Presentation Outline..

- *R&M of Old Units*
- *Advances Steam Parameters for Sub-critical Units*
- *PC - Supercritical / Ultra Supercritical*
- *Use of High Efficiency Gas Turbines*
- *CFBC*
- *IGCC*
- *Emission Control Technologies*
- *Conclusion*

Indian Power Market have Evolved

Generation, Transmission and Distribution in government hand

Independent Power Producers (IPP)

MOU with government

Electricity Act 2003:

Open Access

De-licensing for generators,

competitive tariff bidding

Indian Power Market poised for market driven tariff

Market Driven Tariff	Cost of generation ↓
Environmental regulations	Cost of generation ↑

For long term sustainability of Power Generation Company, Advance Technologies to produce power at competitive price are required

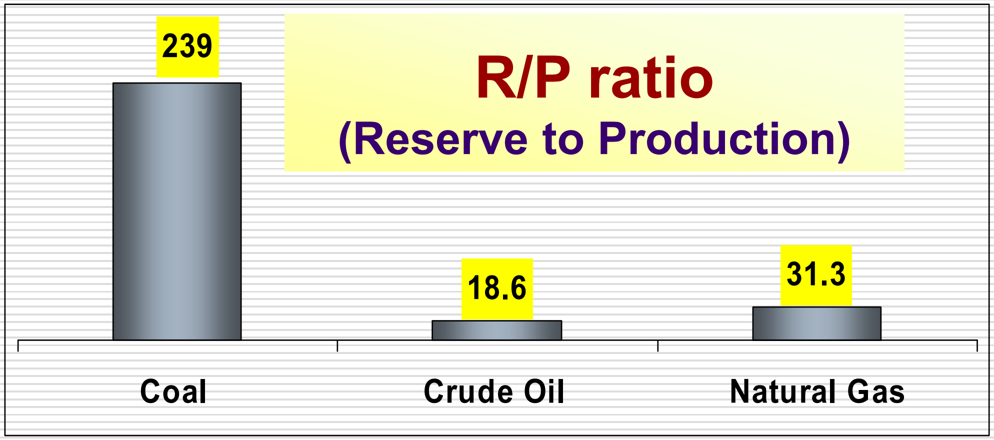
Fuel option

Coal has Highest Resource Potential

Indian Fuel Resource Scenario*

	Reserves	Production
Coal (proved) MT	93,000	382
Crude oil (MT)	700	38
Natural Gas(BCM)	920	29.4

Resource / Reserve Scenario*



Nuclear Resource Scenario@

	Reserves	Potential
	Tonnes of Metal	Gwe-Yr
Uranium	78,000	42,530
Thorium	5,18,000	150,000

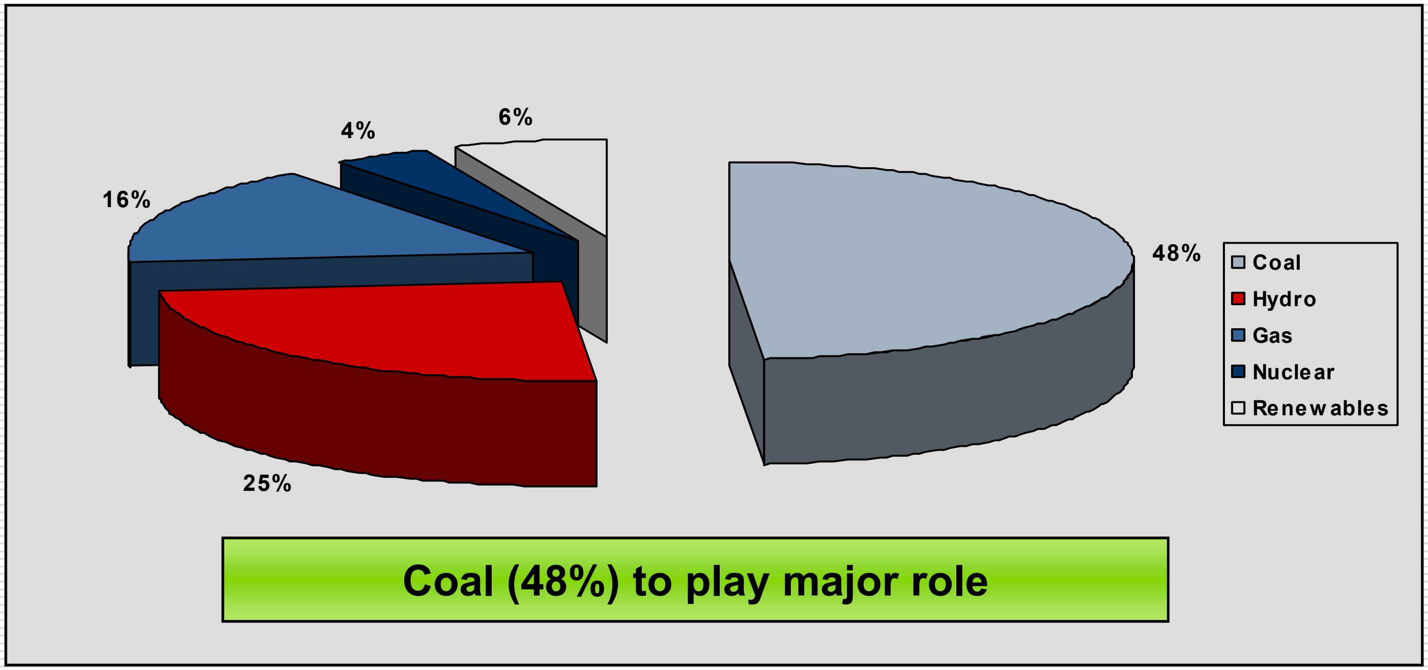
Hydro Resource Potential**

Total Potential (Assessed by CEA):

As installed Capacity	148,700 MW
Present Installed	30,936 MW
Balance (Recoverable)	117,764 MW

* CIL, BP Statistical Review of World energy, 2005 **Central Electricity Authority, GOI @NPCIL, India

Coal to be major component in 2005-2012 capacity addition programme and next few decades



Coal	Hydro	Gas	Nuclear	Renewable
46,900 MW	24,500 MW	15,600 MW	3,800 MW	6,000 MW

Total Capacity by 2012 is targeted to be around 212,000 MW

Figures based on tentative plan estimates of CEA, GOI

Coal has economic advantage but it is challenging from Environment Point

COAL

- *Advantages:*
  - *Abundant coal reserves (about 7% of world reserve)*
  - *Comparatively stable prices*
  - *Energy Security due to indigenous availability*
- *Challenges:*
  - *Environmental impact*
  - *Efficiency Improvement*
  - *Poor Calorific Value and quality*
  - *Increasing Capital Cost due to environmental mitigation measures*
  - *Competitive Pricing of Power*
- *Answer:*
  - *Advanced Technologies*

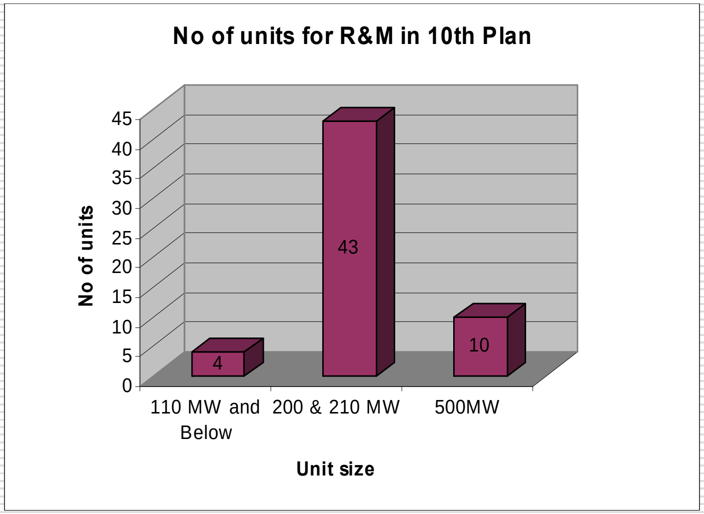
Environmental Impacts of Coal	
Air pollution	High particulate matter emission levels due to burning of inferior grade coal which leads to generation of large quantity of fly ash. Emissions of SO_2, NO_x & Green house gas (CO_2) are also matter of concern
Water pollution	Mainly caused by the effluent discharge from ash ponds, condenser cooling /cooling tower, DM plant and Boiler blow down.
Land Degradation	About 100 million tonnes of fly ash is generated by use of coal for energy production. The disposal of such large quantity of fly ash has occupied thousands hectares of land which includes agricultural and forest land too.

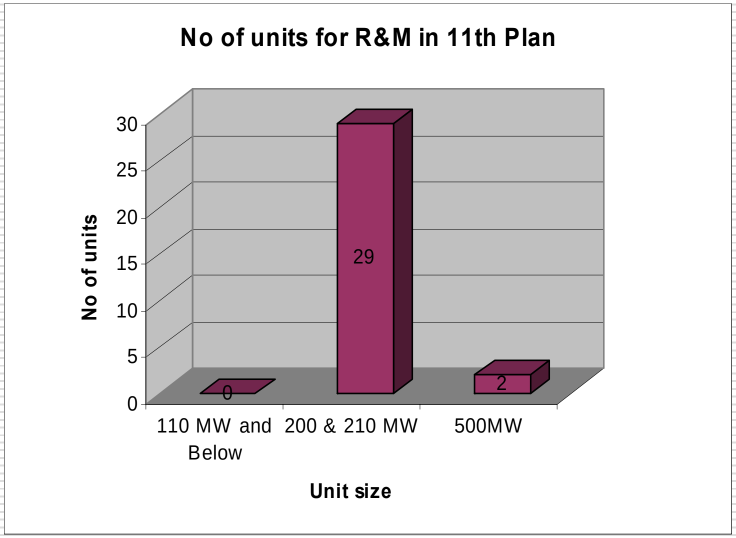
Coal Shall Remain India's Main Stay for Energy requirement till 2031-32

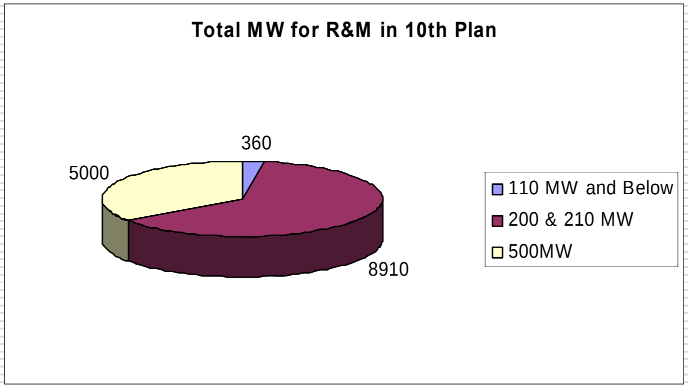
Re-powering

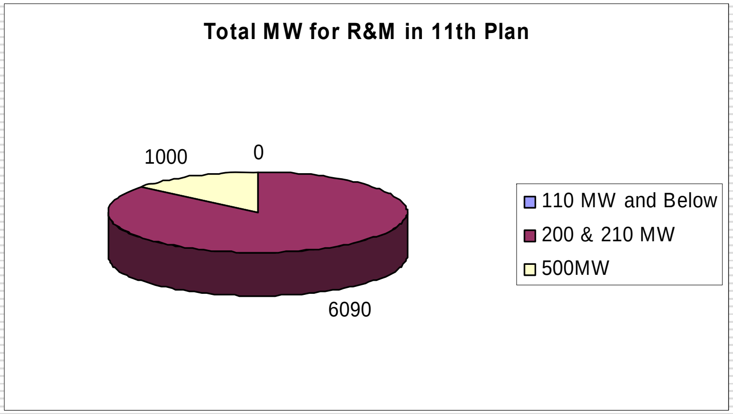
- India has large number of old plants which are inefficient and running below design capacity
- Operating pressure and temperature of these old plants are lower (pressure less than 130 kg/cm2 and temperature in the range of 535 ºC) and in some cases there is no reheating
- Fuel available at present is different from what plant were designed for
- Some of the equipments have degraded
- Re-powering of these plant can quickly increase the power generation at relatively lower cost to consumer
- Re-powering can increase the cycle efficiency and hence reduce emission of greenhouse gases and pollutants
- As Re-powering is challenging from technology as well as engineering view point, it offers potential for international cooperation

Thermal Units for R&M

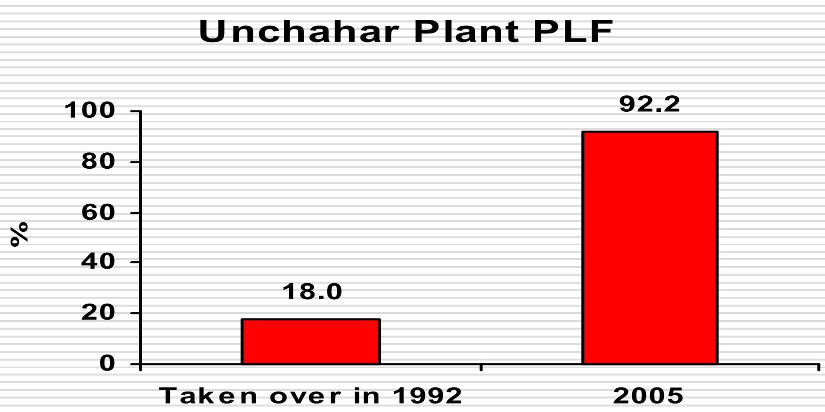


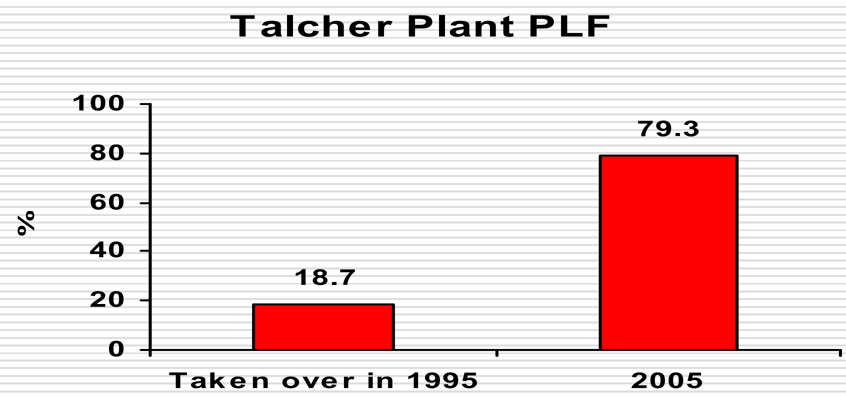


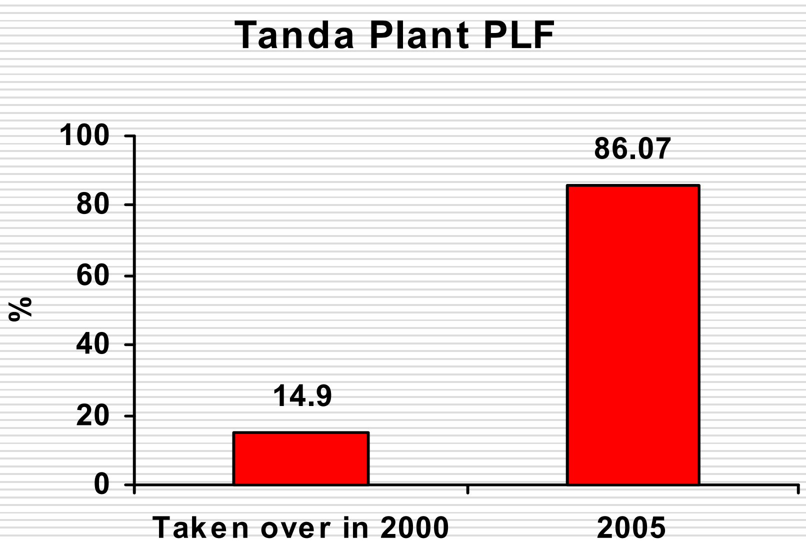




Turn Around Capability

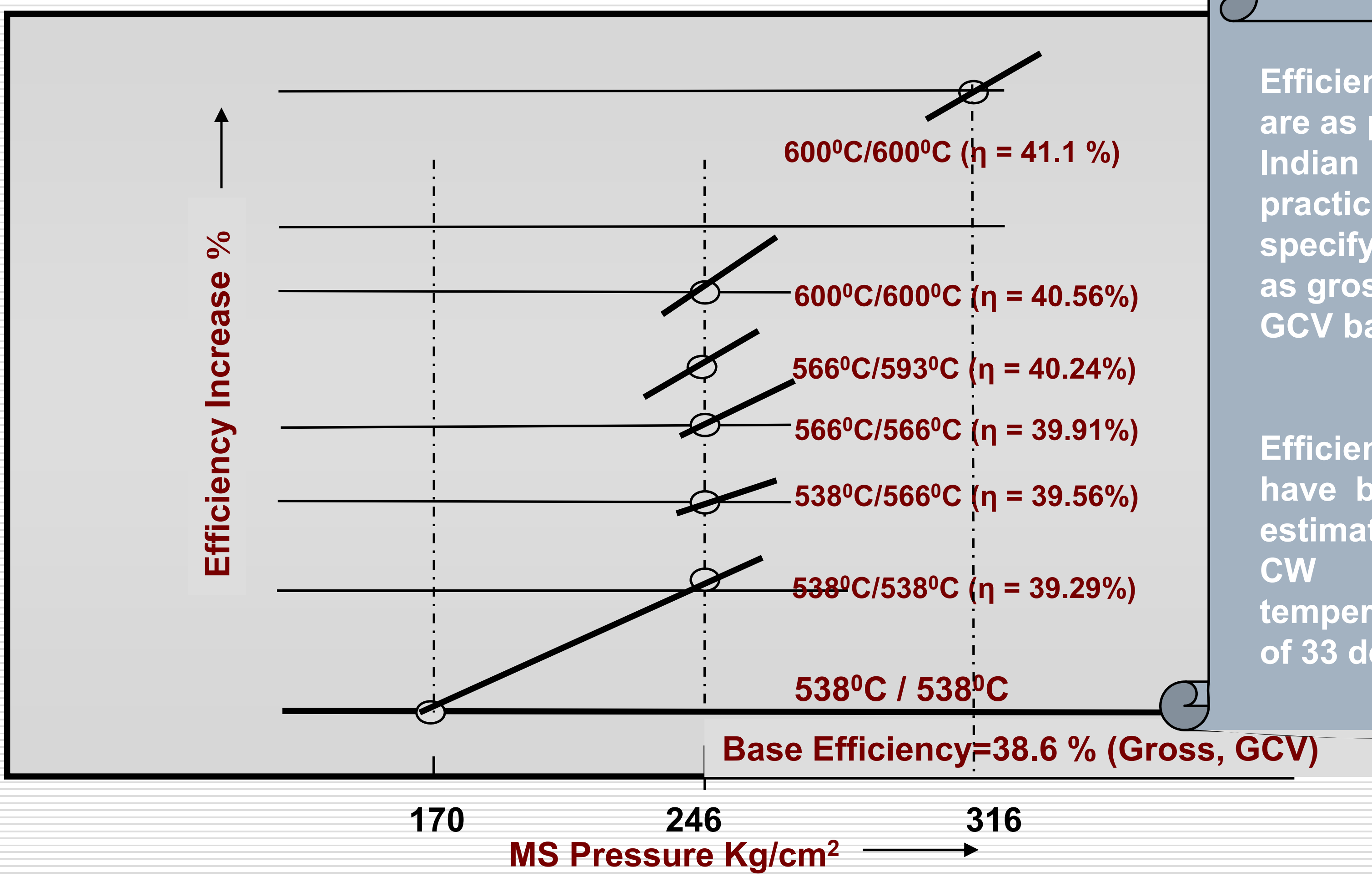






Supercritical / Ultra-supercritical

Super Critical Technology will improve efficiency

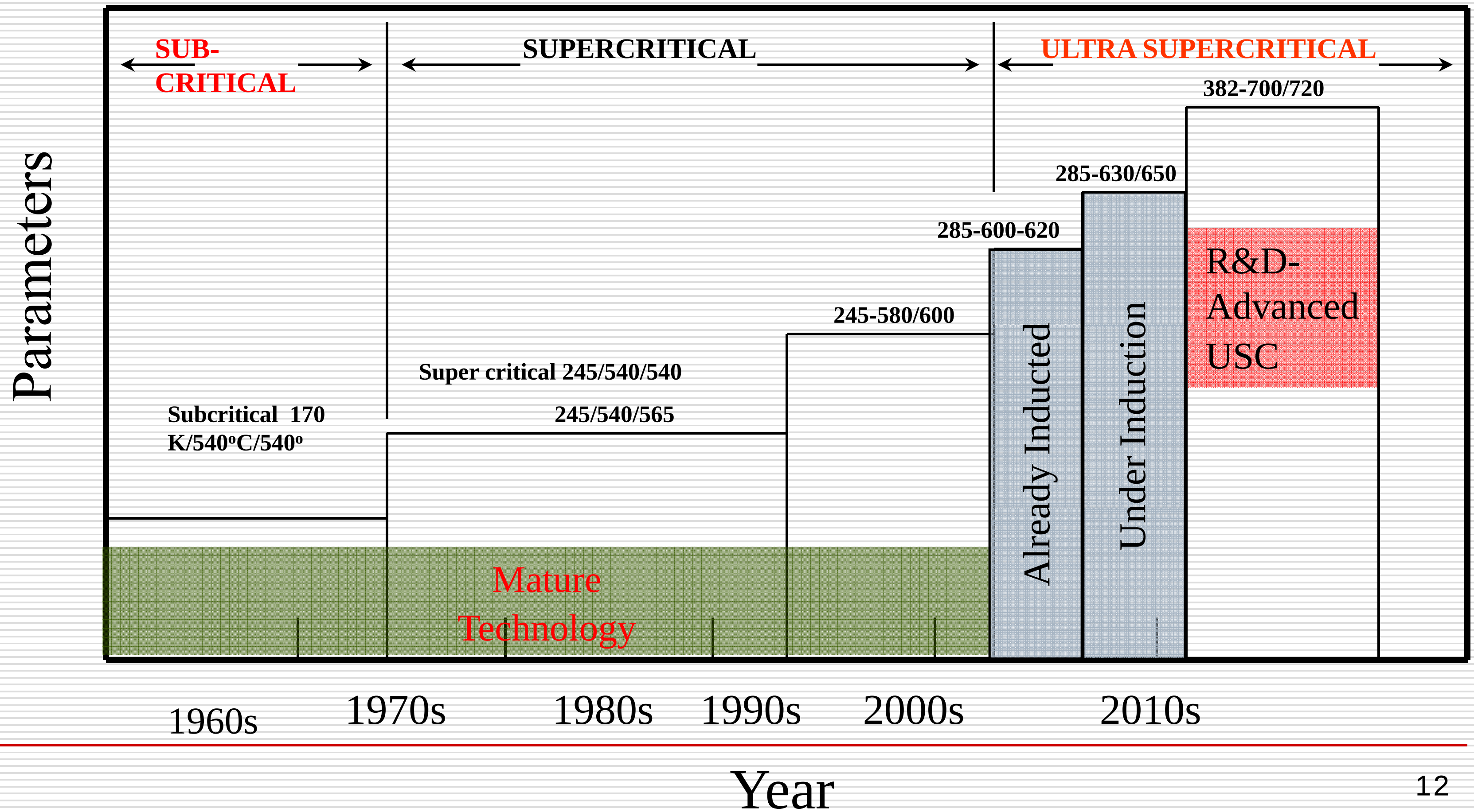


Efficiencies are as per Indian practice of specifying it as gross on GCV basis.

Efficiencies have been estimated for CW temperature of 33 deg C

Supercritical Technology is mature and Ultra-supercritical Technology is being inducted and developed

International Scenario of Supercritical Technology



NTPC is adopting Super Critical Technology

Supercritical Technology in NTPC

NTPC adopted supercritical technology for unit size over 500 MW in steps as under:

- *PLANTS UNDER CONSTRUCTION (with steam parameters of 247 kg/cm2/545^{0}C MS/ 568^{0}C RH)*
  - *3 x 660 MW Sipat STPP Stage-I*
  - *3 x 660 MW Barh STPP*
- *UPCOMING PLANTS*
  - *3 x 660 MW North Karanpura*
  - *2 x 660 Barh-II with advanced steam parameters of 247 kg/cm^{2}/565oC MS/ 593oC RH.*
  - *Higher size Integrated Mining Supercritical Projects with 800 MW unit size having steam parameter of 256 kg/cm^{2}/568^{o}C/593^{o}C under advanced stage of planning at Darlipali and Lara*

Advantages Of Super Critical Technology

- More Efficient : Lower *Operating Cost and Coal Consumption* Reduction in *auxiliary power consumption*
- Environmental benefits: Lower *Emission of CO_2 and other pollutants*, Lower *ash generation*, lower *land requirement for ash disposal* and
- Better load following Capacity: Suitable for *part load operation and higher load ramping rates*
- Higher Unit Size: Lower operating cost offsets the increased Capital cost only above or equal to 660 MW unit size hence larger unit size are preferred with supercritical parameters
- In case of constraint in installing larger size units, 500 MW plants are being designed with steam parameter of 170 ksc/540^{o}C/565^{o}C

Efficiency, CO_2 Reduction and Coal consumption for Different steam parameters

Steam parameter	Efficiency	CO_2 Emission Kg/MWhr	Sp. Coal Consumption Kg / MWhr
170/537/537	38.6%	853	675
247/537/565	39.56%	832	659
247/565/593	40.24%	818	648

Induction of Higher Size Units

Number of units in the range of 800 to 1000 MW installed worldwide are tabulated below :-

USA	Russia	Japan	Germany	Ukraine	Uzbekistan	South Korea	China
35	19	21	5	2	1	3	3

Total Units = 89 **Coal Fired = 54**

- Matured technology operating for last 20 to 30 years
- Main steam pressure in the range of 240-250 Kg/cm2
- Units built in 1970s have MS/RH temperature of 540/540 or 540/565 deg C
- Units built in late 1990s have MS/RH temperature of 566/593 or 593/593
- Ultra super critical units are mainly in Japan and Germany
- There are certain ultra supercritical units of less than 800 MW capacity
- Work on ultra supercritical parameters for pressure over 300 Kg/cm2 and temperature over 700 Deg C is in progress under THERMIE program in Europe and Project Set 66 C in USA

Recent Advancements in Gas Turbine Technology

Turbine Inlet Temperature

The turbine inlet temperatures have increased from 1100 deg.C in recent past to 1450 deg.C with more sophisticated gas path cooling which is the main reason for the increase in combined cycle efficiency by almost 10-12 % points, from 46% to 60%

Compressor

- *Pressure ratios increased from 11 to almost 30*
- *Aerodynamic blade design introduced*

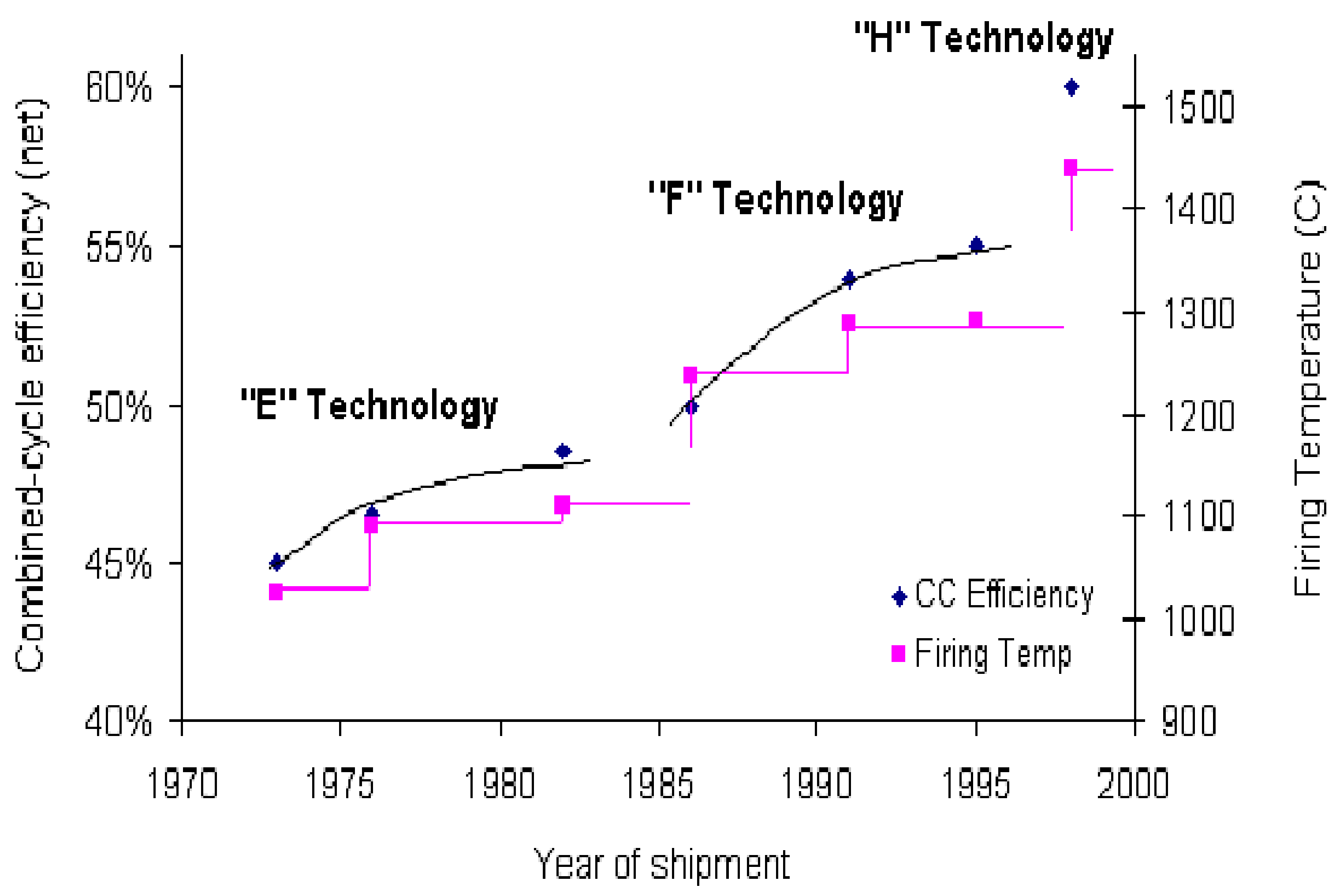
Blading

- *Serpentine and turbulated cooling passage in blades*
- *Film cooling design of blades*
- *Use of Thermal Barrier Coatings*

Indian Status:

- *Most of the recent installations are with E class turbine with net efficiency ranging from 48 to 50% on LHV basis*
- *Latest machines used are Advanced F and FA class Turbines with Net efficiency up-to 56% on LHV basis*

Gas Turbine Inlet Temp. Trends

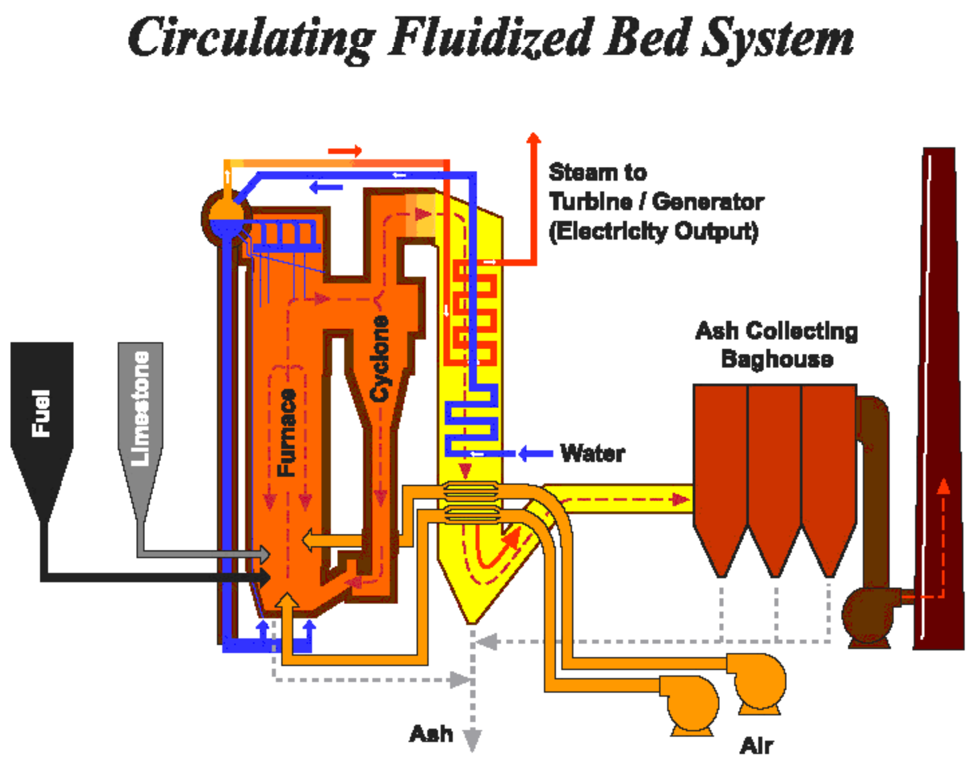


	PARAMETER	CONVENTIONAL	ADVANCE CLASS
1.	Gas Turbine Output	120 – 160 MW	250 – 334 MW
2.	CC Output (1/1)	185 – 240 MW	390 – 484 MW
3.	Compression ratio	10 - 14	16 - 30
4.	Gas Turbine TIT	950 – 1150 ^{0} C	1250 - 1430 ^{0} C
5.	GT Exhaust Temp.	450 – 570 ^{0} C	600 – 650 ^{0} C
4.	SC Efficiency (Gas)	31 – 34 %	34 – 37 %
5.	CC Efficiency (Gas)	46 – 53 %	54 – 60 %
6.	No. of Press. Levels in Bottoming Cycle	1 or 2	3
7.	HP Steam Press.	40 – 90 bar	100 – 160 bar
8.	HP Steam Temp.	430 – 530 ^{0} C	530 – 565 ^{0} C
9.	Reheat Steam Cycle	NO	YES
10.	No. of GTs / ST	1 - 3	1 or 2
11.	Fuels	NG/ Distillate/ Ash Bearing	NG/ Distillate
12.	NOx Emission with DLN (@ 15% O_2).	25 – 50 ppm	09 – 25 ppm

CFBC

CFBC is environment friendly technology for smaller size unit

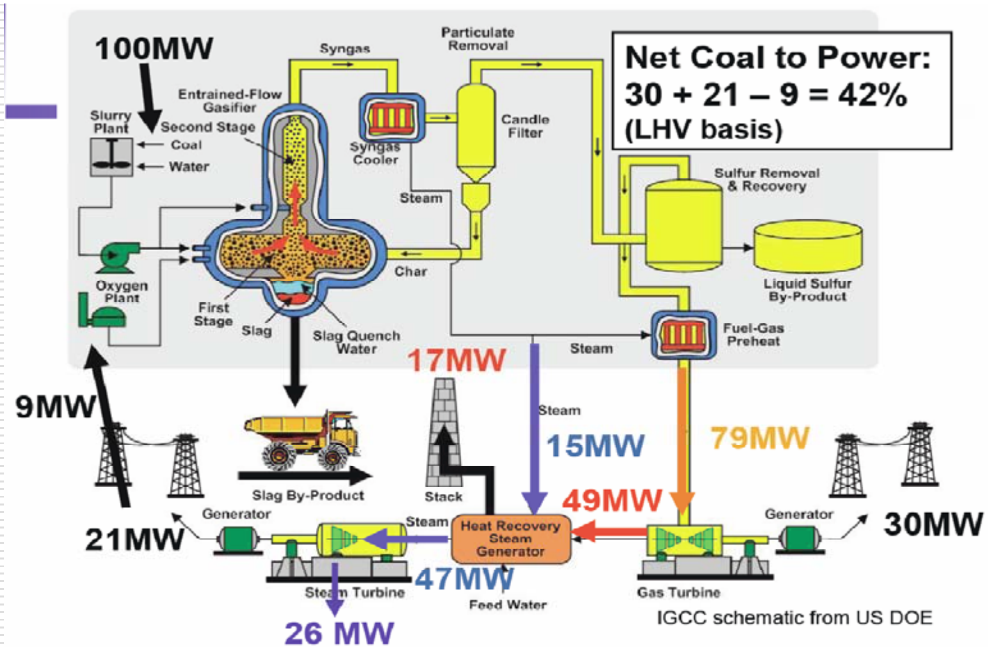
- ***Fuel is burnt in a bed of granular solids in suspension.***
- ***It can burn low-grade fuels like washery-rejects, biomass etc.***
- ***In bed Sulfur Capture - capable of achieving more than 95% removal of SO_2***
- ***Typically slightly less efficient than the pulverized coal fired boilers***
- ***Only few plants above 250 MW in operation***
- ***Number of vendors is limited***
- ***Largest unit in India 125 MW***
- ***Lower NOx emission***



CFBC will become cost effective for more stringent environmental norm

IGCC

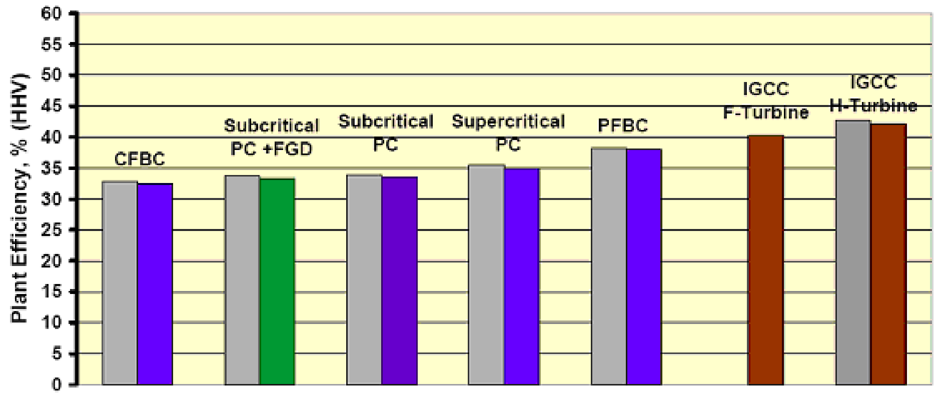
IGCC offers opportunity to utilize coal in high efficiency combined cycle



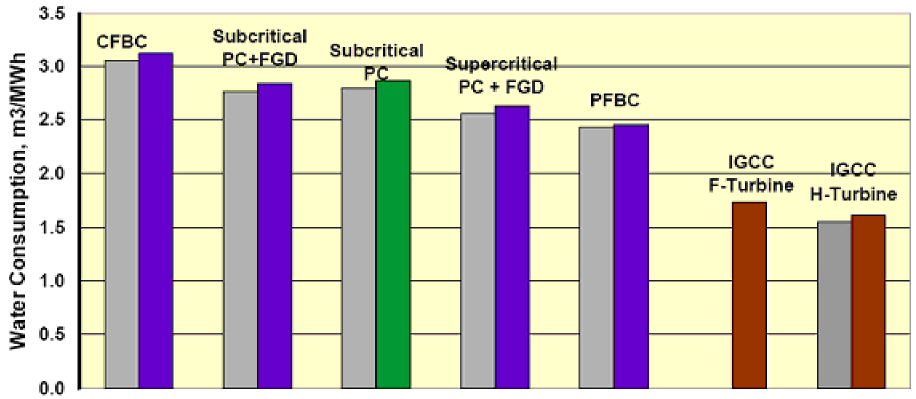
- *IGCC is gasification of coal and then its use in combined cycle*
- *Due to higher efficiency, suitability for carbon capture and ease of capturing other pollutant IGCC is promising technology.*
- *With high natural gas prices and pressure for reduction of emission of green house gases, IGCC with carbon capture seem to be a favorable option for fossil fuel based power generation*

IGCC is expected to give higher efficiency and lower water consumption than PC pant

Plant Efficiencies for 2x 500MW Plant



Water Consumption for 2x500MW Plant



Solid bars-Washed coal, coloured bar – ROM coal

IGCC has major advantage in reducing pollutant like SO_X and heavy metal
Because of lower volume of syngas carbon capture is economical

IGCC for Indian Coal needs Indian Coal Specific Development

- *Selection and design of gasifier is coal dependent*
  - *Entrained bed gasifier suitable for low ash coal*
  - *Moving bed gasifier has not been used in IGCC. It is not good at handling fines in coal. Tar and phenol are difficult to handle*
  - *Fluidized bed gasifiers are limited to pilot scale. It is suitable for high ash coal but present gasifier operate at low temperature*
- *Penalty for cold gas cleanup is very high for air blown fluidized bed gasifier*
  - *Hot gas particulate cleaning, desulphurization and alkali cleaning is key to utilizing full potential of IGCC*
  - *These technology are still under development around the world*
- *Gas turbine combustor for low Btu gas from atmospheric fluidized bed gasifier are not available*

High temperature Fluidized bed gasifier, Hot gas cleanup and Low BTU Combustor are required for Indian Coal based IGCC

IGCC for Indian Coal needs Indian Coal Specific Development

- *Utilization of high ash Indian coal offers special challenges, Co-operation in the field of following will be useful:*
  - *Coal Gasification*
    - *High ash Indian coal require use of fluidized bed gasifiers which need to be developed. Gasifiers experience worldwide (Entrained bed and Moving bed) may not be very much relevant for Indian coal*
  - *Hot gas cleanup system*
    - *Hot gas clean-up system is vital for higher IGCC efficiencies, which is essential to establish its commercial viability*
    - *Hot gas clean-up system, as suited for high ash Indian coal needs to be developed*
  - *Gas Turbine for low CV Syngas*
    - *Air-blown Fluidized bed gasifiers for Indian coals produce comparatively low CV gas*
    - *Development of appropriate gas turbine to utilize low CV syngas is essential for commercial viability of IGCC which otherwise has to depend on oxygen blown gasifiers/air-enrichment, making it expansive*

Pollutant Control Technology

Characteristics of Indian Coals

SO_x

- Reduction techniques required

NO_x

- Low NOx burners adequate for international limits

Particulates

- Very difficult (S + Na_2O) approx 0.7%

At Present There is no SOx Emission Norm in India

Emission from Existing Power Plants Utilizing Low Sulphur Coal – 1200 to 1500 mg/Nm3

No norms in India to limit SO_2 emission from Power Plants

- *Control through dispersion by Stack Height*

World Bank limits SO_2 emissions from a plant

- *0.1 tons per day per MW*
- *Max. 500 tons per day from a single plant*

CPCB NORMS FOR STACK HEIGHT OF THERMAL POWER PLANTS	
Unit Capacity	**Stack Height H (m)**
Less than 200/210 MW	$H = 14(Q)^{0.3}$, where Q is the emission rate of SO_2 in kg/hr.
200/210 MW or less than 500 MW	220
500 MW and above	275

NORMS FOR SO_2 EMISSION IN DIFFERENT COUNTRIES	
Japan	180 mg/ Nm^3
China	400 mg/ Nm^3
USA	738 mg/ Nm^3
Europe	200 mg/ Nm^3

FGD is popular option for post combustion Sulfur removal

FGD uses alkaline substance like lime/lime-stone to neutralize acidic SO_2

Spray-dry Process

- *Concentrated lime (calcium hydroxide) slurry is injected into the flue gas into the spray-dryer vessel, upstream of the ESP.*
- *By-products removed with ash in ESP or Bag Filter.*

Fluid Bed Process

- *Flue gas from the Airheater is carried through a fluidized bed of Lime, reaction products and fly ash particles contained within the vertical reactor tower.*

Ammonia Process

- *Similar to Limestone gypsum process, except that aqueous Ammonia is used to scrub SO2*

Wet Lime / Limestone Gypsum process

- *Lime / Limestone slurry is sprayed into the Flue Gas in the absorber (after ESP) where water dissolves the SO2 and forms H2SO3.*

NTPC is adopting the Wet Limestone – Gypsum Technology for high sulphur coal at the upcoming Bongaigaon Power Plant

At Present There is no NOx Emission Norm in India

No norms in India to limit NOx emission from Power Plants

- *NTPC follows norm of 260 g/GJ (~ 750 mg/Nm^3)*

World Bank limits NOx emissions from a plant

- *450 mg/Nm^3*
- *1500 mg/Nm^3 (Vdaf 10%)*

NORMS FOR NOx EMISSION IN DIFFERENT COUNTRIES	
Japan	185 mg/ Nm^3
China	450-1100mg/ Nm^3
USA	411 mg/ Nm^3
Europe	200 mg/ Nm^3

International Norm may be met using Combustion Control Technique

NOx in PC Plant may be controlled during combustion or removed after combustion

NOx Formation

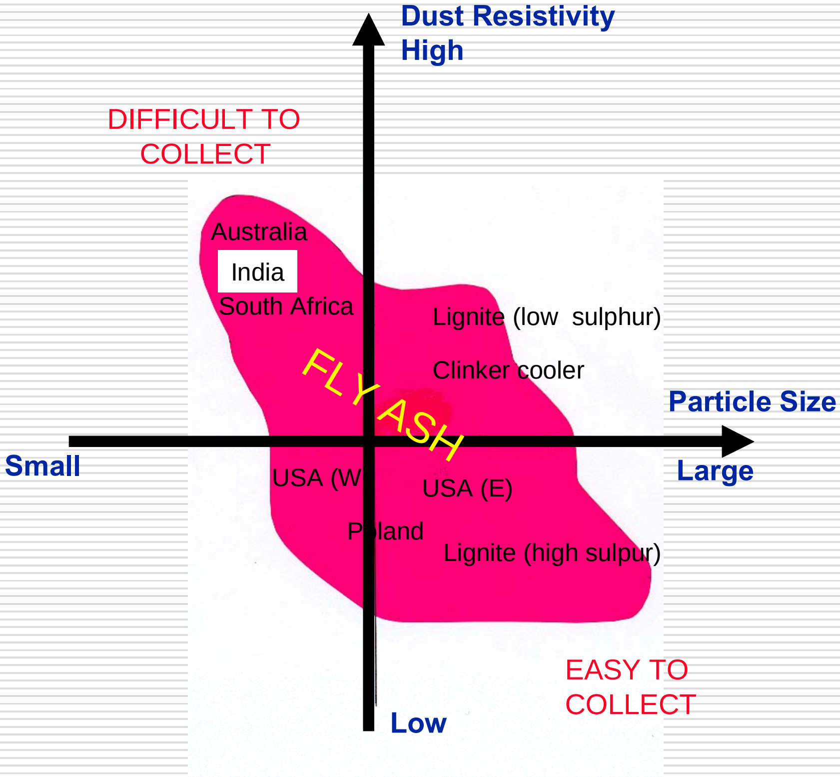
- *Thermal NOx*
  - *Result of high temperature in Combustion Zone*
  - *Primary cause of NOx formation in NG CC Plant*
- *Fuel NOx*
  - *Oxidization of nitrogen in fuel to NOx*
  - *Not dependent on flame temperature*
  - *Depends on oxygen concentration in volatile combustion zone*
  - *Primary Mechanism in Coal Fired Plant*

NOx Control

- *Combustion Control*
  - *It involves Staged air injection*
  - *Leading to volatile combustion in oxygen deficit zone*
  - *Tertiary air for char combustion in oxygen rich*
  - *Combustion control meets present NTPC norm*
  - *Even more stringent norm may be met by combustion control*
- *Post Combustion Treatment*
  - *Selective Catalytic Reduction (SCR)*
  - *Selective Non Catalytic Reduction (SNCR)*

ESP is used for Particulate Matter (PM) Emission Control

- *Present norm – 150 mg/Nm³*
- *NTPC follows norm of 50 mg/Nm³*
- *NTPC norm in line with international norm*
- *But Emission from old plant is much higher*
- *Because of low alkali and sulfur content of Indian coal, flue gas conditioning offers opportunity of Flue Gas Conditioning (FGC)*
- *NH_3, SO_3 and dual FGC is being considered to improve the performance of old ESPs*



Bag Filter can reduce PM emission below 25 mg/NM³
It can remove particle below 10 micron size

ESP Performance Enhancement

S.No.	ESP Performance Enhancement Technology	Method in Brief	Result / Data	Potential / Limitation
1.	Flue gas Humidification	Spraying water in to the gas stream	Reduction of 20-25%	Chances of water mixing with ash and solidifying inside ESP.
2.	Sodium conditioning	Mixing of sodium sulphate with coal	Emission reduction to 120 mg/Nm^3.	Associated corrosion problems of Equipment/structure.
3.	Ammonia conditioning of Flue Gas	Spraying ammonia into flue gas	Encouraging results with reduction in emissions to less than 100 mg/Nm3.	The method has High potential for adoption in ESPs. No associated problems.
4.	Dual FGC system with NH3 + SO3	Spraying NH3 & SO3 in to flue gas Suited for high flue gas temperatures of 150 DegC	Encouraging results with reduction in emissions to less than 100 mg/Nm^3.	The method has High potential for adoption in ESPs with high flue gas temperatures. No associated problems.
5.	Skew Gas flow	By skewing the gas flow inside ESP. Even distribution of ash across the entire collecting electrode.	Efficiency reduction claimed only by 20%. Specialized technology with few vendors.	Limitation of reduction by 20%. No firm guarantees by vendor.

High Concentration Ash Slurry Disposal

- **Slurry Concentration : 55%~65% by wt instead of 25%**
- **Disposal area required is less by 50%**
- **Lower water Consumption**
- **Power requirement is less by 30 to 40%**
- **Transportation of thick slurry to disposal area by positive displacement pump**

Plant Layout Designs

- **Reducing the plant areas by optimization layout combining different off-site facilities**
- **Common control room for balance of plant i.e. water treatment, ash handling and coal handling**
- **Reducing the TG hall span, 32.0m for 500 MW and 36.0m for 660 MW. The operating floor level has been lowered to 16.5m for 500 MW and 17.0 m for 660 MW.**
- **Central control room for all the units has been located in the service building adjacent to the TG hall.**
- **Semi-open buildings are envisaged for the off-site facilities e.g. DM plant etc.**

Conclusion

- *Coal will continue to play major role in meeting the power demand of India*
- *Environmental regulations are going to be stricter in coming years*
- *Deregulation of power market will require induction of Advanced Technologies at competitive price in future projects*
- *Super critical/ Ultra-supercritical PC fired plants at present appear to be the most commercially used and viable option for power generation using coal.*
- *With development of higher size CFBC boilers, this technology is expected to be more popular in future .*
- *With present level of efficiency and capital cost requirements IGCC may not be very attractive.*
- *IGCC will become viable for more stringent environmental norms and also when water consumption becomes a major issue*
- *Development of IGCC should be perused toward improving efficiency and reliability.*

Thank You!