaussian plume model (given by USEPA ISCST3, 1995).

Input data for Emission details of Stack

Parameter	Unit	Value
Capacity	MW	2 x 660
Number of Stacks	Nos.	1 (Twin flue)
Physical Stack height	m	150
Internal diameter of stack at top	m	6
Exit velocity of the flue gas	m/s	23.4
Temperature of the flue gas	^0C	90
Mass flow rate	Nm^3/hr	2,260,000
Emission limit for NO_x	mg/Nm^3	100
Emission limit for SO_2	mg/Nm^3	100
Emission limit for PM_{10}	mg/Nm^3	30



Windrose for Annual meteorological data

2. Environmental Analysis (3/5)

Predicted ground level concentration of NOx (μg/m³) is shown in below Figures.

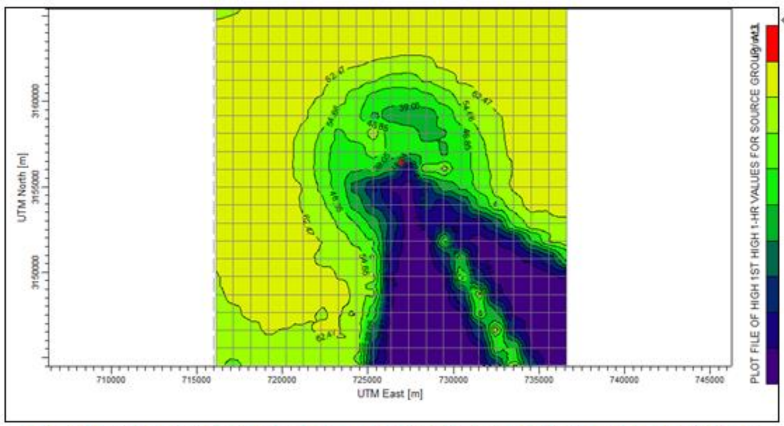


Figure 1.13: Predicted Ground Level Concentration of NOx (hourly average)

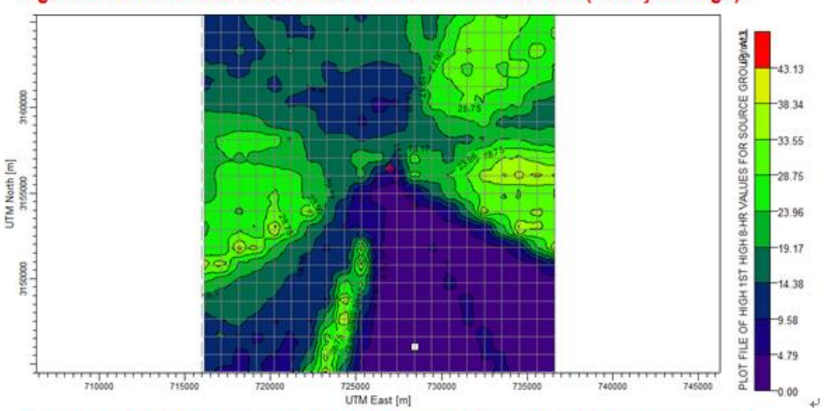


Figure 1.14: Predicted Ground Level Concentration of NOx (8 hour average)

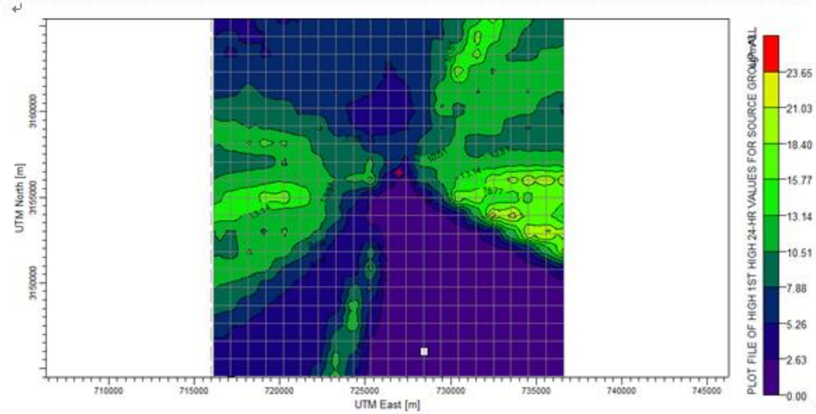


Figure 1.15: Predicted Ground Level Concentration of NOx (24 hour average)

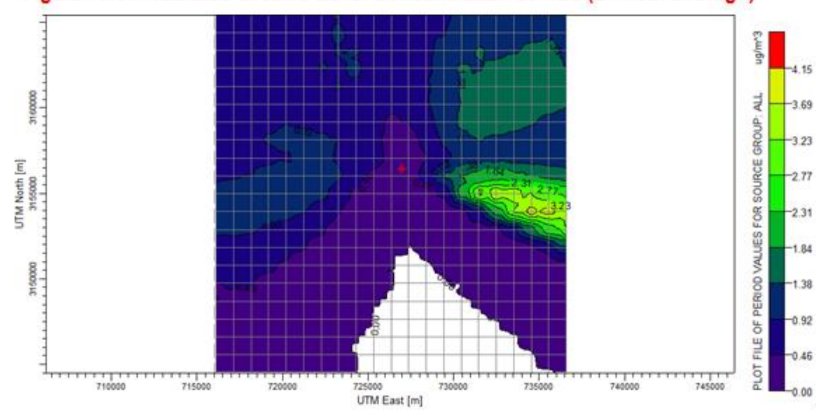


Figure 1.16: Predicted Ground Level Concentration of NOx concentration during winter season (Average)

2. Environmental Analysis (4/5)

Predicted ground level concentration of PM_{10} (µg/m^3) is shown in below Figures.

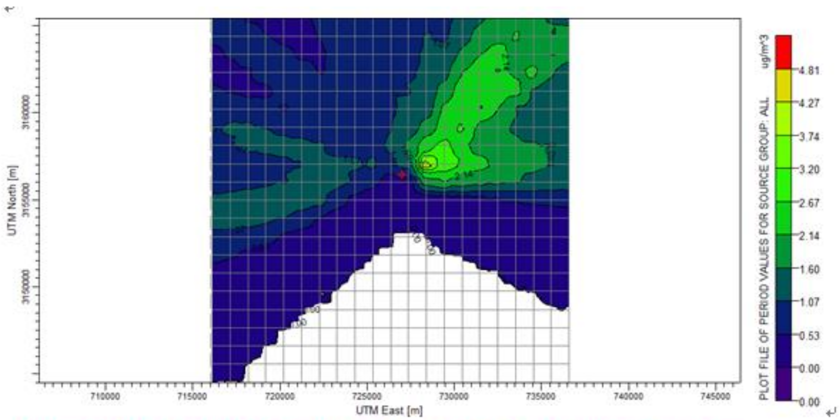


Figure 1.17: Predicted Ground Level Concentration of NOx concentration during summer season (Average)

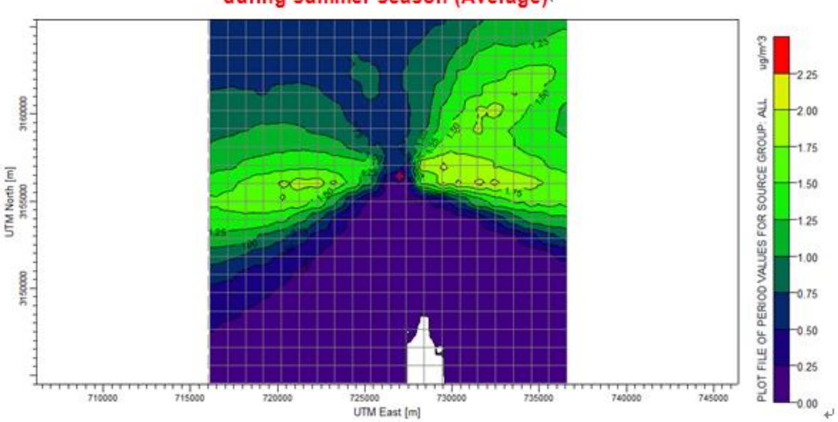


Figure 1.18: Predicted Maximum Ground Level Concentration of NOx

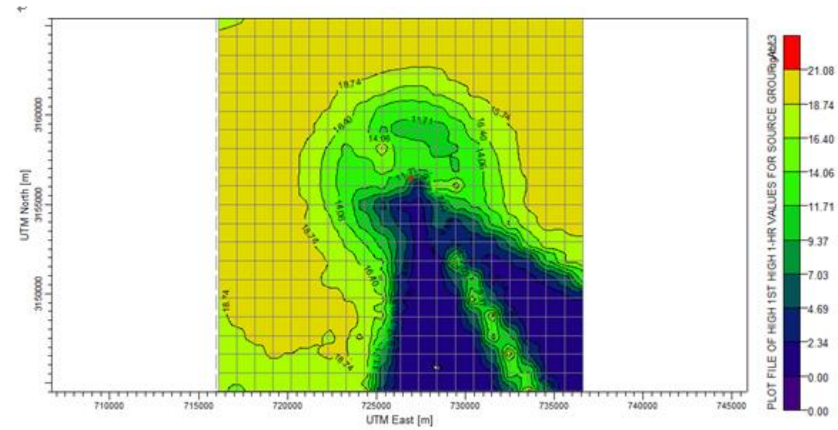


Figure 1.19: Predicted Ground Level Concentration of PM_{10} (hourly average)

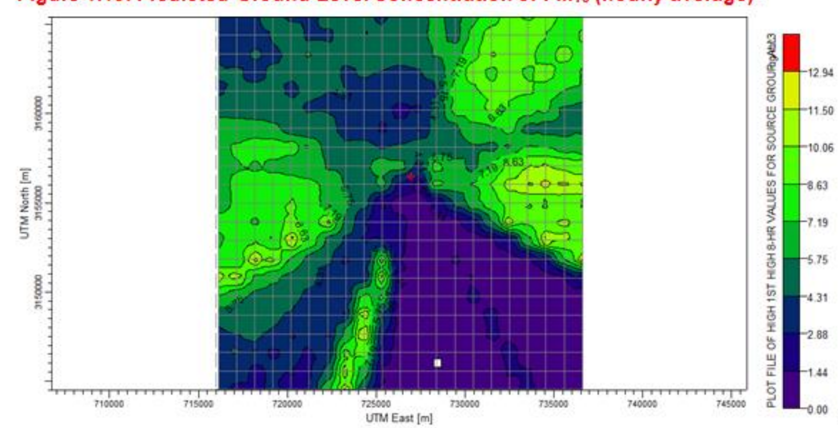


Figure 1.20: Predicted Ground Level Concentration of PM_{10} (8 hour average)

2. Environmental Analysis (5/5)

Predicted ground level concentration of SO_2 (µg/m³) is shown in below Figures.

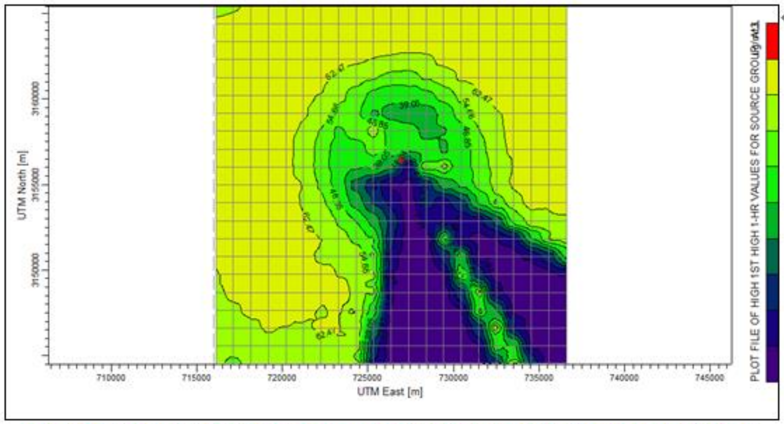


Figure 1.13: Predicted Ground Level Concentration of NOx (hourly average)

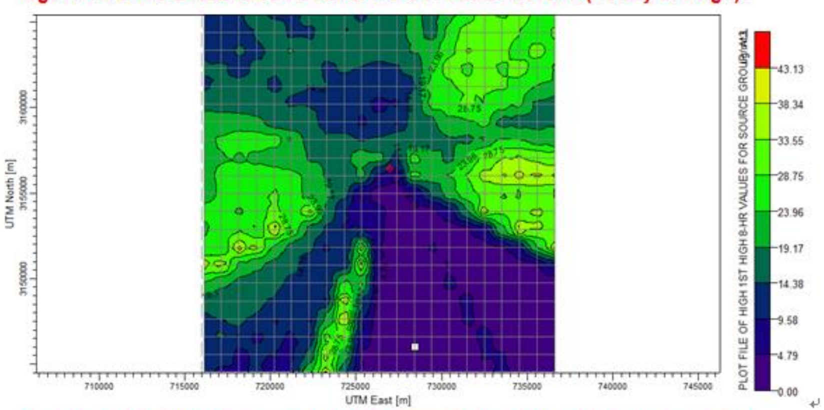


Figure 1.14: Predicted Ground Level Concentration of NOx (8 hour average)

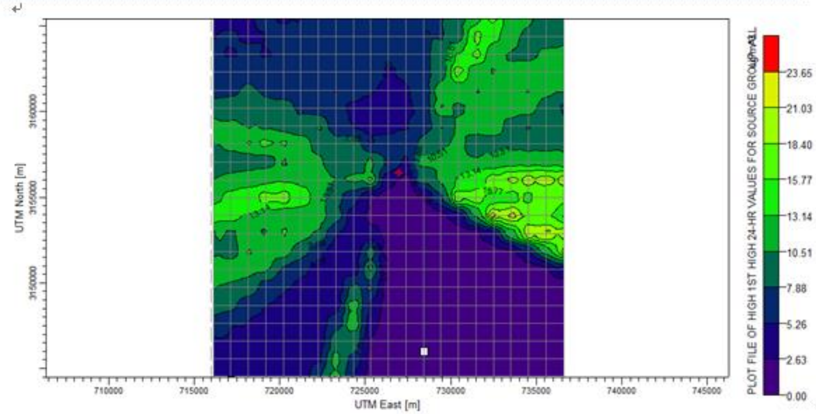


Figure 1.15: Predicted Ground Level Concentration of NOx (24 hour average)

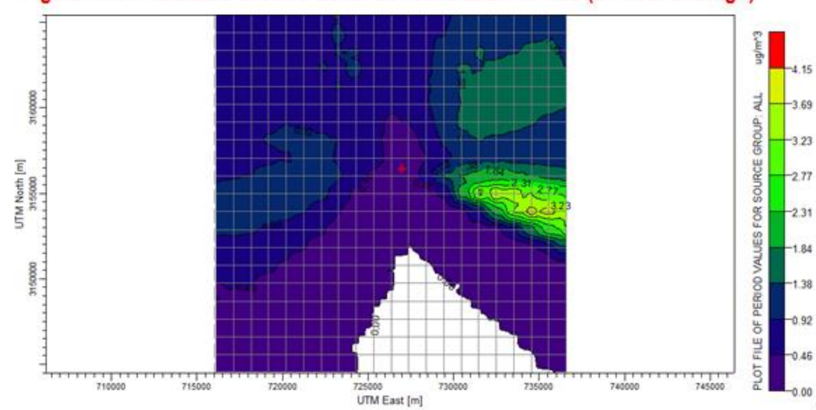


Figure 1.16: Predicted Ground Level Concentration of NOx concentration during winter season (Average)

3. Study on CO2 Emission Reduction（1/2）

Calculation Method

Method	Description	Comparison
Performance of Benchmark Technology	> Using emission factor of high efficient coal fired power plant (Super Critical) as a benchmark	Compared to Overall India
Grid Emission Factor	> "CO2 Baseline Database for the Indian Power Sector" issued by Ministry of Power can be referred for setting grid emission factor	Compared to Overall India
PAT (Perform, Achieve and Trade)	> Setting emission factor by referring to the energy consumption reduction target in PAT	Compared to Before Replacement
Actual Emission Factor	> Setting emission factor by using historical operation data (3 years) of the power plant	Compared to Before Replacement

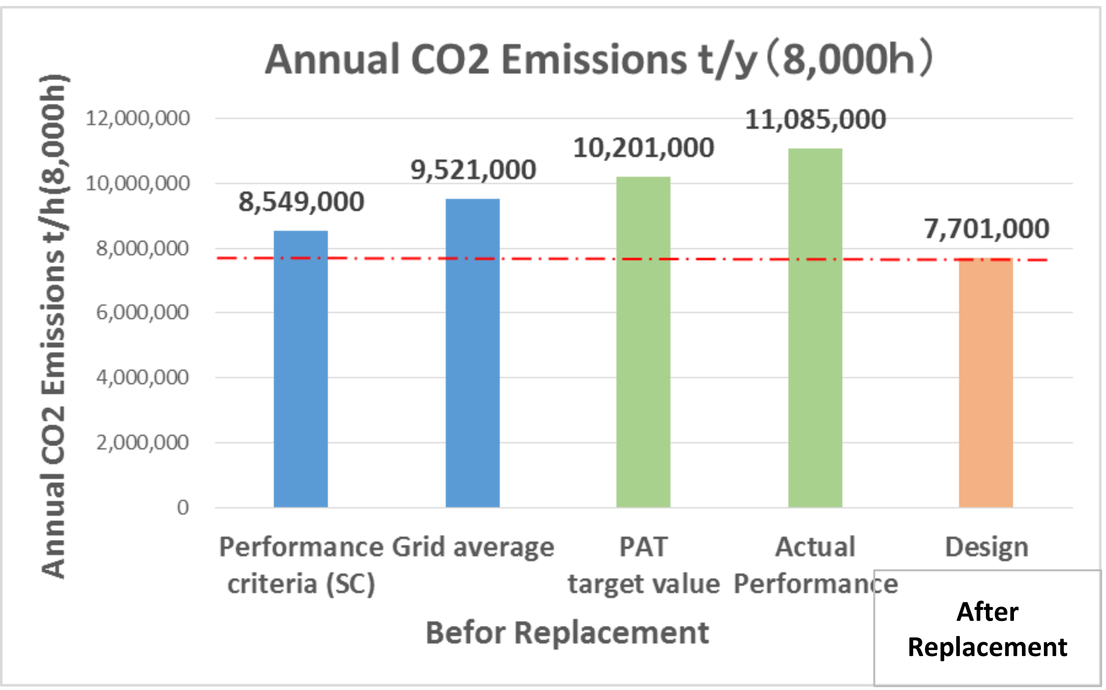
3. Study on CO2 Emission Reduction (2/2)

Study of the CO2 emission reduction effect

Options for Baseline	A. Baseline CO2 Emissions（tCO2/y）	B. Project CO2 Emissions（tCO2/y）	(A-B) CO2 Emission Reduction（tCO2/y）	(A-B/A) CO2 Emission Reduction Rate（%）
1) Performance criteria (SC)	8,549,000 (0.88)	7,701,000 (0.793)	848,000	9.9
2) Grid Emission factor	9,521,000 (0.98)		1,820,000	19.1
3) PAT target value	10,201,000 (1.050)		2,500,000	24.5
4) Actual emission factor	11,085,000 (1.141)		3,384,000	30.5

Note: Figures in ( ) show the CO2 emission factor (tCO2 / MWh)

CO2 emissions comparison of before and after the replacement



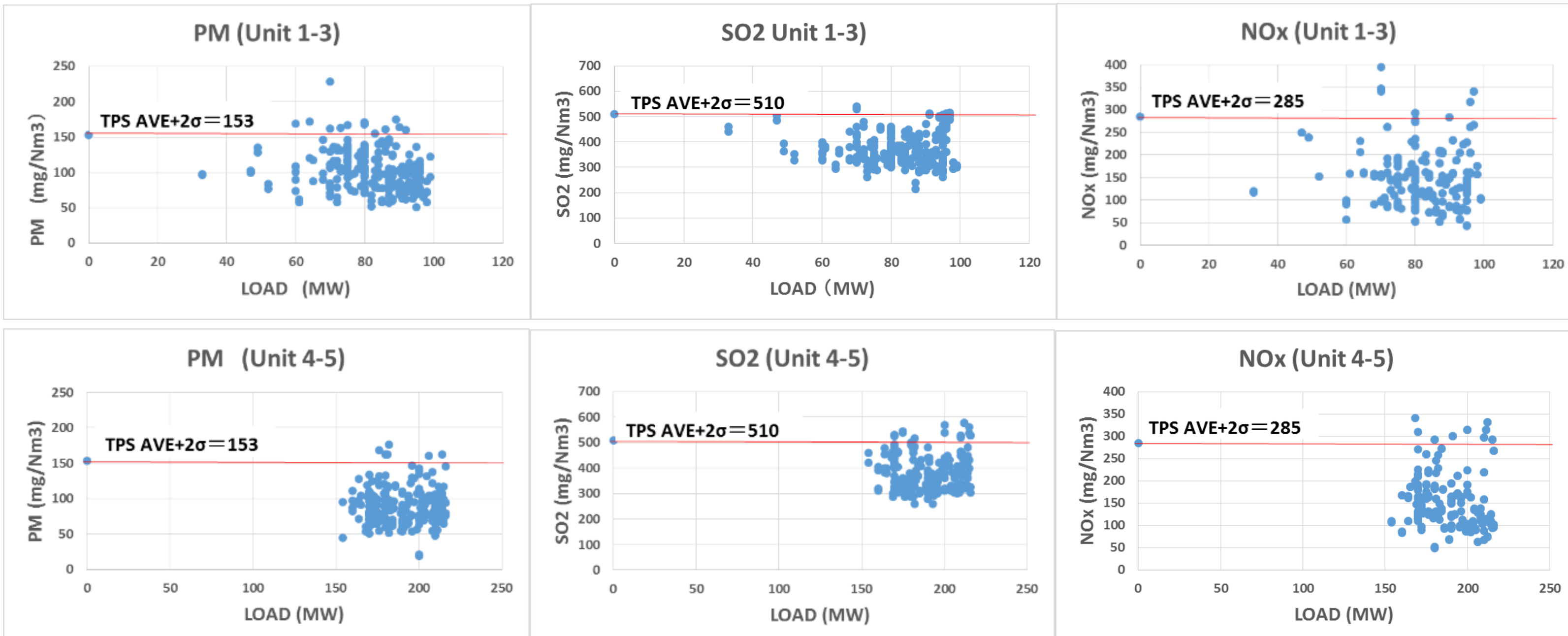
CO2 reduction effect of the replacement is 10～20%、compared with performance criteria(SC) or grid emission factor of over all India.

So, the replacement to the USC unit is very effective.

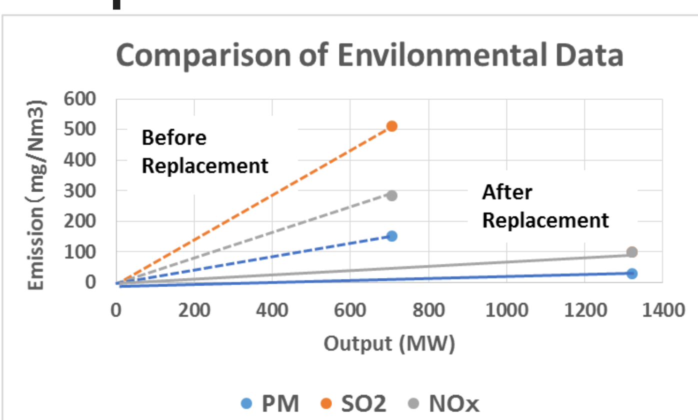
In case of replacement of under 210MW units, CO2 reduction effect is larger than this value.

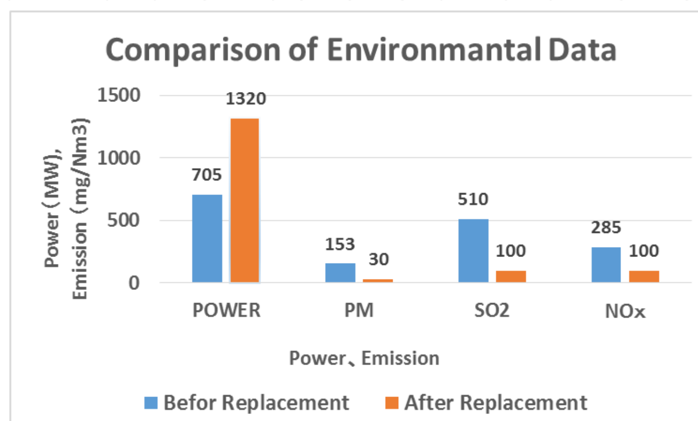
4. Estimated Improvement of Emissions (1/2)

Environmental Operating Data of Badarupur Power Station



Comparison of Environmental Data of before and after of Replacement



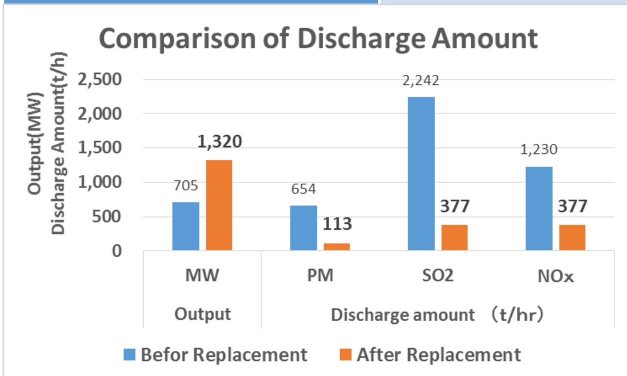


According to the new emission standards in 2015 December

4. Estimated Improvement of Emissions (2/2)

Comparison of Environmental Data of before and after of Replacement

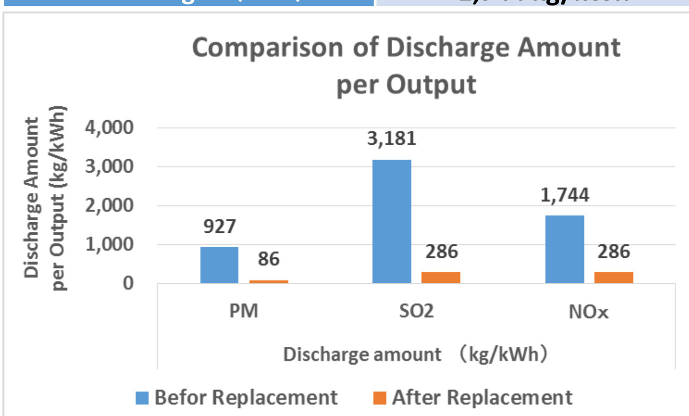
	Before Replacement	After Replacement
Particulate Matter（PM）	654 t/h	113 t/h
Sulphur Dioxide（SO_2）	2,242 t/h	377 t/h
Oxide of Nitrogen（NOx）	1,230 t/h	377 t/h



The replacement , although power plant output is approximately doubled , by reducing the emission concentration , impact on the environment is greatly reduced.

Comparison of Environmental Rate of before and after of Replacement

	Before Replacement	After Replacement
Particulate Matter（PM）	927 kg/kWh	86 kg/kWh
Sulphur Dioxide（SO_2）	3,181 kg/kWh	286 kg/kWh
Oxide of Nitrogen（NOx）	1,744 kg/kWh	286 kg/kWh



Emission concentration of Badarpur was confirmed to be a typical value in India. By following the new emission standards , PM, SO2, NOx both emissions per unit power generation amount is reduced to about 10 to 17% lead to the improvement of significant environmental value.

5. Indicative EPC Cost (tentative)

Typical Cost of 2x 660MW Coal-fired Power Plant (USC)
with or without DeNox & DeSOx Systems

Item		Turnkey EPC	Turnkey EPC w/o DeNOx & DeSOx
Boiler Island	Cr.	4,719	3,505
TG Island	Cr.	1,802	1,802
BOP	Cr.	2,869	2,869
Civil & Structural	Cr.	1,468	1,488
Total	Cr.	10,858	9,664
indicator	US$/kW	1,233	1,115

6. Fuel Supply Plan
Outline of current fuel supply in BTPS and its issues

Current Status

- Average GCV of coal supplied is around 4,000 kcal/kg.
- 25 – 30 % out of 4,000,000 t is supplied as washed coal to meet its ash content is below 34%.
- Fuel cost is very high, Dominant factor to push up BTPS's generation cost. Its transportation cost is main reason for high cost.

Linkage	main coal mine	FSA	grade	washery
CCL	Kedla	4,000,000	G9-12	
	Saunda			
	Dhori			
	Ramgarh area			
	Giddi			✓
	Bachra			✓
ECL	Sheeralpur	200,000	G6	
	J K Nagar			
	Sone Bazaari			

Issues to be considered.

1. Additional coal
   1,000 kTPA
   (2,900 x 2unit) 5,800 kTPA

2. Fuel cost

> Possibilities for expansion of coal supply

1) Expansion of current linkage might be 4,800 kTPA from CCL.
2) Tapering linkage, *Bridge linkage, reallocation of linkage,* new linkage.
4) Purchase through e-auction
5) Imported coal
6) *NTPC Captive mines*

6. Fuel Supply Plan
Fuel supply issues and measures to be considered (1/3)

- **Cost breakdown**

Additional cost @ CIL

Size of coal, loading method, etc.

Transportation cost

km	Rs/t
1–100	150.2
101–125	177.2
126–150	206
151–175	230.9
501–550	631.2
551–600	685.1
1001–1100	1214.3
1101–1200	1320.0
3001–3500	2902.7

Several tax are added

Final Landed cost of coal is 3– 4 times of coal mine price.

- Proposal for fuel supply plan

1) Tapering linkage, Bridge linkage, reallocation of linkage, new linkage.
   Reduction of transportation cost by restructuring coal linkage, but need negotiation by government level

2) NTPC Captive mines
   Reduction of coal cost directly by supplying from NTPC captive mine.

3) Washed coal
   Upgrade of G12 to G10-8 grade is worth to be considered to reduce transportation cost.

4) Supply form Upgrade lignite by UBC process
   Reduction of ash contents, transportation cost, etc., by applying UBC (Upgraded Brown Coal) technique at Rajasthan

6. Fuel Supply Plan
Fuel supply issues and measures to be considered (2/3)

- Example of cost accumulation.

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

4 times of mine price

6. Fuel Supply Plan
Fuel supply issues and measures to be considered (3/3)

List of NTPC Captive mine

- Reduction of coal cost directly, only 1MTPA from captive mine is enough to address amount issue.

	Coal mine	State	commissioning	annual production (MTPA)		Geological Reserve (MT)	Linked Project
				Current	Plan		
1	Pakri-Barawadhi	Jharkhand	2015-16		15.0	1,436	shortfall in Lara and Darlipalli
2	Chatti-Bariatu	Jharkhand	2016-17		7.0	548	Barh-II (1,320MW)
	Chatti-Bariatu South	Jharkhand	2015-16				
3	Kerandari	Jharkhand	2016-17		6.0	285	Tanda-II (1,320MW)
4	Dulanga	Odisha	2015-16		7.0	196	Darlipalli-I (1,600MW)
5	Talaipalli	Chhattisgarh	2015-16		18.0	1,267	Lara STPP (4,000MW)
6	Banai	Chhattisgarh	2021-22		12.6	629	Barethi-I (2,640MW)
7	Bhalumunda	Chhattisgarh	2021-22		11.0	550	Kudgi-I (2,400MW)
8	Kudunali-Luburi	Odisha	2021-22		5.3	266	Bilhaur-I (1,320MW)
9	Mandakini-B	Odisha			15.0	1200	Telangana STPP (4,000MW)
10	Banhardih	Jharkhand			7.0	800	Patratu STPP (4,000MW)
	Total (MTPA)				103.9	7177.0	

7. Utilization of Discharged Ash
Outline of current ash flow in Badarpur Thermal Power Station

<u>> Fly ash demand</u>

Demand in NCR Delhi is high and is expected to continue another 20 years Further detail of cement demand will be recommend to obtain from cement industry statistics, etc.

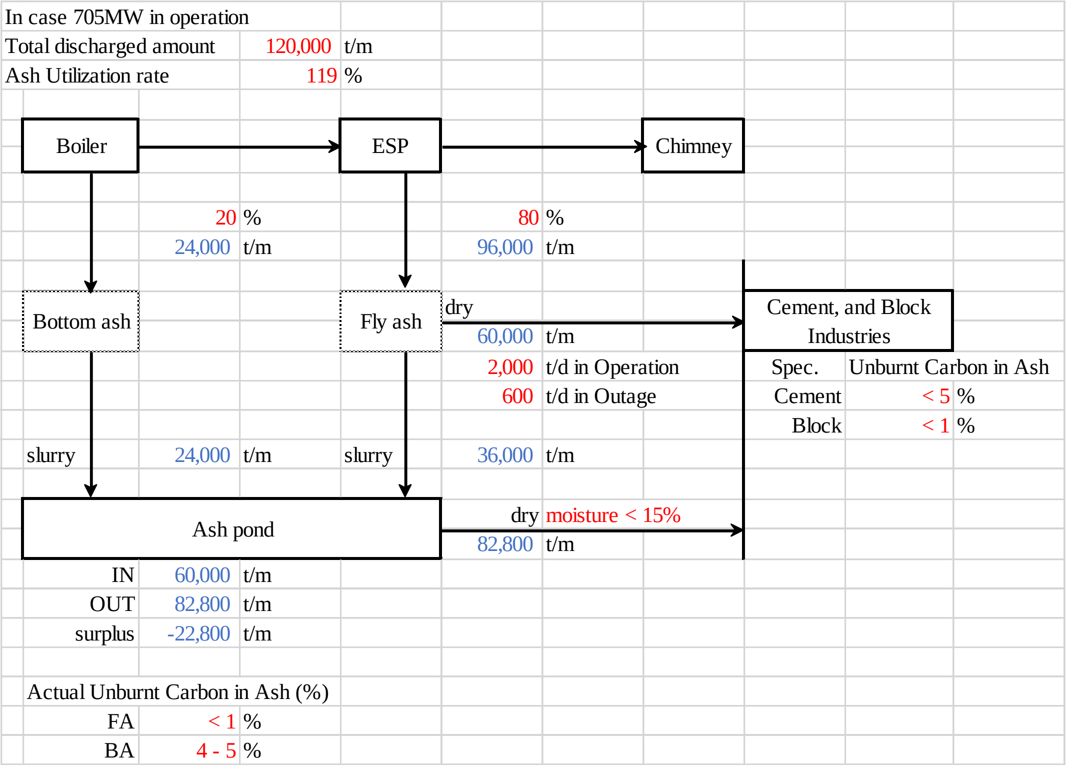
Construction of Eastern peripheral road is required approx. 25,000,000 t of ash during coming 4 years.

<u>> Ash Pond Area</u>

Ash Pond Area is 800acres. After Replacement(Total units capacity is 1320MW), 800acres is enough.

> Selling price of Fly ash

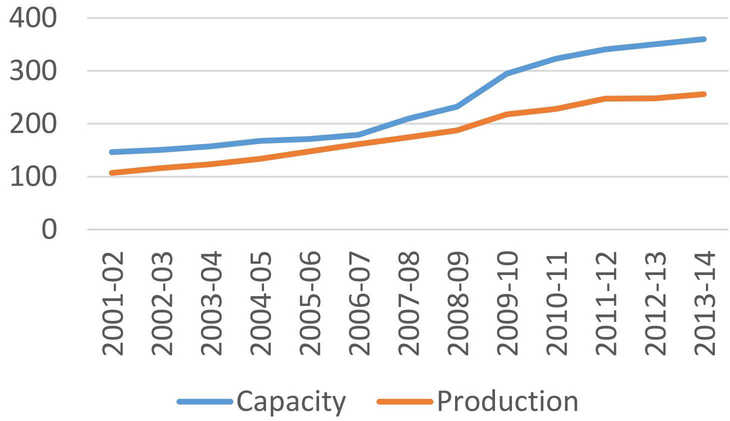
Selling price depends on operation, 270 Rs in low PLF and 460 Rs in high PLF .



7. Utilization of Discharged Ash
Hearing from ash user side (Cement manufacture's Association)

1. Fly ash demand
Demand in NCR Delhi is high and is expected to continue another 20 years
Further detail of cement demand will be recommend to obtain from cement industry statistics, etc.
Construction of Eastern peripheral road is required approx. 25,000,000 t of ash during coming 4 years.

2. Selling price of Fly ash
Selling price depends on operation, 460 Rs in low PLF and 270 Rs in high PLF.



All India Cement performance (Mt)   source: CMA

1. Fly ash demand
Utilization for Cement is 40% out of 55% of total ash utilization. Cement demand is strongly depends on economy growth.

2. Selling price of Fly ash
Fly ash has been purchased from FY 2006. this is a dominant factor to push up cement cost as well as transportation cost.

3. Ash quality
Low quality of ash causing coal quality is concerned.

Thank you

J-POWER

Kyushu Electric Power Co., Inc.

ずっと先まで、明るくしたい。

JCOAL
Japan Coal Energy Center