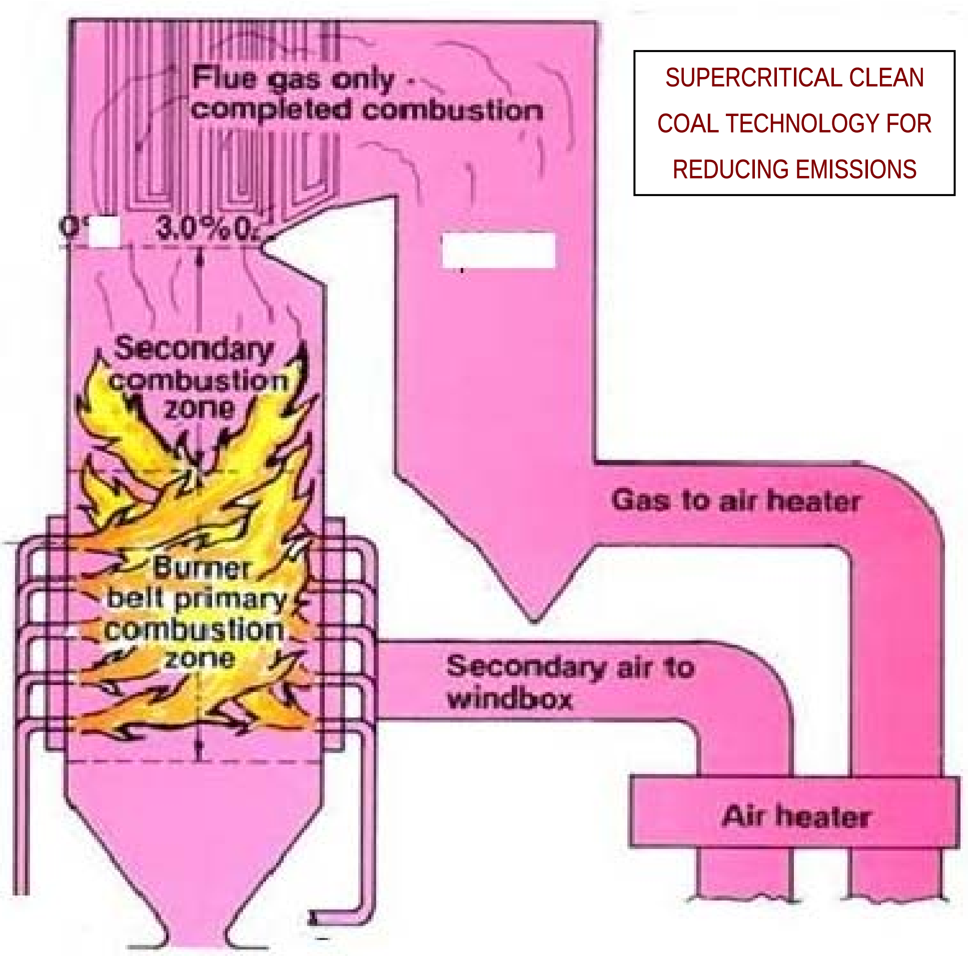
GREEEN HOUSE GAS EMISSIONS - STUDY REPORT



SUPERCRITICAL CLEAN COAL TECHNOLOGY FOR REDUCING EMISSIONS

July 2010

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Abbreviations

CEA	Central Electricity Authority India
DEH	Digital Electro Hydraulic
ESP	Electro Static Precipitator
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GHG	Green House Gas
GWP	Global Warming Potential
HFC	Hydro Fluoro Carbons
HFO	Heavy Fuel Oil
HHV	Higher Heating Value
LDO	Light Diesel Oil
LSHS	Low Sulphur Heavy Stock
MCR	Maximum Continuous Rating
MMT	Million Metric Tons
MoEF	Ministry of Environment & Forests, Government of India
NAPCC	National Action Plan for Climate Change
PLF	Plant Load Factor
TMCR	Turbine Maximum Continuous Rating
UMPP	Ultra Mega Power Project
UNFCCC	United Nations Framework Convection on Climate Change

GREEN HOUSE GAS EMISSION STUDY

1.0 INTRODUCTION

Coal would continue to play a significant role in the Indian power sector. Hence, the important issue is to use coal efficiently and in an environment friendly manner. The Integrated Energy Policy of Government of Indian also advocates that "efficiency of coal power plants themselves can be improved substantially. The average gross efficiency of generation from coal power plants is 30.5%. The best plants in the world operate with super critical boilers and get gross efficiency of 42%. Germany is even claiming gross conversion efficiency of 46%. It should be possible to get gross efficiency of 38-40% at an economically attractive cost for all new coal-based plants. This alone can reduce coal requirement by 111 Mtoe of coal (278 MT of Indian coal). Thus a very high priority should be given to developing or obtaining the technology for coal-based plants of high efficiency."

One of the methods to improve efficiency of thermal power plants is to adopt supercritical steam condition, which is also known as super critical technology. This technology is already commercially proven world wide and is readily available. Use of super critical technology results in higher turbine efficiency and hence better heat rate, which ultimately leads to lower fuel consumption and reduced CO_2 emissions and other pollutants.

Recognizing the fact that economies of scale leading to cheaper power can be secured through development of large size power projects using latest supercritical technologies, Ministry of Power, Government of India, Central Electricity Authority (CEA) and Power Finance Corporation are working in tandem for development of Ultra Mega Power Projects[1] 4,000 MW capacity each.

Sasan Ultra Mega Power Project is the first domestic coal based ultra mega power project being developed by Sasan Power Ltd, a wholly owned subsidiary of Reliance Power Limited. The project is based on super critical technology, which has higher efficiency than conventional sub-critical technology based plants in India. Super critical power plants consume lesser coal per unit of power generation and thus produce less carbon-dioxide. This is India's contribution to clean green power for sustainable economic growth and ensuring power to all.

2.0 INDIA's LOW CARBON GROWTH STRATEGY

India is faced with the challenge of sustaining its rapid economic growth while dealing with the global threat of climate change. In order to achieve a sustainable development path that

[1] *HTTP://WWW.PFC.GOV.IN/MOP_UMPP.PDF*

simultaneously advances economic and environmental objectives, the National Action Plan for Climate Change (NAPCC)[2] has been designed. The NAPCC hinges on the development and use of new technologies. There are Eight National Missions which form the core of the National Action Plan, representing multi-pronged, long-term and integrated strategies for achieving key goals in the context of climate change.

The focus will be on promoting understanding of climate change, adaptation and mitigation, energy efficiency and natural resource conservation. The missions cover Solar, Enhanced Energy Efficiency, Sustainable habitat, Water, Sustaining Himalayan ecosystem, Green cover, Sustainable Agriculture and Strategic Knowledge for Climate Change.

NAPCC propagates use of Supercritical and ultra-supercritical plants since these can achieve efficiencies of 40 and 45% respectively, compared to ~35% achieved by sub-critical plants. NAPCC acknowledges that since coal-based power generation will continue to play a major role in the next 30-50 years, it would be useful, wherever cost-effective and otherwise suitable, to adopt supercritical boilers, which is a proven technology, in the immediate future, and ultra-supercritical boilers when their commercial viability under Indian conditions is established.

3.0 MITIGATION OF GREENHOUSE GASES

The Government of India has conveyed to the United Nations Framework Convention on Climate Change (UNFCCC) that India will endeavour to reduce the emissions intensity of its GDP by 20-25% by 2020 in comparison to the 2005 level through domestic voluntary mitigation actions.[3]

[2] *HTTP://PMINDIA.NIC.IN/CLIMATE_CHANGE.HTM*

[3] *HTTP://UNFCCC.INT/FILES/MEETINGS/APPLICATION/PDF/INDIACPHACCORD_APP2.PDF*

4.0 OBJECTIVE OF THE STUDY

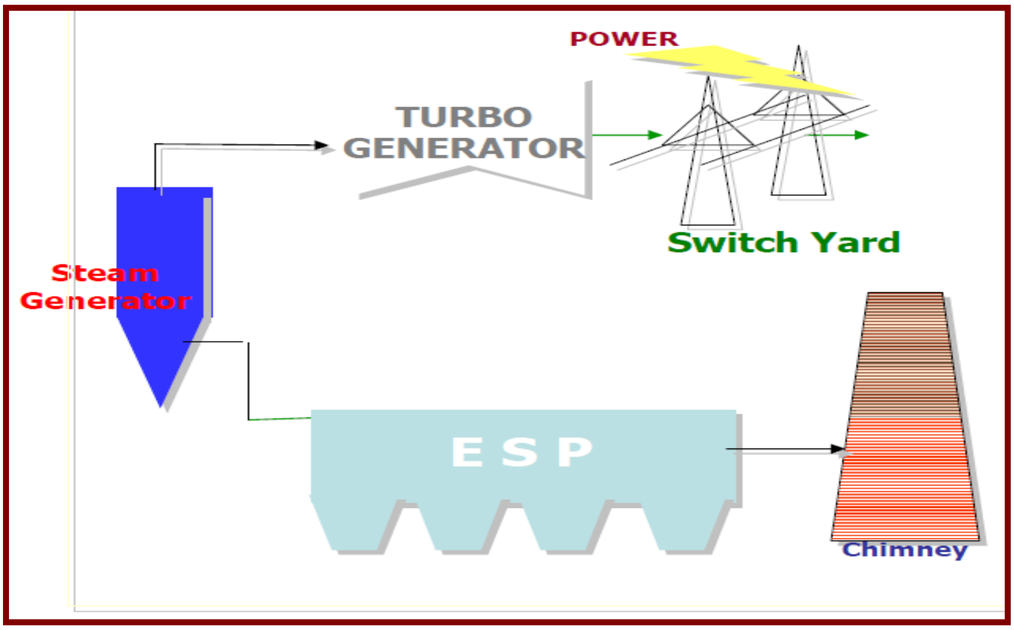
The objective of this study is to assess the entire emissions inventory including greenhouse gas emissions of the power plant with appropriate emission factors. The study covers emissions during construction phase, commissioning period and operations thereafter.

In this report, the following issues are addressed.

a. Scope 1 and Scope 2 GHG emissions inventory as per the Greenhouse gas protocol
b. Project design features to maximize the conversion efficiency.
c. Assumptions & predictions of assessment of greenhouse emissions from the project during its life cycle.
d. Comparison with CEA, Government of India guidelines.

5.0 SALIENT FEATURES OF SASAN UMPP

Sasan UMPP has six units each of 660 MW operating on super critical parameters. The salient features of the power plant are given below:



Steam Generator:

With a steaming capacity of 2134 TPH, at Super heater pressure 259 kg / cm^2 and super heater temperature 571 °C. The salient features are:

a) The Steam Generator is a once through, water tube (Spiral / Vertical), direct pulverized coal fired, top supported, balanced draft furnace, single reheat, radiant, suitable for out door installation. The gas path arrangement is of two pass type.

b) The furnace is radiant, dry bottom type with tangential wall firing and enclosed by water cooled and all welded membrane walls. The furnace bottom is suitable for installation of a water impounded bottom ash hopper.

c) The coal burners designed are of low NOx emissions type to meet the International Standards.

d) Start-up, warm up and low load (up to 40%) carrying shall be done by HFO / LDO/ LSHS. The pulverizers are of vertical spindle type, bowl mills.

e) A balanced draft system with two axial type FD fans and two axial type ID fans and two tri-sector regenerative rotary type air pre-heaters.

f) Boiler is designed for variable pressure operation.

Steam Turbine:

The salient features are:

a) The turbine is of tandem compound, single reheat, regenerative, condensing, multi cylinder design with combined HP-IP and two LP cylinders, directly coupled with generator suitable for in door installation.

b) The fixed blades of the last one or more stages shall be hollow and be provided with slots to draw away water droplets to the condenser. The LP rotor blades are designed to operate in speed range corresponding to 47.5 Hz to 51.5 Hz grid frequency.

c) The turbine is provided with an electro hydraulic governing / DEH system with suitable back up.

ESP:

The Electro Static Precipitator (ESP) is designed with an efficiency of 99.97% to limit suspended particulate matter concentration to 50 mg/Nm^3.

Stack:

Two stacks of 275 m are provided to ensure adequate dispersion of SO_2 emissions as per Indian Environmental Standards. Each stack is provided with three flues. As per the environmental norms, the flue gas velocity at the stack outlet is maintained as 25 m/s

6.0 ASSESSMENT OF EMISSIONS:

The main Green House Gas emissions generated in the coal fired thermal power station are:-

a) Carbon di Oxide (CO2) - due to combustion

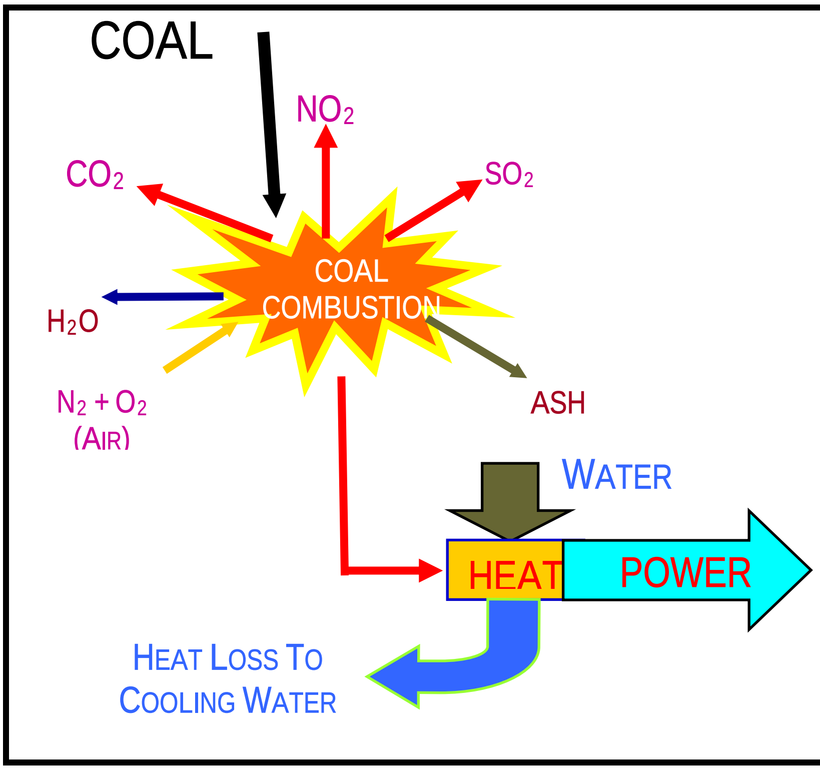
b) Methane (CH4) - From handling/storage of coal

c) Nitrous Oxide (N2O) - due to combustion

Apart from the above, other minor green house gases in a thermal power plant are:

a) HFCs - from Air conditioners

b) SF6 – from electrical systems



Due to combustion of coal, CO2 is produced, which is one of the main green house gases. High temperature combustion also produces Nitrogen oxides, NOx. Since coal contains sulphur, SO2 is also generated.

7.0 FUEL CHARACTERISTIC

The captive coal for SASAN UMPP is linked from a Moher-Moher Amlohri extension mine near SASAN village. The mine is developed in two parts and blended coal will be used. The average quality of coal from the mine "As Received" is given below:

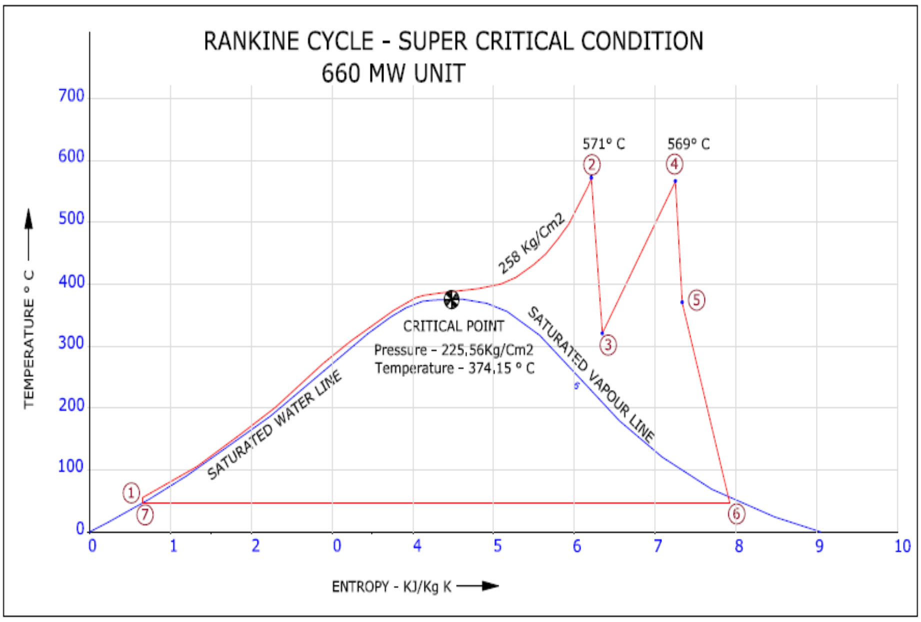
Parameter	% Composition
Ash + Moisture (%)	36.54
Volatile Matter (%)	21.61
Fixed Carbon (%)	41.37
Sulphur (%)	0.48
GCV (kCal/kg)	4445

The carbon fraction derived from the above data is 47.93%, Nitrogen: 1.67%

8.0 RANKINE CYCLE

In the steam turbine, the thermal energy of the steam is converted into mechanical energy. The steam turbine operates on Rankine cycle. In super critical system the water in the boiler is converted into steam beyond critical point as shown in the figure below. Steam turbine cycle efficiency (usually represented in terms of Heat rate) depends on steam parameters i.e. higher the steam parameters, better the turbine efficiency.

As steam parameters remain relatively constant, the Turbine Heat rate of 1900 kCal/kWh guaranteed by turbine manufacturer has been considered. Since units would be operated at high PLF (over 90%), it is possible to achieve the guaranteed heat rate of the turbine.



9.0 POWER PLANT PERFORMANCE

The power plant performance is summarized as given below:-

Parameter	Unit	Value	Remarks
Turbine heat rate	kCal/kWh	1900	Guaranteed by Turbine manufacturer
GCV of Coal on "As Received Basis"	Kcal/kg	4445	HHV
Plant Load Factor	%	90	Expected Annual Average
Annual coal consumption	MTPA	14.99	For the above parameters
Specific Oil Con.	ml/kWh	0.2	Based on industry experience confirmed by power sector expert (Intermittent)
Annual Generation	kWh	31221×10^6	Calculated based on 90% PLF for 6X660 MW

10.0 GREEN HOUSE GAS (GHG) EMISSIONS

The GHG emissions are based on excess air of 20 to 25% corresponding to excess oxygen content of 3 – 4 %. Since different GHG have different potential of global warming, in order to compare different GHG emissions, CO2 equivalent called the Global Warming Potential (GWP) for the above gases as published by IPCC/EPA is considered. Same is provided below:

Description	Value
CO_2	1
CH_4	21
N_20	310
R-407C	1610
R-410A	1725
R-134A	1300
SF_6	23900

Apart from the above, other gases likes NOx, Sox and CO etc are also generated in the power plant. These are known as pollutants and do not directly contribute to global warming. However the quantity of these pollutants is also calculated.

11.0 POWER PLANT EMISSIONS DURING OPERATIONS

All the emissions of the thermal power plant operation are computed. The emission factors are based on the power industry practice.

Carbon Dioxide Emissions (CO2)

CO2 emission is due to combustion of coal & Oil in the furnace. The CO2 impact is assessed based on the emission factor and annual coal consumption. The total quantity of CO2 estimated to be generated annually and the Intensity is tabulated below:-

CO2 Emissions					
		Emission Factor	Annual emission (MTPA)	CO2 intensity g/ kWh
	Coal	1.722	25.80	826.6
	Oil	2.7	0.0169	0.54044
	Coal & Oil		25.8169	

Emission factor is based on carbon fraction; Oxidation factor – 98% as per CEA guidelines; MTPA – Million Tons/ Annum

Nitrous Oxide (N2O)

N2O is generated from the reaction of Nitrogen in the fuel with oxygen and is part of the NOx gases. N2O has a Global warming potential (GWP) of 310. The quantity of N2O is estimated to be in the order of 1 PPM in the flue gas. Based on this, the quantity of N2O generated with intensity as equivalent CO2 is 2.28 g/kWh. This works out to emission of 0.0712 MTPA.

Methane (CH4)

Coal stack yard in power plant is a source of CH4. The GWP of CH4 is 21. This is estimated based on the emission factors applicable for coal at the plant end. Since crushed coal stacked at the plant end is compacted and regularly watered, CH4 generated at the stack yard is likely to be negligible. However the estimated CH4 quantity from the stack yard is calculated and the intensity in equivalent CO2 is 0.056 g/kWh, which cumulates to 0.001748 MTPA.

Refrigerants:

The refrigerants used in the Air conditioning equipment are the source for HFC gases in the Power plant. The GWP of these gases used in the power plant are in the range of 1300-1700. Even though there is little possibility of leakage, the quantities are calculated based on the power plant experience. The refrigerant consumption is calculated and the equivalent intensity is 0.0024 g/kWh and accounts to 0.0001 MTPA.

Sulphur Hexa Fluoride (SF6):

SF6 is used in the Electrical systems. It has a GWP of 23900. While the systems are designed and operated for zero leakage, the quantities are calculated based on most probable condition based on industry experience confirmed by the power plant expert. The calculated SF6 intensity as CO2 equivalent based on the GWP is 0.0215g/kWh and amounting to 0.0007 MTPA.

From the above data, the total CO_2 emissions for 6x660 MW are tabulated below:-

1	CO2 Emissions		
		CO2 intensity g/ kWh	Annual Emission MTPA
	Coal	826.6	25.8
	Oil	0.54044	0.0169
	Carbon Equivalent of		
2	N2O Emissions	2.28	0.0712
3	SF6 Emissions	0.0215	0.0007
4	Refrigerants Emissions	0.0024	0.0001
5	CH4 Emission	0.056	0.001748
		829.43	25.895

The above GHGs emission annually totals to 25.895 MTPA and 99.65% of it due to coal combustion.

<u>NOx Emissions:</u>

NOx is formed during combustion process due to reaction of Nitrogen in combustion air with excess Oxygen in the furnace called as Thermal NOx and oxidation of nitrogen in the coal referred to as fuel NOx.

NOx production is strongly affected by two factors: temperature at which combustion takes place and amount of oxygen available during combustion. Controlling these parameters provides a way to control quantity of NOx generated. This is achieved using a low NOx burner. A low NOx burner is designed to create an initial combustion region for the pulverized coal particles where the proportion of oxygen is kept low. When this happens, most of the available oxygen is captured during the coal combustion process, leaving little oxygen to react with nitrogen.

To achieve this, some of the air needed to burn the coal completely is prevented from entering the initial combustion region with the coal; instead it is delayed briefly, and being admitted to this primary region after some of the combustion has been completed, known as staged combustion. This procedure can reduce the level of NOx. The total NOx emission as per our calculations for above-mentioned coal with low NOx burners is estimated to be around 175 g/GJ which is equivalent to 501 mg/NM3.

SO_2 Emissions:-

The sulphur of Indian coal consists of organic sulphur, pyritic and sulphate sulphur. The organic sulphur is approximately 51% of total sulphur content for Sasan coal. As per the power sector expert, about 1/3rd of the inorganic sulphur is also taking part in the combustion process along with Organic sulphur. The SO_2 formed works out to 3026 mg/kWh which is equivalent to 843.36 mg/NM^3 . Even though the specific oil is very less, considering its impact, on conservative estimate, quantity would be around 2 mg/NM^3. The total SO2 works out to 846 mg/NM^3 totaling to 94756 TPA for the station as a whole.

Carbon Monoxide Emissions:-

The combustion is tuned to ensure complete combustion with minimum excess air and no CO formation. However for the purpose of this study, a minimum of 40 ppm of CO is considered which may occur occasionally. This works out to 0.1490 g/kWh and is equivalent to 42 mg/NM^3. The total CO emission works out to 4.652 TPA for the station as a whole.

Suspended Particulate Matter Emission including PM10:-

High efficiency i.e. 99.97% ESP's are provided, designed for an emission of 50 mg/NM^3 under worst conditions. During normal operation this would be further less. This works out to 5600 TPA for the station as a whole.

12.0 GREEN HOUSE GAS (GHG) EMISSIONS DURING CONSTRUCTION & COMMISSIONING

The SASAN UMPP has 6X660MW units. The construction and commissioning phase of the plant is spanning over 5 years i.e. from 2010-11 to 2014-15.

During construction the CO2 emissions are due to diesel consumption @ 3000 KL for earth moving equipment and material handling equipment operation and construction power of 44 MU per year. The CO2-e per year during construction period is **51528** Tons as per table below.

Sl No	Type/Qty	Emission factor	Emissions
01	Diesel/ 3000 KL	2.7 T CO2-e/KL	8100
02	Construction Power/44 MU	0.987 T CO2-e/Mwhr	43428
Total CO2-e per Annum			51528

During the first three years (from 2010-11 to 2012-13) the erection activity is at its peak. Subsequently due to readiness of units for commissioning, the CO2 emissions taper down. Also the construction power will be supplied from the commissioned unit. The year wise CO2-e emissions during construction phase are shown below:

Sl No	Year	Fuels	CO2-e
01	2010-11	Diesel+ Construction power from external sources	51528
02	2011-12	--do--	51528
03	2012-13	--do--	51528
04	2013-14	Diesel	18957
05	2014-15	--do--	4050
06	2015-16	Diesel for misc. construction activities	2000
Total			179591

The cumulative CO2-e from construction phase is 179591 Tons.

The CO2-e during commissioning phase is as shown in the table:

Type of fuel	Units	Qty	Emission factor	CO2-e generated
LDO (Diesel)	kL	16141	2.7 T/kL	43581
HFO	kL	34969	2.7 T/kL	94416
Coal	MT	0.336	1.72 T/T	577920
Start up Power	MWh	43200	0.987 T CO2-e /MWh	42638
TOTAL CO2-e during commissioning				758555

The total CO2-e emission during Project phase which includes construction and Commissioning is 938136 Tons.

13.0 TOTAL GHG EMISSIONS FROM SASAN UMPP

The total emissions during Construction, Commissioning and operation are shown below:

(Values in Tons of CO2-e)

Activity	Period	CO2 emission (MT)
Construction	2010-11 to 2015-16	179591
Commissioning	2013-14 to 2014-15	758555
Operation	2013-14 to 2038-39	634305000
TOTAL (Million MT)		635.24

14.0 CONCLUSIONS:

From the above study, the CO2-e emissions from the plant are 829.43 gm/kWhr. It could be observed that Green House Gas Emissions from the projects are less than the National baseline data of 944 gm CO2-e/kWh for power stations employing super critical technology.

At SASAN UMPP by employing super critical technology with higher steam parameters, the project would consume approximately 1.25 million Tons of less coal per year compared to sub-critical plants of similar size. Compared to CEA baselines for sub-critical and super critical technologies, the annual CO2 emission reductions for same amount of electricity produced are shown below:

Parameter	CEA Baseline reference[4]		SASAN UMPP
	Sub-Critical	Super-critical	
CO2 Intensity (g/kWh)	1000	944	826.6
MU generated @90% PLF	31221	31221	31221
CO2 emissions in MTPA	31.22	29.47	25.80
CO2 emission reduction MTPA	5.42	3.67	Base

By deploying Super-critical technology, Sasan Project would abate CO2 emissions by 91.75 Million Tons (3.67X25) over 25 years of Project life with reference to CEA baseline reference of 944 g/kWh.

However during actual operation of the power plant, the energy conversion efficiencies will be improved further as a result of following planned efforts, thereby reducing the Green House Gas Emissions:-

a) Combustion tuning will be done regularly
b) Best O & M practices will be adopted
c) Continuous monitoring of process parameters to maintain design values

Similarly best available control technologies would be adopted for mining operations, thereby reducing the emissions further.

Both the power plant and the mining operations would be operated efficiently, effectively in a environmentally friendly manner adopting all energy conservation factors to achieve the economic development of India and support its strategies for Low Carbon Emissions.

[4] CEA Baseline database Version 05, Nov 2009 available at www/cea.nic.in