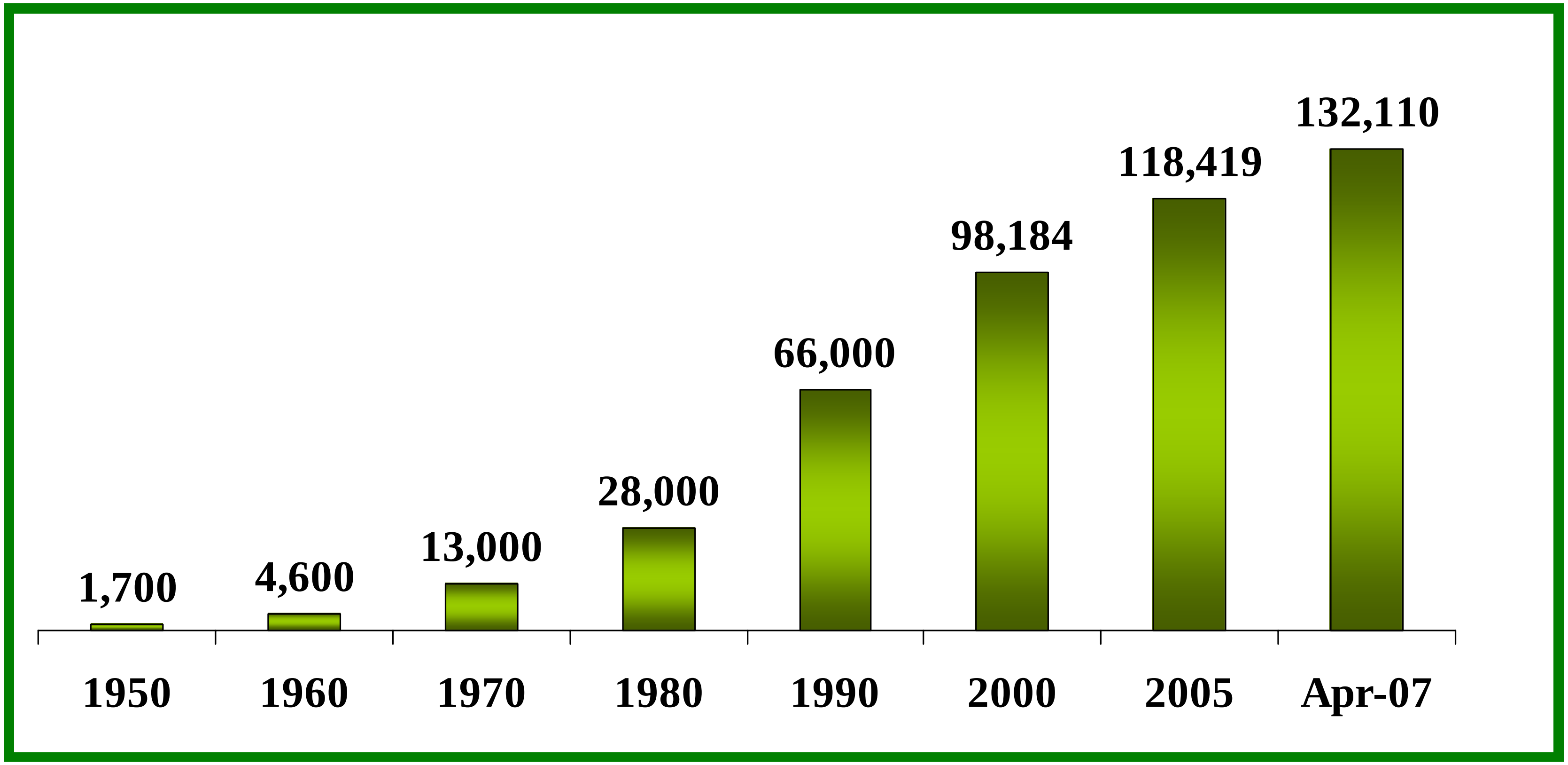
Challenges of Investing in Cleaner Coal
-Indian Perspective

D. K Jain

Executive Director (Engineering), NTPC Ltd., India

India's Progress in Generation Capacity



Generating Capacity needs substantial enhancement to raise living standard

Present Electricity Generation Mix

Generating Capacity (MW) (As on Apr 2007)		
Thermal	85,575	65 %
Hydro	34,653	26 %
Nuclear	4,120	3 %
Renewable	7,760	6 %
TOTAL	132,110*	100 %

Thermal : Fuel Mix (MW)		
Coal	70,682	82.7%
Gas	13,691	15.9%
Oil	1,202	1.4%
Thermal	85,575	100.0%

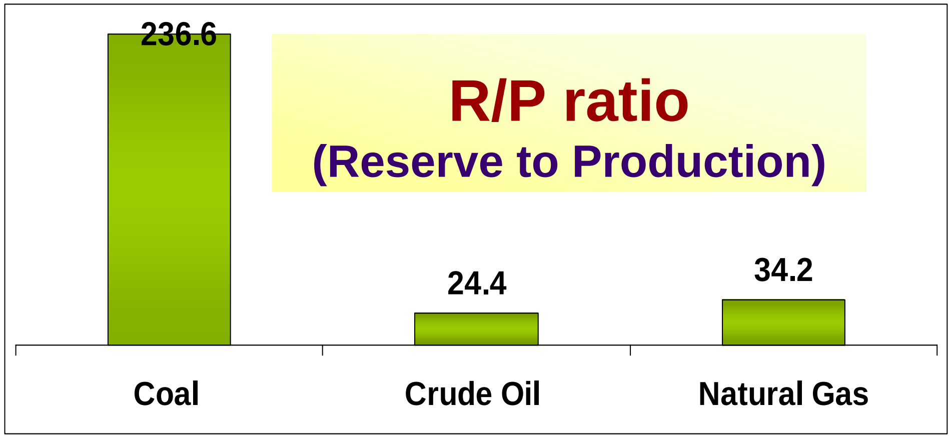
Coal is main-stay of Indian power sector

Coal has Highest Resource Potential

Indian Fuel Resource Scenario*

	Reserves	Production
Coal (proved) MT	95,866	405.2
Crude oil (MT)	786	32.2
Natural Gas(BCM)	1101	32.2

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	**148,700MW**
Present Installed	**34,653MW**

Coal will remain main-stay of Indian power sector in near future
Nuclear technology needs to be developed as long term option

* Ministry of Coal, GOI and Ministry of Petroleum, GOI **Central Electricity Authority, GOI @NPCIL, India

Evolution of Unit Size and Efficiency for Coal Based Plants in India

Period	1950s	1960s	1970s	1977	1983	Uder Constrn.
Unit Size	30 MW to 50 MW	60 MW to 100 MW	110 MW to 120 MW	200 MW to 250 MW	500 MW	660 MW
Turb Inlet Pressure / Temp	60 ata 480^0 C	70 to 90 ata 490 to 535^0 C	130 ata 535^0 C	130 ata 537^0 C	170 ata 537^0 C	247 ata 537^0 C
Reheat Temp.	No Reheat	No Reheat	535^0 C	537^0 C	537^0 C	565^0 C
Turbine Cycle Heat rate (kCal/kW-hr)	2470	2370	2060 to 2190	1965	1945	1900
Gross efficiency (%)	29	30.5	33 to 35	37.2	37.6	38.5

NTPC is adopting Super Critical Technology

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

- *PLANTS UNDER CONSTRUCTION*
  - *3 x 660 MW Sipat STPP Stage-I*
  - *3 x 660 MW Barh STPP Stage-I*
- *UPCOMING PLANTS*
  - *3 x 660 MW North Karanpura*
  - *2 x 660 Barh STPP Stage-II*
  - *Supercritical Projects with 800 MW unit size having steam parameter of 247 kg/cm^2/565^{o}C/593^{o}C under advanced stage of development*

Recent Improvement in Efficiency in above 500 MW Units

	500 MW Old	500 MW New	660 MW (under construction)	660 MW New
Technology	Sub-Critical	Sub-Critical	Super-Critical	Super-Critical
HPT Inlet Pr (kg/cm^2)	170	170	247	247
HPT Inlet Temp (C)	537	537	537	565
IPT Inlet Temp (C)	537	565	565	593
Turbine Cycle Heat Rate (Kcal/kW-hr)	1945	1930	1900	1850

•Adoption of higher parameter made possible due to economic benefit of CDM Mechanism.

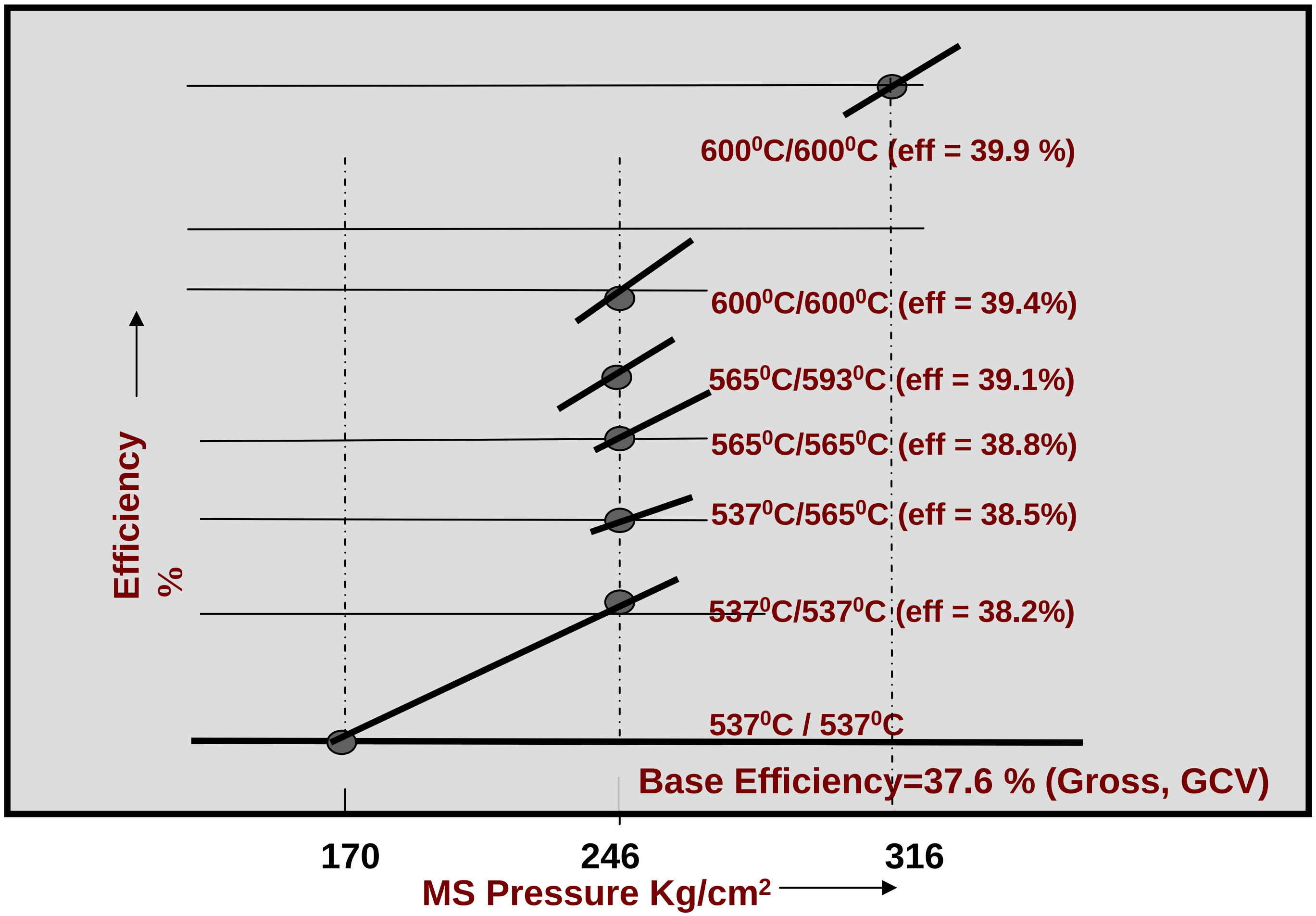
Comparison of Indian Coal with Other Coals

	Australia	China	S Africa	Indian Coal (Dadri)	INDONESIA		
					Type A	Type B	Type C
Total Moisture (AR) %	9	10.0	8	12	14 max	20 max	12-25
Inherent Moisture (AD) %	2-4	2-4	2.0-3.5	9	10 max	12 typical	10-18
Ash Content (AD) %	15	15.0	15.0	**38**	12 max	8 max	7-8
Volatile Matter (AD) %	23-30	25-32	23-28	24	39-45	38-44	30-42
Sulphur (AD) %	0.7	0.7	0.7	0.5	0.9-1.0	0.7 max	0.5-0.6
Fixed Carbon(AD) %	45 approx	40-45		29			25
Gross Calorific Value , Kcal/kg (AD) %	6700	6800	6600	**3692**	6200-6400	5800-6500	5400-6200
HGI	50	55	50	66	35-45	40-55	45-65
Ash Fusion Temperature (C)				+1400	1250 1300 1350	1250 1300 1350	1150 1200 1250

Difficulties associated with Indian Coal w.r.t PC fired plant and other technologies

- PC Plant
  - High ash content along with high quartz content requires design of boiler with lower gas velocity in order to minimize erosion.
  - Larger Furnace Required due to lower burnout rate and lower radiation heat transfer due to high ash content.
  - High inlet dust burden and High Resistively of Ash requires larger ESP.
  - Low CV associated with high ash content requires higher capacity for coal handling, fuel preparation and firing system, and ash handling system
- IGCC
  - High ash coal with high ash fusion temperature is not suitable for gasification in proven entrained bed gasifiers
  - Moderate Reactivity of Indian coal gives lower carbon conversion in existing fluidized bed gasifier
  - High ash content with high abrasive index is likely to creates erosion problem in syngas cooling equipment.
  - Particulate removal system also need to be designed for high dust burden in Syngas

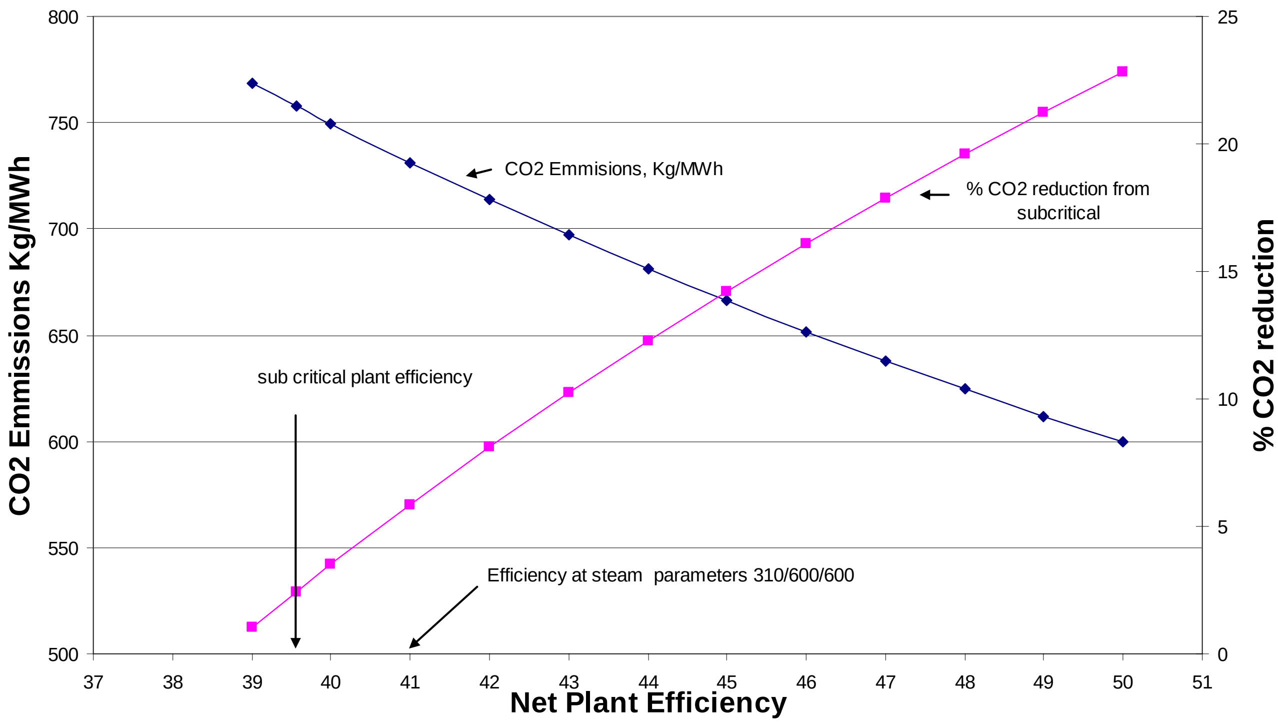
Super Critical Technology will improve efficiency



Efficiency figures corresponds to boiler efficiency of 85% on GCV basis

Increasing Efficiency will Reduce CO_2 emission

Based on Barh Coal (3300 Kcal/Kg, 31.37 % Carbon)

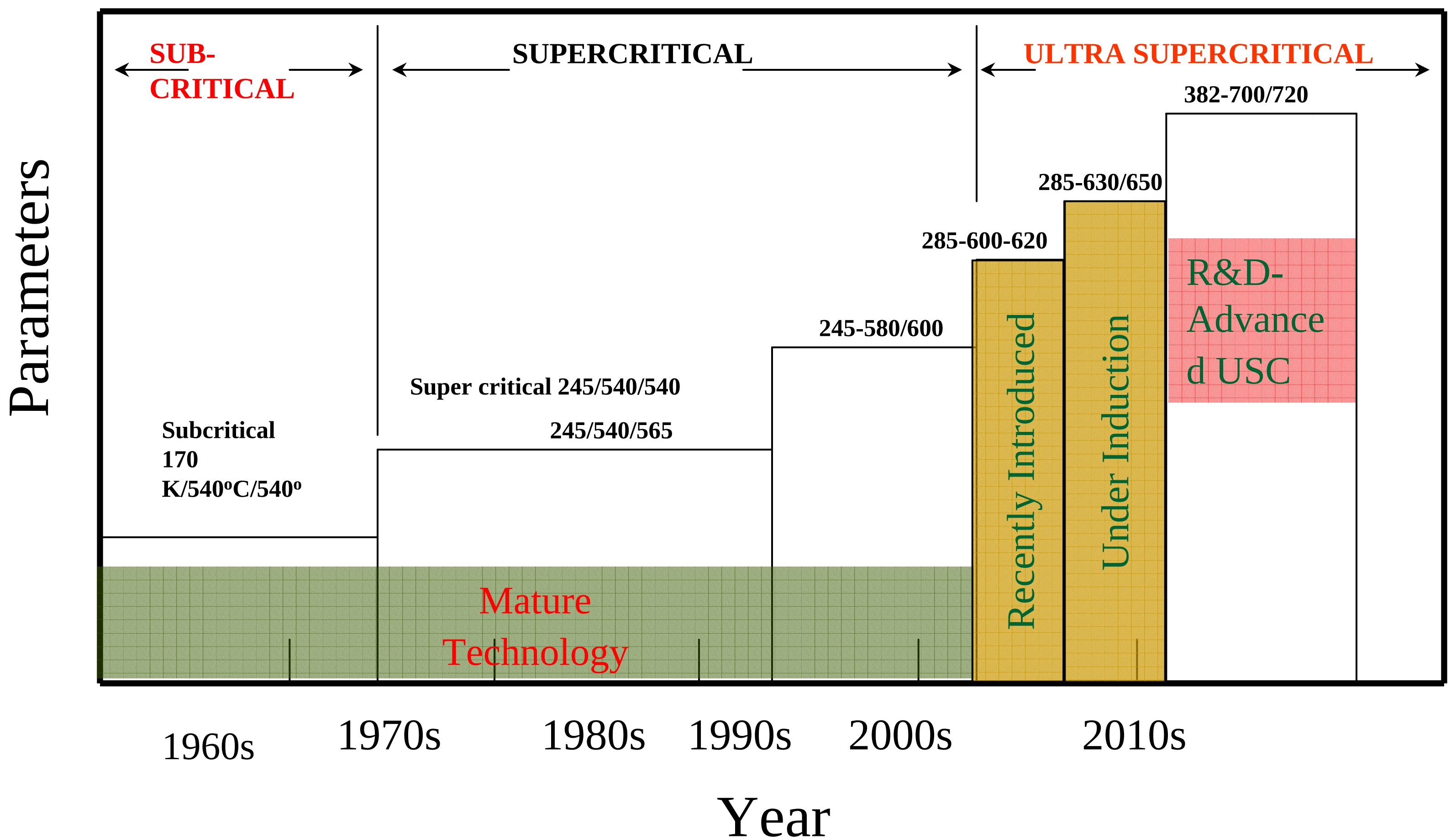


Unit Size for India is limited due to type of coal

- Deciding Factors:
  - Furnace Size for Indian Coals
  - Experience of various manufacturers for large size furnace
- Present Scenario:
  - Indian coal - Operational experience for 500 MW and design experience for 660MW
  - The furnace plan area for 800 MW and 1000 MW size units for Indian coal - of the order of 415 m^2 and 500 m^2 respectively
  - Large size boilers that manufacturers have experience of 400-450 m2 size furnaces for bituminous coal
  - 800 MW size may be the ultimate size with Indian coal at present.

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

International Scenario of Supercritical Technology

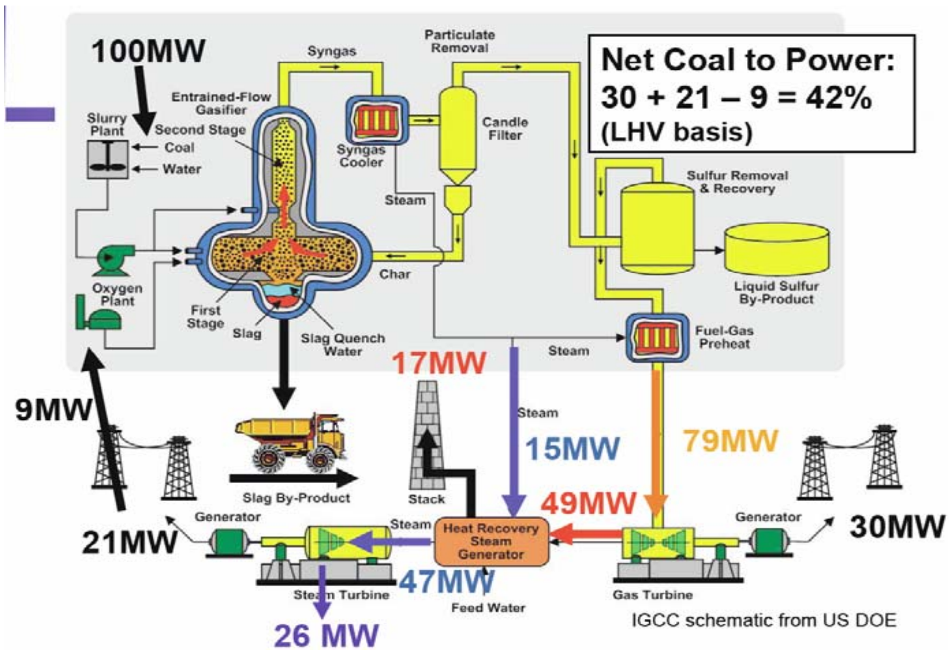


Ultra Super-Critical: Design need to be modified to reduce the incremental cost associated with high steam parameter – 650 ^{o}C and 700 ^{o}C

- Use of better and hence costly material is unavoidable as steam temperature is raised. At steam temperature above 650^{o}C costly Austenitic Steel will be required for MS, RH Pipes and Steam Turbine
- At present, with the commercially available non-austenitic steels, we can go upto 620C
- For economic viability of high efficiency power plants, we need ferritic steels with high strengths at temperatures up to 650C to minimize use of austenitic and nickel based super alloys
- Innovative designs are being developed to reduce the length of MS & RH pipes.
- Turbine is also being redesigned to reduce quantum of high temperature material
- Reducing the incremental cost associated with high temperature will improve the techno economics of higher parameters

•High temperature corrosion for Indian Coal needs to be investigated
•Effect of high erosive Indian coal on new materials needs to be investigated
•Increased Environmental Benefit like enhancement in CDM benefits will provide incentive to this technology

Internationally, IGCC is seen as opportunity to utilize coal in high efficiency combined cycle



- *IGCC is gasification of coal and then its use in combined cycle*
- *Due to higher projected 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*

Major International IGCC Plants

Project/ Location	**Combustion Turbine**	**Gasification Technology**	**Net Output MW**	**Start-Up Date**
Wabash River, IN	GE 7 FA	Global E-Gas (formerly Destec)	262	Oct 1995
Tampa Electric, FLorida	GE 7 F	Texaco	250	Sept 1996
Demkolec Buggenum Netherlands	Siemens V 94.2	Shell	253	Jan 1994
ELCOGAS Puertollano Spain	Siemens V 94.3	Krupp-Uhde Prenflo	310	Dec 1997

New IGCC Projects in USA

Project	American Electric Power	Southern & Orlando	Excelsior and Mesaba	Cinergy
Rating	1200 MW	285 MW	530 MW	500 to 800 MW
Gasifier	GE/Texaco	KBR	Conco / E-Gas	GE/Texaco
Gasifier Type	Entrained Flow	Transport	Entrained Flow	Entrained Flow
Gasifying Medium	Oxygen	Air	Oxygen	Oxygen

Start Up date of Projects is 2010

IGCC – Indian Experience in Fertilizer Sector

Plant	Commissioning date	Technology	Fuel
Ramagundam	Commissioned 1980 Closed 1999	Kopper-Tozek (Entrained Bed)	Coal
Talcher	Commissioned: 1980 Closed: 1999	Kopper-Tozek (Entrained Bed)	Coal
Neyveli	Commissioned: 1963 Closed: 1979	Winkler	Lignite
Bharuch	Commissioned: 1982 Expansion: 1976	Texaco (Now GE)	Vacuum Residue

•Above gasifier were based on internationally available technology

•None of the coal and lignite based gasifier were successful with high ash Indian coal and they have been decommissioned

NTPC experience IGCC – Study-1 (In collaboration with USAID)

- Scope of Study
  - Selection of suitable gasification technology for high-ash Indian coal
  - Selection of configuration for IGCC plant
  - Site-specific feasibility of 100 MW plant
- Outcome of the Study
  - Preliminary study results ruled out entrained bed gasifier for Indian coal
  - Carbon conversion efficiency in pilot gasifiers of GTI and KBR was below 90%. But higher conversion efficiency has been predicted for commercial scale gasifiers
  - For SASOL LURGI, GTI and KBR gasifiers, IGCC plant net efficiency was predicted to be in the range of 31-33% (HHV basis)
  - Oxygen-enriched air blown operation recommended for GTI and KBR gasifier to attain desired calorific value for Syn-gas
  - Capital cost 1.6 time of that of conventional PC plant
  - Further coal testing recommended before proceeding for demonstration plant
  - For 500 MW plant, net efficiency, on HHV basis, is expected to be around 37-40% with advanced class Gas Turbine and other technology advancement.

NTPC experience IGCC – Study-2 (indigenous technology)

- Scope of Study
  - Evaluation of Performance of different size pilot gasifiers with Indian coal
  - Optimization of operating parameters of gasifiers
  - Evaluation of scale up strategy
  - Feasibility study for 100 MW IGCC plant
- Outcome of Study
  - Carbon conversion efficiency around 90% for a large gasifiers
  - Cold gas efficiency around 68-70%
  - Net plant, HHV basis, efficiency 32%
  - Capital cost >1.6 times that of conventional PC plant

IGCC For High Ash Indian Coal: Lower Than Expected Efficiency

Parameter	500 MW Sub Critical	660 MW Super Critical	100 MW IGCC (Feasibility Study)	500 MW IGCC (Expected)
Gross efficiency (Typical)	37.6	38.5	37 to 40%	40 to 43%
Auxiliary Power	5-6%	5-6%	13-20%	13-20%
Net efficiency (Typical)	35.3	36.2	32 to 33 %	35 to 37 %
Capital Cost (Per MW)	Rs 4.5 to 5.5 Cr (US$1.10-1.40 mn)	Rs 4.6 to 6.0 Cr (US$1.15-1.50 mn)	Rs 8–10 Cr (US$2-2.5 mn)	Rs 7–9 Crores (US$1.75-2.25 mn)

Capital Cost High due to cost of development, additional systems etc.

Comparison of Indian IGCC with international IGCC

Plant	100 MW Indian IGCC (Air blown)	Tampa***, Florida (Oxygen blown)	Wabas, Indiana (Oxygen blown)	Buggenum Netherlands (Oxygen blown)
Gasifier	U-Gas /BHEL	Texaco	E-Gas	Shell
GT	GE 6FA	GE 7FA	GE 7FA	V 94.2
Cold gas efficiency	68-70%	72.5%*	71.3%*	75-83%**
Syngas GCV kCal/NM^3	1000-1200	2200	2400-2500	
Carbon Conversion	85 to 92%	96*	>99%	>99**
Net on GCV Efficiency	32-33%	35.4*/39**	38.3*/39.7**	40.5**

* USDOE or other site ** Nexant Phase-A Report *** Climate in Florida is closer to India

Adoption of IGCC: Techno-economic barriers

- Based on available technology for Indian Coal
  - Carbon conversion is low
  - Cold Gas efficiency is low
  - Plant Efficiency lower than PC Plant
  - Oxygen enriched air may be required to meet the CV requirement of GT
  - Cleaning of gas carrying large amount of highly abrasive particulate matter
  - 80 to 100% increase in capital cost wrt to conventional plant
  - Other aspects wrt typical Indian coal – erosion and availability

Biggest challenge – High Investment Cost and high Cost of Generation

IGCC for Indian Coal needs Indian Coal Specific Development

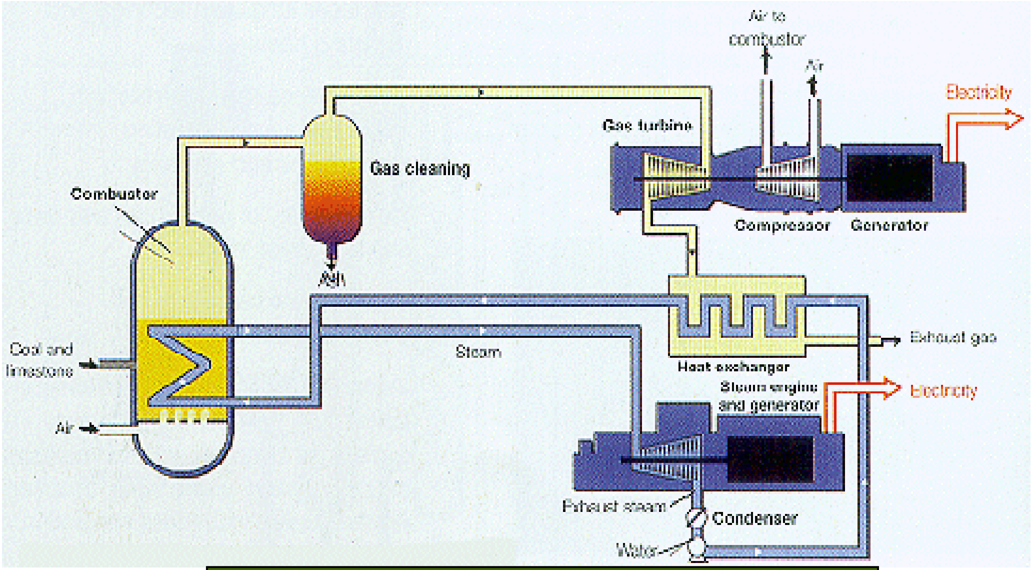
- *Selection and design of gasifier is coal dependent*
  - *Entrained bed gasifier suitable for low ash and low moisture coal*
  - *Moving bed gasifier has not been used in IGCC. It is not good at handling fines in coal. Tar and phenol are difficult to handle*
  - *Fluidized bed gasifiers are limited to pilot scale. It is suitable for high ash coal but present gasifiers are designed for high reactive coal*
- *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 are to be developed and tested for low Btu syngas from air blown fluidized bed gasifier. Alternatively enriched air operation may be required.*

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

Pressurized Fluidized Bed Combustor

Advantage

- Uses coal in high eff. CC
- PFBC is a fluidized bed boiler operating at high pressure. Work is also extracted by expanding Flue Gas in a Gas Turbine
- High pr. reduces boiler size
- Combustion efficiency of PFBC is better than AFBC
- Ca/S ratio of 1.1 for 90% sulfur removal efficiency
- A part of energy is used in combined cycle
- Heat transfer is improved hence thermal load (MW_t/m^2) also improves many times
- SPM: 10 to 25 mg/NM^3
- NOx – 80 to 400 mg/NM^3 for 775 to 900 C bed temperature

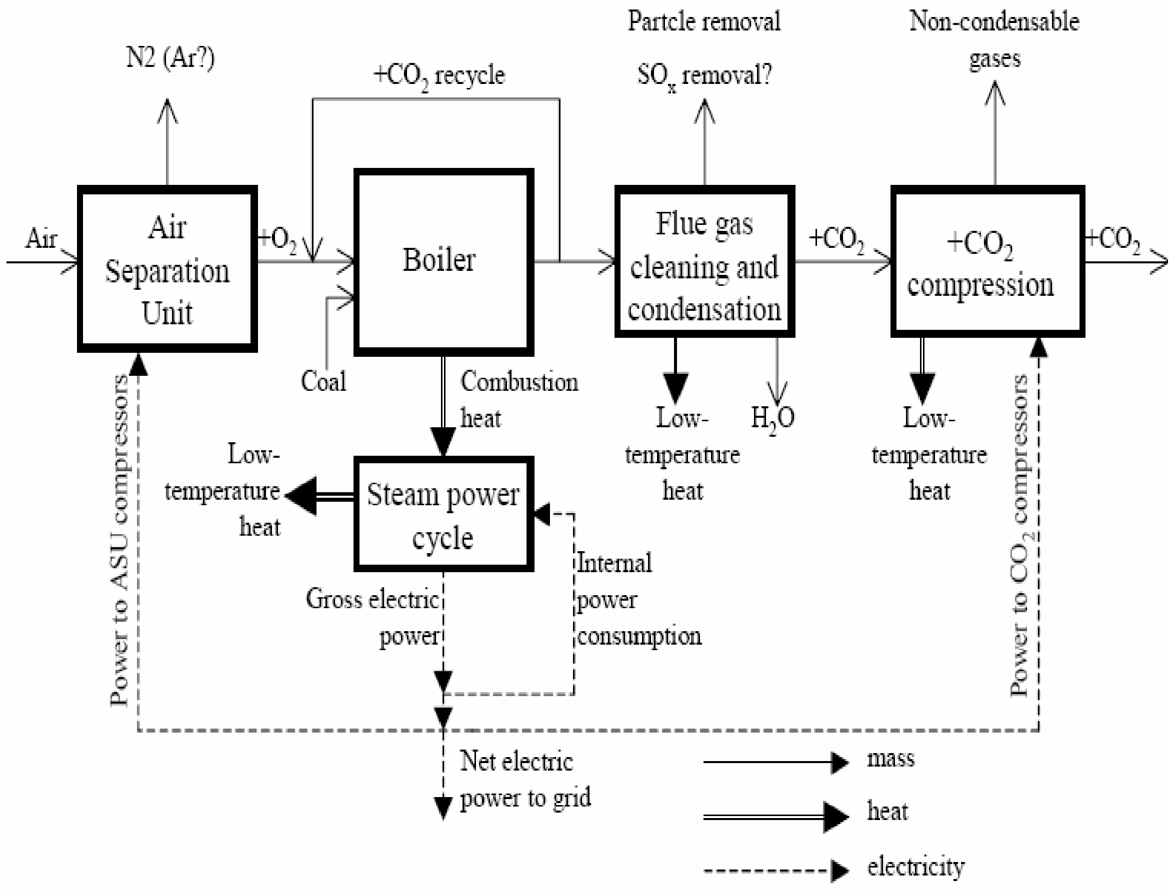


Challenges

- Technology not mature hence reliability low
- Inlet temperature of gas turbine limited by gas cleaning. Hence, major part of the energy is utilized in Rankine Cycle
- Need to develop high temp gas cleaning technology
- Technology not available commercially

Oxy-Fuel Combustion For Carbon Capture

- Oxy fuel combustion is use of mixture of oxygen and recycled CO_2 in conventional power plant
- Almost pure oxygen with two third of total flue gas as recycled gas will be used in Pulverized Coal fired plant to keep the flame temperature same as conventional plant
- Thus flue gas is almost pure CO_2 and hence ready for sequestration
- Control of oxygen injection point will help in NOx control also



Technology in very early stages of development

Adoption of Clean Coal Technology: Conclusions

- High Efficiency PC fired plant and IGCC are the two competing clean coal technologies at present.
- For Indian Coals, the PC fired plants with high cycle parameters are more efficient than the IGCC with current technology.
- Adoption of higher parameters in super critical plants is the means for further efficiency improvement.
- As we move to higher steam parameters for supercritical plants, the economic benefit, accruing due to lower fuel cost associated with higher plant efficiency, does not compensate for the increased capital cost.
- To take advantage of the environmental benefits of higher cycle parameters without jeopardizing affordability of power, the long term strategy is to reduce the cost of material suitable for high steam parameters.
- However, in the short term, there is a need for providing adequate incentives for adoption of higher steam parameters. This will provide near to medium term solution for making electric power available at an affordable cost, and with environmental consequences within acceptable limits.
- IGCC technology needs to be developed in the identified areas to make it suitable for Indian coals. However, suitable mechanism are required to be placed to encourage higher technological and financial investment in this development.

Thank You!