# TECHNOLOGIES AND POLICIES TO MITIGATE ATMOSPHERIC POLLUTION FROM THERMAL POWER PLANTS IN INDIA*

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**SYNOPSIS**

Fossil fuels based thermal power generation dominates the power generation scenario in India. This gives rise to increase in local pollution through fly ash, $SO_X$, and $NO_X$, and global pollution through $CO_2$, the green house gas causing global warming. The solution to mitigate the effect of this pollution lies in adoption of advanced power generation technologies (having higher fuel to electric power conversion efficiency) for fossil fuels – natural gas/oil as well as coal. The combined cycle power generation technology for premium fuels like natural gas and oil has already reached around 58% efficiency. This is likely to reach plus 60% in next few years. For coal fired power stations, the supercritical steam cycle technology is proven in the advanced countries and has already been adopted even by China. The ultra-supercritical steam cycle technology and Integrated Gasification Combined Cycle (IGCC) technologies are presently in commercial demonstration stage in advanced countries. This paper will present the status of all these technologies world-wide.

To mitigate the effect of pollutants from thermal power stations, India will have to adopt these high efficiency advanced technologies. Initially, their capital cost will definitely be high leading to higher cost of generation. But we should be prepared to spend this extra cost if we want to have cleaner atmosphere in India, and also want to help the international efforts in mitigating effects of global warming due to $CO_2$ emissions.

The introduction of advanced technologies for mitigating environment pollution cannot be achieved without policy interventions by the Government. Some of these are –defining medium-term and long-term environment policy with respect to $SO_x$, $NO_x$ and $CO_2$ emissions, defining norms of minimum generation efficiency for future thermal power stations of different capacity ratings with different fuels, internalisation of environment costs, and allowing higher selling price to the power generators (both public-sector and private-sector) in the initial stages.

## 1.0 INTRODUCTION

Electric power is the prime mover of economic development of a country. Thus to meet its development needs, India has increased its installed generation capacity from a mere 1330 MW at the time of independence to 106,216 MW by March 2003. But these achievements have not kept pace with the growth in demand. There are still peaking shortages of 12.2% and energy deficit of 8.8%. Considering this, the Government of India has very prudently set a target of 215,804 MW power generation capacities by March 2012 (Refer Table 1.1). This will require a capacity addition of 109,588 MW in next nine years. If achieved, this will definitely bring in zero deficits in power by 2012 and the country will be able to provide power on demand.

Table 1.1 India's perspective plan for electric power

| Sl.No. | Power Generation | Thermal (Coal and Lignite) (MW) | NG/LNG/Diesel (MW) | Nuclear (MW) | Hydro (MW) | Total (MW) |
|---|---|---|---|---|---|---|
| 1 | Installed Capacity as on March 2003 | 63,977 | NG:11,459 | 2,720 | 26,884 | 106,216 |
| 2 | Addition Capacity | 50,513 | 18,790 | 9,380 | 30,905 | 109,588 |

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| | | | | | |
|---|---|---|---|---|---|
| | on March 2012 | | | | |
| 3 | Total Capacity as on March 2012 | 114,490 | 31,425 | 12,100 57,789 | 215,804 |

Thus the thermal (coal + NG/LNG/Diesel) power by the next nine years will be about 68% of total capacity. All these additions are going to increase the atmospheric pollution due to fly ash, $SO_X$, $NO_X$ and $CO_2$.

The technologies currently used for coal based thermal power generation is conventional steam cycle with sub-critical steam parameters and combined cycles for NG/LNG/Naphtha. A need is felt for introducing advanced technologies such as super-critical, ultra supercritical steam system, PFBC based combined cycles, and integrated gasification combined cycles (IGCC) for coal as fuel, and combined cycle with advance class gas turbines for NG/LNG as fuel. However there are apprehensions about higher cost, and lack of design and operating experience in the country for these technologies. But we have to 'move on' in view of making our environment sustainable, and at the same time producing power at affordable cost from fossil fuels available within the country and thus maintaining energy security.

## 2.0 PREVALENT ENVIRONMENT STANDARDS

The emission standards for thermal power plants in India are being enforced based on Environment (Protection) Act, 1986 of Government of India and it's amendments from time to time. A summary of emission norms for coal and gas based thermal power plants is given in Tables 2.1 and 2.2

Table 2.1 Environmental standards for coal & gas based power plants

| Capacity | Pollutant | Emission limit |
|---|---|---|
| Coal based thermal plants | | |
| Below 210 MW | Particulate matter (PM) | 350 mg/$Nm^3$ |
| 210 MW & above | | 150 mg/$Nm^3$ |
| 500 MW & above | | 50 mg/$Nm^3$ |
| Gas based thermal plants | | |
| 400 MW & above | $NO_X$(V/V at 15% excess oxygen) | 50 PPM for natural gas; 100 PPM for naphtha |
| Below 400 MW & upto 100 MW | | 75 PPM for natural gas; 100 PPM for naphtha |
| Below 100 MW | | 100 PPM for naphtha/natural gas |
| For conventional boilers | | 100 PPM |

Table 2.2 Stack height requirement for $SO_2$ control

| Power Generation Capacity | Stock Height (Metre) |
|---|---|
| Less than 200/210 $MW_e$ | $H = 14 (Q)^{0.3}$ where Q is emission rate of $SO_2$ in kg/hr, H = Stack height in metres |
| 200/210 $MW_e$ or less than 500 $MW_e$ | 200 |
| 500 $MW_e$ and above | 275 (+ Space provision for FGD systems in future) |

The norms for 500 MW and above coal based power plant being practised is 40 to 50 mg/$Nm^3$ and space is provided in the plant layout for super thermal power stations for installation of flue gas desulphurisation (FGD) system. But FGD is not installed, as it is not required for low sulphur Indian coals while considering $SO_X$ emission from individual chimney.

In addition to the above emission standards, the selection of a site for a new power plant has to maintain the local ambient air quality as given in Table 2.3

Table 2.3 Ambient air quality standard

| Category | Conc. ? $g/m^3$ | | | |
|---|---|---|---|---|
| | SPM | $SO_2$ | CO | $NO_X$ |
| Industrial and mixed-use | 500 | 120 | 5000 | 120 |
| Residential and rural | 200 | 80 | 2000 | 80 |
| Sensitive | 100 | 30 | 1000 | 30 |

Table 2.4 World bank norms for new projects

| Existing Air Quality | Recommendation |
|---|---|
| $SO_X$ > 100 ? $g/m^3$ | No project |
| $SO_X$ = 100 ? $g/m^3$ | Polluted area, max. from a project 100 t/day |
| $SO_X$ < 50 ? $g/m^3$ | Unpolluted area, max. from a project 500 t/day |

However the norms for $SO_X$ are even stricter for selection of sites for World Bank funded projects (refe r Table 2.4). For example, if SOX level is higher than 100 ? $g/m^3$, no project with further $SO_X$ emission can be set up; if $SO_X$ level is 100 ? $g/m^3$, it is called polluted area and maximum emission from a project should not exceed 100 t/day; and if $SO_X$ is less than 50 ? $g/m^3$, it is called unpolluted area, but the $SO_X$ emission from a project should not exceed 500 t/day. The stipulation for $NO_X$ emission is that it's emission should not exceed 260 gram s of $NO_X$ per giga joule of heat input.

In view of the above, it may be seen that improved environment norms are linked to financing and are being enforced by international financial institutions and not by the policies/laws of land.

## 3.0 TECHNOLOGIES IN USE

Till 1969, the thermal power generation plants in India were in the capacity range of 30 to 60 MW having moving grade stoker or pulverised coal firing and conventional steam cycle with steam parameters of 90 ata and 540$^0$C, and no reheat (refer Table 3.1). This gave heat rates above 2200 kCal/kWh. Over the years, there have been gradual rise in unit ratings to 210 MW, 250 MW, and 500 MW with pulverised coal firing. The heat rate has thus been improved to a level of 1950 kCal/kWh for 250 MW & 500 MW units. The earlier heat rate of 1970 for a 210 MW unit has also been improved recently by 39 kCal/kWh[?] through T4 blading instead of the earlier T2 type blading, and implemented for Khaperkheda TPS extension units 3&4 of MSEB. Introduction of T4 blade profil es for future 250 MW & 500 MW units will also improve upon the existing heat rates. However, as far as sub-critical steam cycle is concerned, the plant efficiency has reached virtually its peak. Further improvement will be possible only by adopting super -critical steam parameters and other advanced cycles based on pressurised fluidised bed combustion & gasification.

Table 3.1 Power generation steam cycles with different unit ratings

| Unit rating | Cycle parameters | Turbine Heat Rate (kCal / kWh) | *Gross Plant Heat Rate (kCal / kWh) |
|---|---|---|---|
| 70 MW | 90 ata, 540$^0$C, Non -Reheat | 2200 | 2588 |
| 120/130 MW | 130 ata, 540$^0$C/540$^0$C, Reheat | 1980 | 2330 |
| 210 MW | 150 ata, 540$^0$C/540$^0$C, Reheat (with motor driven BFP) | 1970 | 2318 |
| 250 MW | 150 ata, 540$^0$C/540$^0$C, Reheat (with motor driven BFP) | 1950 | 2294 |
| 500 MW | 170 ata, 540$^0$C/540$^0$C, Reheat (with steam driven BFP) | 1950 | 2294 |

[?] BHEL Engineering Newsletter, Vol.25, No. 3, September 2002

* Considering boiler efficiency as 85%. For Net heat rate, auxiliary power consumption also to be considered.

While using the premium fuels like natural gas and naphtha, the contemporary design of gas turbines (refer Table 3.2) has been adopted in the country and the combined cycle power generation efficiency to the level of 53% has been achieved. Now we have to look further to achieve higher efficiencies.

Table 3.2 Contemporary gas turbines

| S. No | MODEL | ISO RATING (MW) | HEAT RATE (kCal/kWh) | EFFICIENCY% | EXHAUST FLOW (kg/sec) | GT INLET TEMP. ($^0$C) | CCPP EFFICIENCY % |
|---|---|---|---|---|---|---|---|
| 1 | V94.2 | 157.0 | 2492 | 34.5 | 508.8 | 1060 | 51.7 |
| 2 | PG9171(E) | 123.4 | 2545 | 33.8 | 403.6 | 1124 | 52.7 |
| 3 | GT13E2 | 165.1 | 2406 | 35.7 | 532.0 | 1150 | 53.2 |
| 4 | M701 | 144.1 | 2472 | 34.8 | 440.8 | 1120 | 51.8 |

SOURCE: ISO – DATA GTW HANDBOOK 1999-2000

For atmospheric pollution control, there has been significant progress with respect to control of emissions of particulate matter to the desired levels of 150 mg/Nm$^3$ for most 200/210 MW units, and 40 to 50 mg/Nm$^3$ for 500 units. The emissions from older units, where retrofit of modified ESP has not been done, is high. However there are no mandatory controls desired for $SO_X$ and $NO_X$ as mentioned in section 2. We, in India, are lucky that coal contains less than 0.5% sulphur and the $SO_X$ emissions are within limits. In new plants, low $NO_X$ burners are also being introduced.

## 4.0 ADVANCED TECHNOLOGIES

### 4.1 FDG and deNO$_X$ Systems

Even though the emissions of $SO_X$ from individual stacks, while using low sulphur coals, is within limits, the total amount of emissions of $SO_X$ from super thermal power stations within a small space may lead to overall high concentration of $SO_X$ leading to acid rain. In such cases, removing $SO_X$ by scrubbing of flue gases with lime, the flue gas desulphurisation (FGD) may become necessary. This will lead to increase in capital and operating cost. The literature search suggests that the increase in capital cost will be of the order of 15 to 20% and cost of generation may increase by 10 to 15%.

The FGD technology is fully established in advanced countries for the last two decades, and can be obtained for applications in India whenever required.

The emission of $NO_X$ in the flue gases of pulverised coal fired boilers can be controlled at combustion stage (through low $NO_X$ burners/overfire air) or through a process of selective catalytic reduction (SCR). In this process, the $NO_X$ and $NH_3$ react to form nitrogen and water vapours. The capital cost of SCR system is in the range of US$90 to 100 per kW of the installed capacity. The systems can be designed both for high dust applications (before APH) and low dust applications (after ESP). However there is no experience available in India for any application.

### 4.2 SUPER-CRITICAL STEAM CYCLE

The steam cycle operating at steam pressure above 225.36 ata is called supercritical. At this pressure, the density of water and steam is the same. Thus, there is no need for a boiler drum that separates steam from water. The boiler used for this application is called once-through unit. The rest of the power plant remains the same, except the number of HP/LP heaters chosen to optimise the cycle. The improvement of heat rates while adopting super-critical parameters for Indian ambient conditions is given in figure 4.2.1

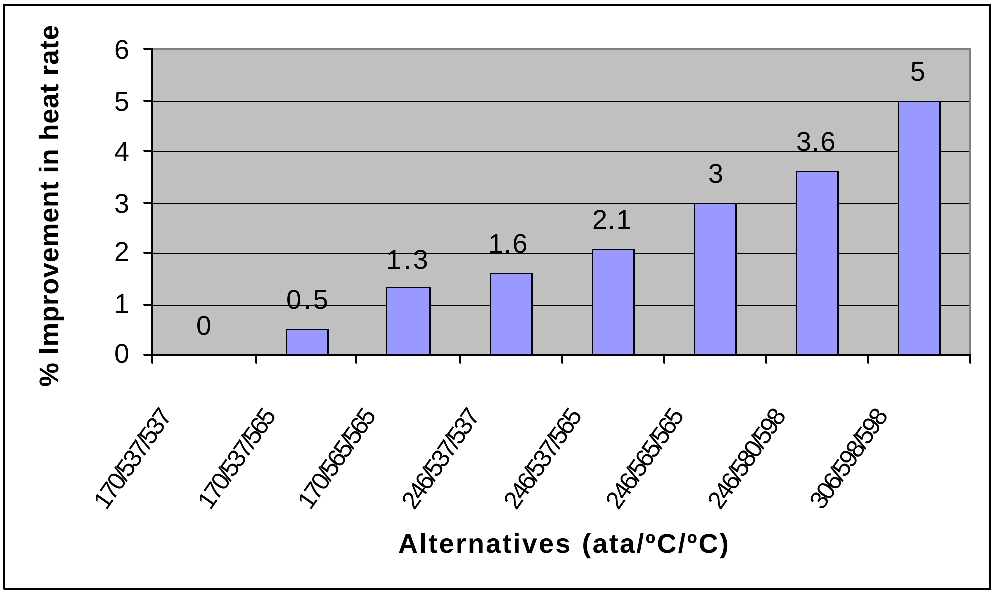



Figure 4.2.1 Improvement in heat rate with steam parameters.

It may be seen from this figure that compared to the base case of steam parameters (170 ata/537 $^0$C/537$^0$C), the improvement of the heat rate[??] will be 2.1% when steam parameters adopted are 246 ata/537 $^0$C/565$^0$C and 5.0% when ultra-supercritical (USC) parameters of 306 ata/598$^0$C/598$^0$C are adopted. For a pithead 3x660 MW supercritical station, the capital cost saving projected in the year 1999 was about 2.5% as compared to 4x500 MW units. In developed countries[???] where the technologies for supercritical power plants are mature, the capital cost per kW is virtually the same as sub-critical plants. Thus, the selection of a subcritical or supercritical unit often depends upon a power producer's experience, and the pressure to reduce fuel consumption (giving benefits of reduction of cost of power generation as well reduced emissions of particulates, $SO_X$, $NO_X$, and $CO_2$).

In terms of operational availability and reliability, EPRI study of supercritical plants operating in USA has confirmed that outage rates are comparable to drum type units, after initial period of learning.

With the commercial introduction of new steel alloys with higher allowable stresses and longer life at elevated temperatures, a number of power plants with USC parameters (above 246 ata with double reheat or 306 ata/598$^0$C/598 $^0$C) have come up in advanced countries like Japan, EU & USA. Based on these successes, researchers continue to improve designs and materials, and it appears that USC plants with main steam parameters of 357 ata/625 $^0$C/625$^0$C will become fully commercial in the next 5 to 10 years.

**4.3 ADVANCE CLASS GAS TURBINES**

With the increase of the cost of premium fuels like natural gas, naphtha and LNG, there is ever-increasing pressure on gas turbine designers and manufacturers for higher and higher efficiency combined cycle systems, to produce power at competitive rates compared to coal fired plants. The improved efficiency obviously leads to reduction in emission of $SO_X$, $NO_X$, and $CO_2$ also.

The introduction of advance class turbines with inlet temperature in the range of 1250 to 1300$^0$C has lead to combined cycle power plant efficiency around 58% (refer Table 4.3.1) A number of plants are in operation throughout the world. However, there are only a few in India (e.g. 2x9FA at Dabhol and 3 nos. 6FA at Kovilkallapal, Peringulam & Dhuvaram respectively).

[??] Presentation by BHEL/BBL on supercritical coal fired power plants to CEA on Oct. 21, 1999.

[???] Joint UNDP/WB ESMAP Technical paper 011 on Technology Assessment of Clean Coal Technologies for China : Electric Power Production, Volume 1, May 2001

Table 4.3.1 Advance class gas turbines

| S. No | MODEL | ISO RATING (MW) | HEATRATE (kCal/kWh) | EFFICIENCY% | EXHAUST FLOW (kg/sec) | GT INLET / EXHAUST TEMP. ($^0$C) | CCPP EFFICIENCY % |
|---|---|---|---|---|---|---|---|
| 1 | V94.3A (S) | 258.0 | 2239 | 38.4 | 634.0 | 1250/567.8 | 57.1 |
| 2 | 9FA | 255.6 | 2331 | 36.9 | 623.6 | 1300/609.4 | 57.1 |
| 3 | GT26 | 265.0 | 2241 | 38.4 | 561.4 | 1280/640.0 | 58.5 |
| 4 | M701F | 270.3 | 2250 | 38.2 | 650.8 | 1300/586.1 | 57.3 |

SOURCE: ISO – DATA GTW HANDBOOK 1999-2000

Further research to improve the efficiency is in progress and gas turbines with gas inlet temperature of 1430$^0$C and combined cycle efficiency of 61% are being ordered now for first of their kind commercial plants in USA.

## 4.4 COAL BASED COMBINED CYCLE SYSTEMS

All approaches for further efficiency improvement or reduction of pollution from coal based power generation leads to thermodynamic cycles including gas turbine in topping cycle and a steam turbine in a bottoming cycle ? the so called combined cycle. However, gas turbines need clean fuel gas or clean flue gas. Therefore, use of coal calls for its conversion to clean combustion products or coal gas at high pressure. Two technologies have been enveloped (a) pressurised fluidised bed combustion & (b) integrated gasification combined cycle.

### 4.4.1 PRESSURISED FLUIDISED BED COMBUSTION (PFBC)

In the PFBC concept, the conventional combustion chamber of the gas turbine is replaced by PFB combustor (bubbling or circulating) and hot gas cleanup system. The combustion products pass through gas turbine and the heat recovery steam generator. The system is thus a combined cycle, and is capable of giving generation efficiency 5 to 6% higher than sub-critical steam-cycle plants. Therefore the system is a strong competitor for USC steam-cycle.

Six commercial PFBC demonstration plants (each less than 100 MW capacity) are in service around the world. The application is generally combined heat & power (CHP). A 360 MW unit based on ABB technology and 250 MW based on Hitachi technology have been commissioned a year back in Japan. The operating experience obtained from these units will have a strong influence on the future of commercial PFBC technology.

In India, only BHEL has done R&D work on pilot scale PFBC and tested combustion characteristics of few coals. Recently they have also tested ceramic candles based hot gas clean-up system. The data generated will be useful for designing a demonstration plant in India.

### 4.4.2 INTEGRATED GASIFICAITON COMBINED CYCLE (IGCC)

Coal gas can be produced by reacting coal with air/steam or oxygen/steam; the former reaction produces low CV gas whereas the later reaction produces medium CV gas. For combined cycle operation, it is economical to adopt pressurised gasification. The hot raw gas from the gasifier is cooled by generating steam through HRSG. This steam is integrated in the combined cycle with the steam produced from HRSG downstream of the gas turbine. Part of the steam produced is used in the gasifier. Thus the cycle is called integrated gasification combined cycle (IGCC).

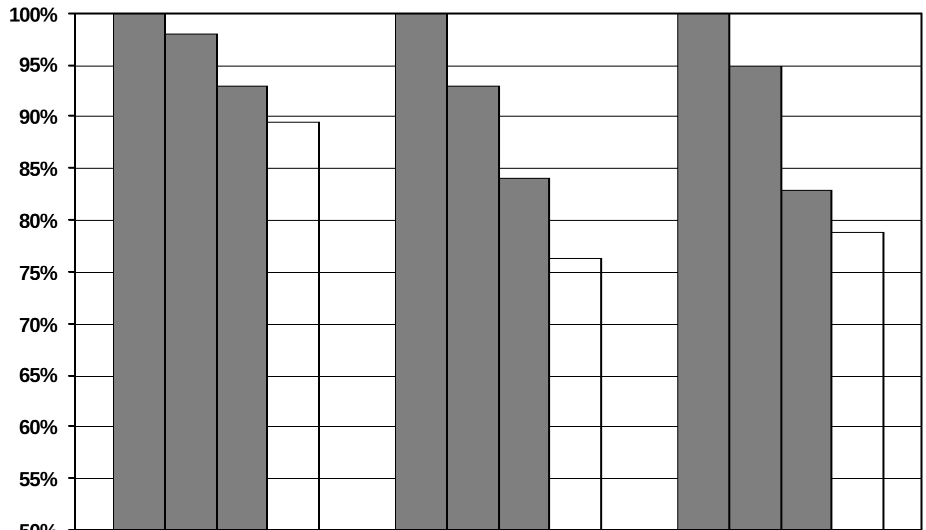
Typically the IGCC efficiency is the product of efficiency of the gasifier (achievable 80%) and the combined cycle efficiency (58% with contemporary gas turbines, as explained in section 4.3), giving a value of 46.4% compared to 40% achievable through USC steam cycle. This will proportionately reduce the $CO_2$ emission. The $SO_X$ emission can be brought down to 40 to 115 mg /$Nm^3$ as the sulphur is removed in the gasification process itself. The $NO_X$ emission has also been reported to levels below 125 mg/$Nm^3$.

A number of commercial demonstration as well as commercial plants, using coal or refinery residues as fuel, have come up all over the world (refer Table 4.4.2.1).

Table 4.4.2.1. IGCC experience in the world

| Project | Process | Start-up | Output | Feed | Power Block |
|---|---|---|---|---|---|
| GSK (Japan) | Texaco | 2001 | 540 MW | VB Tar | 2xGE 9EC |
| Fife Power (Scotland) | BGL | 2000 | 400 MW | Coal/RdF | 2xGE 9FA |
| Shell Pernis (Netherlands) | Shell | 1997 | 120 MW+$H_2$ | Heavy oil | 2xGE 6B |
| Sierra Pacific (1) (Nevada) | KRW | 1998 | 100 MW | Coal | GE 106 F |
| Elcogas (Spain) | Pernflow | 1998 | 300 MW | Coal/coke | KWU V94.3 |
| ISE (Italy) | Texaco | 2000 | 520 MW | Asphalt | 2xKWU V94.3 |
| SARAS (Italy) | Texaco | 2000 | 550 MW | VB Tar | 3xGE 109E |
| Star (Delaware) | Texaco | 1999 | 240 MW | Petcoke | 2xGE 6FA |
| API (Italy) | Texaco | 2000 | 275 MW | VB Tar | ABB 13 E2 |
| Cool Water (California) | Texaco | 1984 | 120 MW | Coal | GE 107E |
| Dow Plaquemine (USA) | Destec | 1986 | 220 MW | Coal | GE 107E |
| Demkolee (Netherlands) | Shell | 1993 | 250 MW | Coal | KWU V94.2 |
| Tampa Electric (Florida) | Texaco | 1996 | 260 MW | Coal | GE 107 FA |
| Texaco-Eldorado (Kansas) | Texaco | 1996 | 40 MW | Petcoke | GE 6B |
| PSI-Wabash (1) (Indiana) | Destec | 1996 | 262 MW | Coal | GE 7FA |
| Schwarze/Pumpe (Germany) | Noell | 1996 | 40 MW | Coal/oil | GE 6B |
| Fife Power (Scotland) | BGL | 1999 | 120 MW | Coal/sldg | GE 106FA |
| Total (France) | Texaco | 2004 | 365 MW | Ref. Residue | ABB |
| EXXON (USA) | Texaco | 1999 | 40 MW | Petcoke | GE 6B |
| EXXON (Singapore) | Texaco | 2000 | 180 MW | Ref. Residue | 2xGE 6FA |
| NPRC (Japan) | Texaco | 2003 | 340 MW | Asphalt | |
| Repsol (Spain) | Texaco | 2004 | 824 MW | Ref. Residue | |
| CITAGO (USA) | Texaco | 2004 | 350 MW | Petcoke | |

The main barriers to widespread adoption of IGCC technologies are (a) high capital cost compared to PC Plant, and (b) demonstration of high availability, at least equal to existing PC Plants. However, the costs are coming down. A recent joint study by Texaco, General Electric, and Praxair has shown that for a 550 MW power block, with the introduction of 9H gas turbine technology with firing temperature in the range of 1400 to 1450$^0$C, the efficiency, capital cost, and cost of generation has significantly improved (refer figure 4.4.2.1.) from year 1994 levels to year 2000 levels.




| | HEAT RATE % | TOT. INST. COST% | COST OF ELEC.% |
|---|---|---|---|
| 1994 9F HEQ | 100% | 100% | 100% |
| 1997 9FA HEQ | 98% | 93% | 95% |
| 1999 9H HEQ Coal | 93% | 84% | 83% |
| 2000 9H HEQ Oil | 90% | 76% | 79% |

Figure 4.4.2.1 Economic impact of IGCC Design Study Improvements

In India, pioneering work has been done on coal based IGCC by BHEL on 6.2 $MW_e$ pilot plant at Trichy, using both pressurised moving bed gasifier and pressurised fluidised bed gasifier (PFBG). Based on this work, design of a 100 MW IGCC demonstration plant with PFBG has been developed. It is learnt that BHEL & NTPC are jointly working for setting up a plant of this rating with partial funding from USAID. Also a techno-economic feasibility study for around 500 MW IGCC plant is being worked out. CSIR has also published in 1992 a feasibility assessment of IGCC for a 500 to 600 MW plant for the primary objective of selecting gasification technology for its application for high ash Indian coals (base case of North Karanpura coal with HHV of 3332 kCal/kg). This study gave the cost comparison as given in table 4.4.2.2.

Table 4.4.2.2. Cost comparison of different IGCC technologies (1989 pricing)

| | IGCC Plant<br>Entrained bed | Fluidised bed | Moving bed | PC Plant<br>Without FGD | With FGD |
|---|---|---|---|---|---|
| Net power output, MW | 564.4 | 496.2 | 577.2 | 585.7 | 549.0 |
| Capital cost ratio | 2.17 | 1.33 | 1.36 | 1.00 | 1.22 |
| Cost of generation ratio | 1.94 | 1.18 | 1.32 | 1.00 | 1.17 |

## 5.0 TECHNOLOGY AND ENVIRONMENT POLICY

Coal is the primary fuel for thermal power generation in India. It gives rise to atmospheric pollution due to particulate matter, $SO_X$, $NO_X$, and $CO_2$. The use of natural gas is also picking up; the only advantage in this case is no particulate matter pollution, and reduced CO2 emission per kWh of power generated. The present environment policy defines primarily for particulate matter control, but gives no strict conformance standards for other gaseous pollutants like $SO_X$, $NO_X$ and $CO_2$. The higher chimney height may disperse $SO_X$ and $NO_X$ in low concentrations over larger area, but does not reduce/eliminate their effects. In addition, the international protocols in future may require limiting emissions of $CO_2$ and $NO_X$, the greenhouse gases (GHGs) leading to global warming.

From the proceedings sections of this paper giving a brief on present environment laws and the status of the technology in the country viz-a-viz the world, it is amply clear that in India we still need to do a lot more to meet the national health requirements as well as the international commitments. It may also be seen that there is a strong linkage between the technology and the emissions from the power plant. The higher efficiency advanced technologies also lead to reduced emissions. Thus there is a need to evolve an integrated policy for technology for thermal power sector and the environmental needs and commitments. A study conducted by Asian Development Bank and Ministry of Environment & Forests, Government of India *, had In fact suggested development of 'Indian Policy on Energy and Environment' as a part of Environment Management Plan of the country. The study had suggested integrated approach to coal mining, cleaning, transportation, power generation, and transmission & distribution.

The integrated policy for technology and environment for thermal power generation should encompass the following action plans:

a) All future coal based thermal power plants of 250 MW and above should be with supercritical steam parameters. Immediately, studies should also be initiated for ultra-supercritical steam parameters and the aim should be to put these plants in next 6 to 7 years.
b) CFBC based plants of 250 MW rating with high sulphur lignite & petcoke, and very high ash coal/washery rejects should be encouraged.
c) Environment (Protection) Amendment Rules, 1997 for use of washed coal for the plants located beyond 1000 km, should be enforced without giving further extension. This will definitely reduce the problems related to particulate emissions and fly ash disposal.
d) All the generating stations should be directed to examine the techno-economic feasibility of using blended coals in a mixture of presently used high ash coal with good quality coal from other mines in India or through import of coal. This can be easily established through generation efficiency (specific fuel consumption) tests on an operating station.
e) Benchmark for introduction of IGCC technology in India should be 7 to 8 years. For this, decision for a 250 to 300 MW commercial demonstration plant should be taken up immediately.
f) Regular energy audit of operating plants for generation efficiency should be made mandatory, and the recommendations for improvements should be implemented. This is possible under the Energy Conservation Act 2001.
g) The new Electricity Tariff Policy (draft being circulated) should suitably reward energy efficiency improvements, through sharing of the benefits by the power generator and the consumer.
h) The coal pricing should be linked to the calorific value of the delivered fuel so that supplier has incentive to improve quality and the power generator gets good and consistent quality.
i) The development of advanced technology for thermal power generation is very closely linked to the environment policy with respect to emissions of particulate matter, $SO_X$, $NO_X$, and $CO_2$. It takes 10 to 15 years for introduction of any new technology. Thus we must have long-term environment policy to guide the development & introduction of new technologies

**6.0 CONCLUSION**

The improvements in energy efficiency for existing stations can be achieved through systematic energy audits and modifying operating practices. This may not require much investment. However, cost of first few new advanced technology plants will definitely be higher than present technology plants. Subsequently, when more and more plants are being installed, the cost will come down. The extra price thus paid initially is worth compared to the cost of health hazards due to pollution from power plants.

* National Programme for Environment Management for Coal-fired Power Generation, Study by Ewbank Preece, July 1994.