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Energy, Electricity & Environment

1·1. Energy Needs

Electric power is one of the most important infrastructure sector of the national economy because electric power is a clean and versatile form of energy. Its demand has been growing faster than other forms of energy. The demand for electricity in the country has been growing at an average growth rate of 7 to 9% and demand-supply gap has widened over the years. Providing reliable and inexpensive electricity is essential for economic development of the country and better standard of living of the people.

Table 1·1 shows relative position of India vis-a-vis other countries in respect of per capita electricity consumption and human development index (HDI).

Table 1·1. Per Capita Electricity Consumption & Human Development Index (HDI)

Country	*kWh*	*HDI*
Canada	18212	0·943
USA	11000	0·939
Australia	11205	0·946
Singapore	8010	0·902
Korea	6632	0·888
Malaysia	4100	0·793
China	2800	0·793
India	612	0·595
Pakistan	479	0·497
Bangladesh	115	0·509
Nepal	63	0·504

Note : Human Development Index (HDI) is a composite index prepared on a scale of 0-1 measured by three key components—longevity, knowledge and income.

It is obvious from above table that India has taken all measures to accelerate the pace of electric power generation

The availability of reliable, affordable and environment friendly energy with appropriate energy security plays a vital role in the economic and social development of our country.

India has abundant coal and hydro resources but limited resources of hydro-carbons and nuclear fuels. India is also rich in non-conventional energy resources like sun, wind, biomass etc. but their exploitation has not so far been very significant. There is substantial import of oil and gas to meet the growing demand of the power, transport, fertilizer and other sectors. Nuclear development has been rather limited in past but the pace of nuclear power development is now expected to be accelerated.

1·2. Demand for Energy

In India almost 79% of electricity is produced from thermal sources, e.g. coal, lignite, oil and gas, about 18% by hydro and the rest by nuclear and renewable sources etc.

Demand for energy may be categorized as follows :

(*a*) **Household.** In rural area mostly wood, coal and bio-mass are used in their primary form. Kerosene oil (a byproduct of mineral oil) is widely used for lighting. In electrified villages, electricity is also used but on a limited scale due to its scarce availability.

(*b*) **Agriculture and Rural Development.** Irrigation pumping and fertilizer production are the main areas of energy consumption. Electricity is the main energy source for underground water pumping. Diesel pumps are also used where electricity is not available. In some states, solar pumps are also being promoted.

The potential for growth of electricity supply for the development of rural areas is increasing at fast pace because the demand for electricity in rural areas not only for household and agriculture but also for development of other rural infrastructure like education, health care, clean drinking water supply, and other civic amenities is growing rapidly.

(*c*) **Industry.** This sector is a major consumer of electricity. The electricity consumption in industries is of the order of 47% of total consumption. Due to an acute shortage of electricity and that too being of poor quality, a large number of industries have their own captive generation.

(*d*) **Transport.** This sector is a major consumer of oil—both diesel and petrol and to some extent electricity by Railways. Despite new oil finds in various parts of the coountry almost 70% of petroleum requirement is imported mostly to meet the transportation needs. Volatility in crude oil prices in the international market has adverse impact on our country's economy. Production of biodiesel through massive plantation of Jatropha and Carcas plants has started. Research is going on for its development on commercial scale so that it can be used in transport and also in agriculture. Mixing ethanol which can be produced within the country with diesel for transportation is another alternative which can be produced from sugarcane, sorghum, maize or other materials such as straw etc.

1·3. Energy Sources

Energy security means "availability of energy at all time at an affordable price in appropriate quality and quantity". Energy is crucial for human civilization. It is vital for economic development. Coal is and will continue to remain the dominant energy fuel.

Table 1·2

Year	*Total Elect Genre-ration (BU)*	*Hydro (BU)*	*Nuclear (BU)*	*Wind (BU)*	*Ther-mal (BU)*	*Coal (MMT) (MMT)*		*Oil (MMT)*		*Natural Gas*	
						Power	*Non-Power*	*Power*	*Non-Power*	*Power*	*Non-Power*
03-04	633	75	18	3	537	318	91	6	113	13	13
06-07	761	100	26	5	630	375	123	6	119	18	15
11-12	1097	179	59	8	851	493	164	8	149	25	22
16-17	1524	226	110	12	1176	656	221	9	192	41	28
21-22	1983	283	206	15	1479	814	299	12	247	58	41
26-27	2866	400	301	19	2146	1133	408	14	320	89	53
31-32	3880	500	441	24	2915	1478	562	17	418	134	73

It is important to know broadly the energy resources situation in the country. Table 1·2 gives estimated growth of coal, oil and natural gas for power and non-power use in next twenty years. Considering the position of reserves in country it appears that only coal and nuclear resources (thorium) are substantial to give energy security partly.

Coal reserves in country are indicated below :

Coal Reserves

Indicated	49,000 MTOE	- 120 BT
Proved	39,000 MTOE	- 96 BT
Inferred	15,000 MTOE	- 37 BT
Mineable	12,500 MTOE	- 30 BT
Extractable lignite	1,200 MTOE- 3	BT

1·3·1. Indigenous Energy Availability

The primary energy resources of India mainly comprise coal, oil, gas, uranium/thorium which are finite and water, sun, air and biomass etc., which are infinite and renewable.

Broadly the scenario of our finite resources is as follows :

(*a*) **Coal.** India has a proven reserve of 75 billion tonnes of non-coking coal against a total reserve of 213 billion tonnes. There is a further 103 billion tonnes of indicated reserves. Some studies indicate that India's exploitable coal resources may not last more than 40-50 years. To meeet country's need of electricity, it may become necessary to import coal. It will therefore be desirable to plan for import of high grade coal from environmental consideration and set up coal based power plants along the sea-coast to reduce inland transportation of coal.

(*b*) **Oil.** The production of crude oil in India is more or less stabilized between 650 to 700 barrels/day. Substantial new finds both in and off shore are quite promising. However our import requirement which is of the order of 70% will continue at this level because of increasing oil demand. The demand projection for oil by 2020 for different sectors of economy by Planning Commission is shown below :

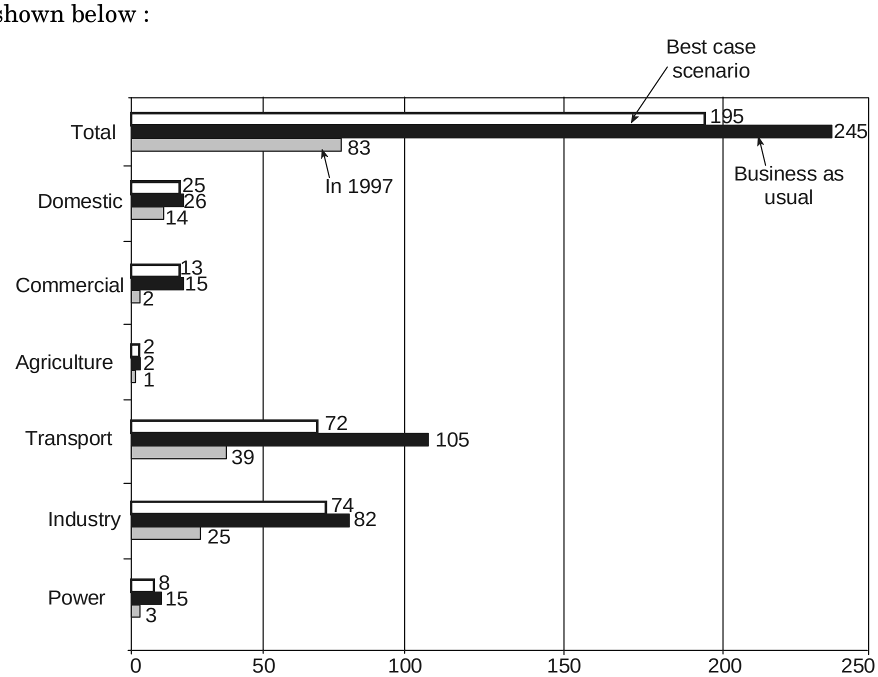

Fig. 1·1. Projected demand for oil in million ton.

(*c*) **Natural Gas.** The current dry natural gas production level of India is 0·82 trillion cubic feed (tcf). With massive off-shore gas discovery along the east coast and also in-land there may be marginal improvement in this situation but still our import requirement will continue at the recent level of 80%. Efforts are on to import gas from Myanmar and Gulf countries, and the success of these initiatives will bring about a major shift in the current energy mix pattern of the country. Planning Commission has projected the Demand for natural gas in different sectors of economy in the year 2020 as shown below :

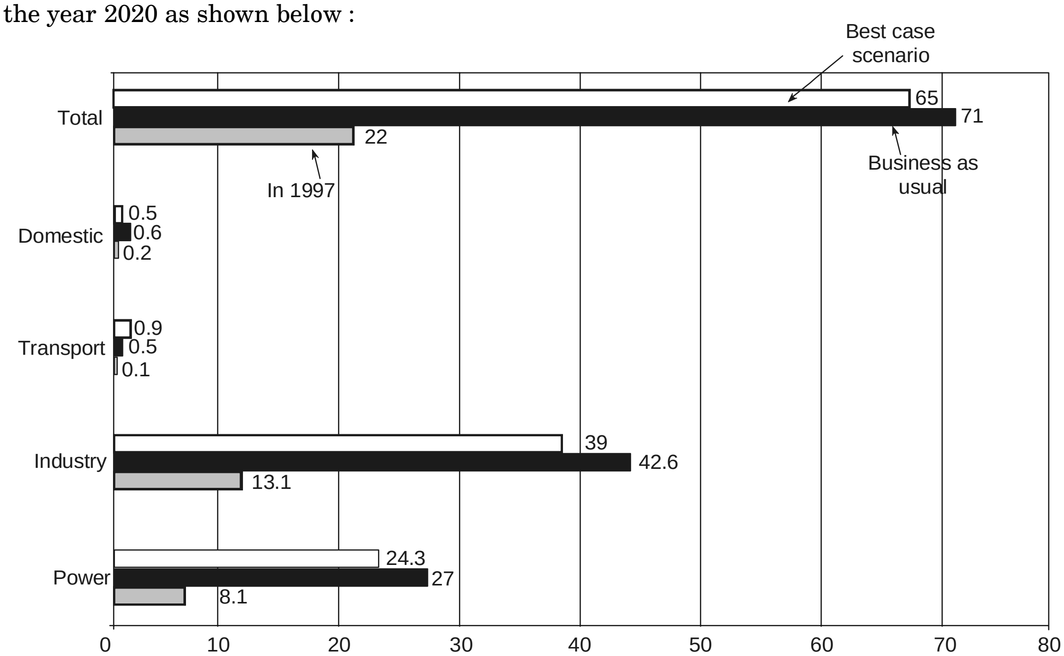

Fig. 1·2. Projected demand for gas in billion cubic meters.

1·3·2. Nuclear Power. India is endowed with limited uranium resurces. But its thorium resurces are vast. The potential of Nuclear Energy in India (GWe-YEARS) is :

Uranium (78,000 tonne metal)	PHWRs	-	330
	FBRs	-	42,200
Thorium (518,000 tonne metal)	Breeders	-	150,000*

(* This is equivalent to India's total electricity requirements for several hundreds of years considering current consumption levels.)

With a view to judiciously utilise this vast potential, a long term three stage programme has been envisaged from the very beginning of nuclear power programme in the country.

The three stages of the nuclear power programme are :

—Pressurised Heavy Water Reactors (PHWRs) using natural uranium in the first stage.

—Fast Breeder Reactors (FBRs) utilising plutonium based fuel, in the second stage.

—Advanced Nuclear Power Systems for utilisation of thorium, in the third stage.

As of now the first stage programme is in progress and has reached a stage of maturity. A beginning is being made on the 2nd stage programme with the proposed commencement of construction of 500 MW PFBR (Prototype Fast Breeder Reactor) at Kalpakkam (TN). This is expected to be followed by more 500 MW units in future. Thereafter it will be followed by a number of FBRs. When the capacity through FBRs builds up to reasonable level, the deployment of thorium through 3rd stage will begin and get realized in the long term.

1·3·3. Renewable Energy Resources

(*a*) India has a large hydro resource in its various river basins, some snow fed and some rain fed with a total power generating capacity of around 1.5 lakh MW but taking into account geological, seismological and ecological risks, logistical difficulties and other factors only small portion of hydro potential has so far been developed. The Government has taken a massive initiative of developing 50000 MW hydro electricity in the next 10-15 years and has formulated an accelerated hydro development programme in which both private and public sector participation is sought. Apart from large hydro-electric projects small hydro projects have also good potential.

(*b*) **Non-conventional energy sources.** Development of non-conventional energy sources has now attracted the attention of the planners and also of promoters because of various tax incentives. Several wind farms have been established in Tamil Nadu, Gujarat, Maharashtra and other states. There is however more reliable statistics available of actual generation of electrical energy by wind farms. Solar energy also has a lot of potential in the country. The main deterrent in its rapid development is the cost. With extensive research work going on in India and other countries the solar technology will mature into a viable option.

A good amount of work is being done on Bio-Mass and generation of electricity from municipal waste. Bio-fuel has a significant potential to lead our country towards energy independence. The other critical options are development of electric vehicles, hydrogen based vehicles, electrification of Railways and urban mass transportation.

The need for exploring renewable energy resources is all the more important because scientists have become increasingly convinced that the consequences of continuing to burn fossil fuels at current or expanded rates will have disastrous impacts on the climate. Use of renewable energy is an extremely promising option for both reducing greenhouse gas emissions and enhancing diversity of energy supplies. The potential for renewable energy in India is estimated to be around 100,000 MW. Against this the wind power potential in the country is estimated to be around 45,000 MW. The National Wind Resources Assessment Programme in India which covers 24 states, is one of the world's largest effort of its kind and so far about 900 wind monitoring stations have been established under this Programme. Wind energy equipments are modular in nature and the investment requirement for these equipments as compared to conventional energy equipments is not large.

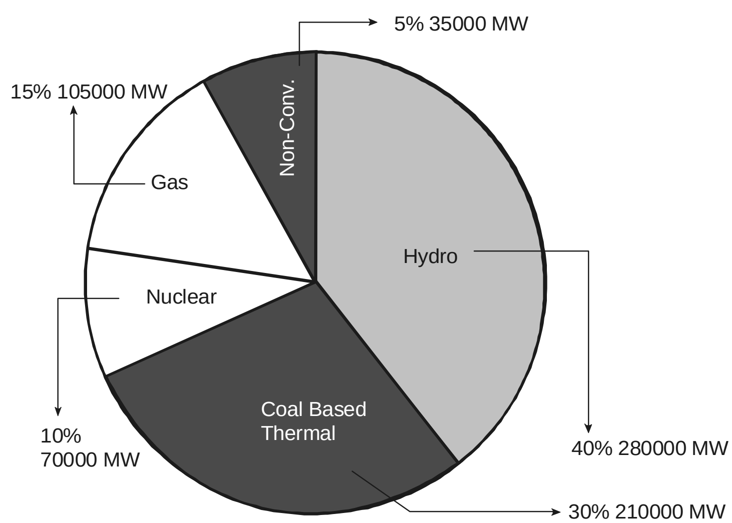

Fig. 1·3. Wish list of sources of power generation

It has been observed that wind power installations, especially in backward rural areas, have produced the following benefits :

(*a*) Creation of local employment opportunities;
(*b*) Improvement of transmission networks;
(*c*) Reduction of transmission cost;
(*d*) Improvement in availability of power;
(*e*) Improvement in quality of power; and
(*f*) Long term energy security.

A wish list of sources of power generation for achieving 2500 Kwh per capita consumption by 2050 when India's population may have stabilized at around 1500 million is depicted in Fig. 1·3.

1·4. National Grid

In view of uneven disposition of generation resources all over the country and the merit of setting up of pit-head station and transmission of power over setting up of load-centre based generation with transportation of fuel, some of the regions have surplus capacity especially during some seasons and also during off peak periods. It is necessary that this surplus power is utilized by effecting inter-regional transfers from surplus to the deficit regions. A National Grid in stages has been contemplated for the purpose. In view of different frequency regimes of operation of various regional grids, it had been decided too initially affect inter-regional transfers through asynchronous HVDC links except Eastern and North-eastern Regions, which operate in synchronism. Towards this end a 500 MW link between Northern and Western Regions, a 1000 MW link between Western and Southern Regions and 500 MW links between Eastern and Northern and Eastern and Southern Region are existing. The 400 kV double circuit Rourkela-Raipur line has now been commissioned and the Eastern and Western Regions are being operated in synchronism. The inter-regional power transfer capability is planned to be about 30000 MW by 2012.

In the transmission and distribution front, there are many areas where improvement is feasible which would enhance the capability and efficiency of the transmission and distribution system. Already India has developed considerable expertise in the area of HVDC transmission. Indigenous capability has been built up and presently a 100 kV, 100 MW National HVDC project has been working since 1991 with total indigenous efforts. This line has been upgraded to 200 kV, 200 MW with state-of-art digital control, etc. Further, a pilot project of Flexible AC Transmission (FACT) is also contemplated. This is proposed to be developed with total indigenous efforts.

Keeping in view the need for optimization of the transmission system, there is a need to develop and use multi-circuit, multi-voltage lines and up-rating and up-gradation of existing transmission lines, use of gas insulated substations at higher voltages, better quality meters etc.

1·5. Clean Coal Technologies for Power Generation

Coal is India's most plentiful and least expensive fuel. Coal occupies pre-eminent position in Indian economy. For these reasons and with limited availability of other petroleum fuels and natural gas, coal has been and will continue to remain the backbone of future electricity generation programme.

While going in for increased use of coal for power generation to meet the growing demand for electricity, we have to strike a balance between the growing need for power and environmental concerns and develop strategies to mitigate the impact on environment. Some major environmental concerns associated with use of coal are summarized below :

— Fine particulates from combustion eventually reach the ground and pose threat to human health.

— Gaseous emissions like SOx and NOx can precipitate as acid rain.

— Carbon dioxide contributes to global warming.

— Power stations require large chunk of land for siting power station and area for ash disposal. Leaching ash can contaminate ground water.

— Associated environmental impacts of coal mining/transport.

The vast geographical area of our country, its tropical climate and low level of industrial development and power consumption have prevented the situation of environmental emissions reaching alarming levels as in some developed countries. However, emissions from coal based power generation coupled with attendant pollution from other areas of economy especsially transport and select industries could bring pressure in select geographical area (*e.g.* regions with clusters of power stations) for reduction of pollution and adoption of selective advanced technologies. The global concern for reduction in emission of green house gases (GHG) especially CO_2 emissions makes it necessary to adopt improved generation technologies. CO_2 emissions per unit of electricity generated are relatively high in India as large proportion of power generated comes from low sized, old and relatively inefficient generating units. The situation is however improving as new units installed have efficiencies comparable to international levels. Also, technology upgradation during life extension of old units is expected to increase the generating efficiency of these units thereby reducing CO_2 emissions.

Clean Coal Technologies

New generation of coal technologies, referred to as Clean Coal Technologies, are environmentally cleaner and in most cases result in higher efficiency. However, the pace of their adoption would be dictated by various factors including economics, technology risk factor etc.

The term Clean Coal Technologies encompasses all the stages of 'coal to power' chain as classified below:

(*i*) Coal quality improvement before combustion (Pre-combustion stage).

(*ii*) Advanced coal burning technologies (Combustion stage).

(*iii*) Flue gas cleaning (Post-combustion stage).

Coal Quality Improvement Before Combustion (Pre-Combustion Stage). The pre-combustion coal quality improvement, commonly referred to as coal beneficiation, envisages reducing the inert materials present in coal before burning. Indian coals available for the purpose of power generation have ash content of the order of 45-50% which is amongst the highest in the world. The quality of coal supplied to power stations has constantly deteriorated over the years mainly due to increase in open cast mining and lack of adequate facilities/equipment of quality control. Power utilities often receive supply of oversized coal, coal containing extraneous material like stones, shale, iron pieces etc. resulting in higher outages and higher O & M costs. Also increasing transportation costs warrant improvement in coal quality to partially offset high transportation costs and also address environmental issues.

In this context, increased use of beneficiated coal may offer benefits like increased generation efficiency and reduced capital as well as O&M costs. Besides, it would also result in savings in transport cost and better use of rail infrastructure. Beneficiated coal could also overcome the generation capacity constraints being faced by some old thermal power stations, which were originally designed for low ash coals but are not able to operate to their rated capacities due to coal degradation.

Considering the above, there is merit in the case of limited beneficiation of non-coking coal at least for distant consumers along with utilization of rejects at pit-heat. However, Indian coals are less amenable to washing and the resulting yield is rather low. **Economic trade off is therefore necessary to balance cost of washing with reduction in transportation cost and O&M cost.** The need of the hour is to have simple and inexpensive coal washing technology so that the accrued benefits outweigh the cost of beneficiation and **use of washed coal does not reuslt in additional financial burden on consumer.** To this end, the utilities should also be prepared to pass on the benefits of using washed coal (less O&M charges, lower net heat rates etc.) to the consumer.

Advanced Coal Burning Technologies (Combustion Stage)

A brief introduction of Clean Coal Technologies for thermal power generation is given in succeeding paras below. Their induction in Indian power scene has started taking place.

Supercritical Technology. The cycle efficiencies in the past had been limited mainly due to limitation on availability of high grade materials to withstand a combination of higher temperature and pressure. This had led to the temperature being confined in the range of 535°C in the main steam and 566°C for reheat steam. With these barriers overtaken due to advancement in metallurgy and availability of better materials, the path for adoption of higher parameters beyond the critical point was paved. Though super-critical units had been operational worldwide since last three decades, the results were not very encouraging. However, increased experience and availability of better technology and materials has led to stable and reliable operation of super-critical units.

Most of the supercritical units are operating in USA, Russia, Japan, Germany, Italy, South Korea. Super-critical units necessarily require use of once through boilers. Steam parameters adopted on these units have generally been in the range of 240-250 kg/cm^2 with temperature of 538°C for main steam and 538/566°C for reheat. Few state of the art units with temperatures upto 600°C are also in operation. The unit sizes have ranged from 300 MW to 1300 MW. However, supercritical units are more suitable for higher unit sizes. Adoption of higher unit size could also lead to faster additions in generation capacity.

With the adoption of higher parameters, efficiency gain of about 2-3% is possible over sub-critical units. To further increase the efficiency, process improvements are necessary like adoption of double reheat system involving two nos. of reheat in the boiler by tapping steam from intermediate stages of the turbine. However, this leads to making the cycle more complex with only marginal improvement in efficiency.

Efforts are under way to further improve the generation efficiency by adopting ultra super-critical parameters of the order of 300 kg/cm^2, 630°C and further increase to 700°C. A group of leading manufacaturers of super-critical power plant equipments worldwide have jointly undertaken research for development of materials/systems for adoption of ultra super-critical parameters. In addition to materials, research and development to optimize all aspects of the steam cycle is underway. State of the art plants are expected to operate at 620°C within next 5 years and at 650-700°C by the year 2020. These units would normally be required to have double reheat system to contain moisture levels within acceptable limits during the entire expansion path.

Advanced Fluidized-Bed Combustion. Fluidized-bed combustion (FBC) technology has proven itself for lower and medium size power units burning low grade fuel which is difficult to burn in conventional boiler or fuel containing high sulphur. This technology reduces emissions of SO_2 and NO_X by controlling combustion parameters and by injecting a sorbent (such as crushed limestone) into the combustion chamber along with the coal.

Two parallel paths were pursued in FBC development—bubbling and circulating beds. Bubbling fluidized-beds use a dense fluid bed and low fluidisation velocity to effect good heat transfer and mitigate erosion of an in-bed heat exchanger. Circulating fluidized beds use a relatively high fluidization velocity that entrains the bed material, in conjunction with hot cyclones to separate and recirculate the bed materials from the flue gas before it passes to a heat exchange surfaces in second pass. Hybrid systems have evolved from these two basic approaches. Fluidized-bed combustion can be either atmospheric (AFBC) or pressurized (PFBC). The AFBC systems operate at atmospheric pressure (either bubbling bed or circulating bed type) while PFBC operates at pressure 6 to 16 times higher.

Circulating Fluidised Bed Combustion (CFBC) technology entails higher capital cost as compared to PC technology. However, cost is comparable when PC technology necessarily requires installation of FGD system. This technology also has the disadvantage of higher auxiliary consumption (higher by about 2%). First 250 MW unit was installed in France (Gardanne) in 1985.

Pressurised Fluidised Bed Combustion (PFBC) systems offer higher efficiency by using both a gas turbine and steam turbine. Consequently, operating costs and waste as well as boiler size per unit of power output are reduced relative to AFBC. Second-generation PFBC integrates the combustor with a pyrolyzer (coal gasifier) to fuel a gas turbine (topping cycle) and the waste heat is used to generate steam for a steam turbine (bottoming cycle). The inherent efficiency of the gas turbine and waste heat recovery in this combined-cycle mode significantly increases overall efficiency.

Integrated Gasification Combined Cycle (IGCC). The IGCC process has four basic steps : (1) fuel gas is generated from coal reacting with high-temperature steam and an oxidant (oxygen or air) in a reducing atmosphere (2) the fuel gas is either passed directly to a hot-gas cleanup system to remove particulates, sulphur and nitrogen compounds, or the gas is first cooled to produce steam and then cleaned conventionally (3) the clean fuel gas is combusted in a gas turbine generator to produce electricity and (4) the residual heat in the hot exhaust from the gas turbine is recovered in a heat recovery steam generator and the steam is used to produce additional electricity in a steam turbine generator.

The chemical composition of the gas requires that the gas stream must be cleaned to a high degree not only to achieve low emissions, but to protect downstream components such as the gas turbine from erosion and corrosion.

IGCC systems have higher over all efficiency of about 40-45% as against about 37% obtained in sub-critical and 39-40% obtained in super-critical pulverized fuel fired units. High levels of SO_X and nitrogen removal are possible. However, IGCC units have significantly higher installation and operation costs than the conventional PC fired units.

Several IGCC plants using refinery residues/low ash coals have been set up globally. Some examples of coal based IGCC projects are Tampa Electric, USA (260 MW), Sierra Pacific USA (100 MW), Duenkolec Netherlands (250 MW). However, their availability is not very high. This technology is yet to be commercially proven fully even with low ash coal.

IGCC could offer substantial benefits of high efficiency and low emissions, if it could be adopted for commercial generation with low quality Indian coals.

Flue Gas Cleaning (Post Combustion Stage)

The post-combustion gas cleaning is a conventional method to mitigate the environmental hazards caused by coal use. The major pollutants emitted by flue gases include solid particulate matter, SO_X and NO_X gases besides other combustion products such as CO_2 and CO. Over the years, Indian power industry has come a long way in controlling solid particulate matter through use of high efficiency Electrostatic Precipitators (ESP) despite the fact that our coals are having high ash content resulting in very high dust loading coupled with very high ash resistivity. ESPs with collection efficiencies more than 99·8% are being used to meet the present day norms of SPM emissions prescribed by the pollution control authorities. Use of high efficiency ESPs would continue for ontrol of SPM emission from coal fired thermal power stations irrespective of the type of combustion process used.

Indian coals are predominantly low sulphur having sulphur contents of 0·3% to 0·5% and accordingly, no necessity has been felt for installation of Flue Gas Desulphurisation (FGD) systems in the Indian power sector and SO_X control have been successfully achieved through provision of tall stacks for wider dispersion. At the insistence of Pollution Control Authorities, FGD system has been installed at Trombay Thermal Power Station (TPS). BSES are also in the process of installing FGD system at Dahanu TPS. The three main technologies widely used for desulphurisation are :

(*a*) Wet Lime Stone Process

(*b*) Spray Dry Process

(*c*) Sea Water Scrubber Process (for coastal sites only)

Over the years through constant R&D worldwide, significant improvements have been achieved in lowering the capital cost of FGD process and also operational costs mainly through reduction in auxilliary power consumption and more efficient use of reagents. All these FGD technologies are commercially available worldwide and readily accessible.

Nitrogen Oxide emissions from thermal stations depends on the boiler technology adopted and types of equipments used specially burner configuration. Generally speaking, NO_X emissions from Indian power plants are well within international standards. The burner systems of most of the old units have been replaced with low NO_X type burners in the Renovation and Modernisation (R & M) programmes being carried out and all the recent units are provided with very high efficiency lower NO_X burners. Apart from primary control of the NO_X in combustion other methodologies for NO_X control through modification in the boiler system (*e.g.* staged combustion, flue gas recirculation, overfiring etc.) exist. In addition, secondary NO_X control technologies like Selective Catalytic Reduction (SCR) are commercially available.

Oxyfuel combustion. Another emerging technology is that of oxyfuel combustion. Its purpose is to produce a concentrated carbon dioxide stream that can then be more readily captured for storage. The process is similar to the conventional pulverised coal combustion generation but near-pure oxygen is used instead of air in the boiler. This significantly reduces the dilution of carbon dioxide in the exhaust gas stream by removing nitrogen from the system. This technology has only been demonstrated at a pilot level and is being developed for commerial use.

Carbon Capture. These technologies enable carbon dioxide emissions to be separated from the exhaust stream of coal combustion or product stream of coal gasification and can be stored in such a way that they do not enter the atmosphere. They are also known as carbon capture and sequestration technologies.

Technologies for capturing carbon dioxide from emission streams have been used for many years in the food processing and chemicals industries. Petroleum companies also separate carbon dioxide from natural gas before transportation to the market through pipelines. Some of these technologies are post-combustion capture, pre-combustion capture, oxyfuel combustion, and chemical looping combustion.

Currently, there are technical and cost challenges to be addressed in separating carbon dioxide from high volume and low concentration flue gases, typically generated by the conventional pulverised coal-fired power station. Current research and developments on a new or retrofit post-combustion capture system are aimed at finding a practical and economic solution to carbon dioxide reduction.

Another technology is that of pre-combustion capture, which can be achieved by reacting the product stream from coal gasification in a water shift process so that carbon dioxide, rather than carbon monoxide, is produced with hydrogen. The crbon dioxide can be captured for storage or use, and the hydrogen can be combusted in a gas turbine. In future, it can also be used in fuel cells. Oxyfuel combustion can also be used to produce a pure carbon dioxide stream simply by burning coal in an oxygen-rich atmosphere. The chemical looping combustion uses a continually looping two-stage reaction process to provide two separate waste streams from coal combustion : carbon dioxide with water and nitrogen with some unused oxygen. The relatively pure carbon dioxide from the first stream can be compressed for storage.

Carbon Storage. Carbon storage can be in the form of geological reservoirs, depleted oil an gas reservoirs, or saline aquifers. They can help in enhanced oil recovery and enhanced coal bed methane.

Creating geological storage is a process of injecting very large quantities of carbon dioxide into the earth's surface with potential for permanent storage. The carbon dioxide is compressed and piped underground deep into the natural geological reservoirs. A number of options are being researched. A logical site for the geological storage is depleted oil and gas reservoirs, which are ideal for permanent storage. Large amounts of carbon dioxide can also be stored in deep saline water-saturated reservoir rocks.

Carbon dioxide storage can have associated economic benefits. A widely practised method in the oil industry is that of increasing oil production by injecting carbon dioxide to push the oil out, thereby increasing the level of recovery from the field. Also, in unminerable coal seams, carbon dioxide can be stored for obtaining improved production of coal bed methane.

1·6. Sustainable Development Using Coal as fuel for generating electrical Energy

Coal plays a significant role in sustainable development of energy sector particularly for the countries having no reserves or limited reserves of oil and gas. Coal provides energy security for power generation and contributes to the economic prospects. Clean coal technologies (CCTs) are available for generating environmentally benign electricity from any grade of coal. Extraction of coal and its utilization through application of clean technologies lead to social development and its advancement.

Sustainable development is often defined as 'development that meets the nees of the present, without compromising the ability of future generations to meet their own needs'. Sustainable development in the context of use of coal for power generation implies how humanity can continue to enjoy the many economic and social benefits associated with its extraction and utilisation, while at the same time reducing or eliminating environmental impacts.

The basic and inter-related objectives which must be met to achieve sustainable development are :(*i*) energy security and economic prosperity; (*ii*) environmental sustainability ; and (*iii*) social development and advancement.

Much of the industrial world was entirely dependent on coal until oil and natural gas emerged as major energy sources due to technological developments and environmental considerations. Coal is the major fuel source used for electric power generation.

In future many countries are expected to rely increasingly on natural gas fired generation due to technical, economic and environmental advantages of natural gas based power generation supported by highly efficient gas turbines and use of combined cycle plants which are generally cheaper, have short gestation periods, are more efficient to operate, and more environment friendly.

Share of renewable energy is expected to increase in developing countries. Much of the growth in renewable energy is attributable to large-scale hydrolectric projects in the developing world, particularly China and India. Renewable energy sources of hydro, wind, solar, biomass, wave and tidal, do provide alternative sources for power generation but these face problems of economic viability and environmental acceptability.

The mix of primary fuels used to generate electricity is changing over the past three decades. Coal is by far the most plentiful fossil fuel in the world. It is estimated that around one thousand billion tonnes of global coal reserves are economically accessible. Coal reserves are geographically diverse, being produced by 50 countries and all continents. Plentiful reserves and wide spread production mean a long-lasting supply. Large increase in coal use is expected in the developing countries like China and India.

Necessity of using coal for generation of electrical energy. Coal is the most readily available indigenous fossil fuel in India and there is huge shortage of oil and natural gas. Many households do not have access to electricity. As standards of living improve, they need more electricity.

India has to continue to depend on coal. Its energy resources particularly coal and hydropower are unevenly distributed. Bulk of the reserves of coal *i.e.* 73% is located in the eastern states of Bihar, Orissa and Bengal. 73% of the hydro potential is available only in north and northeastern parts of the country. 80% of the lignite resources are located in southern India. The uneven distribution of energy resources is being managed by both transportation of coal and transmission of power over long distances. There are problems in case of hydro and nuclear power generation. The renewable projects are expensive and are economically viable only through Government subsidies/incentives. Hence their contribution is very limited to meet the country's power demand. India has very limited reserves of oil and natural gas. The demand of oil is being met through large imports. Hence our dependence on coal for generation of electrical energy.

Environmental Sustainability. The key environmental challenges facing the coal industry are related to both in coal mining (particle emissions and disturbance of land) and in the use of coal (greenhouse gas, acid rain, ground level ozone and waste disposal).

The technological advances due to mechanisation have led to simultaneous improvements in both productivity and safety. Coal is a comparatively stable material. It does not present the leakage and spillage problems assoiated with oil and gas. Distribution of coal by conveyor belt, road or rail is inherently safer. Thus coal is safe both during storage, handling and burning in power plant. However coal fired power plants are the most polluting ones compared to oil and gas fired plants. Clean coal technologies, pollution abatement technologies help in maintaining environmental pollution standards.

Coal industry is one of the largest industries in many countries including India. Indian coal industry has collaborations with major coal producing countries of the world. Indian railways transport about more than 50% of the coal produced in the country and derive major revenue from it. The government also gets royalty from coal mined. Coal mining is still a labour intensive exercise despite mechanisation and improvement in productivity.

Coal mining generally takes place in rural areas where unemployment is high compared to urban areas. Coal mining directly employs millions worldwide. It also generates income and employment in other regional industries that are dependent on coal mining. Coal companies also provide housing and potable water to its employees. The industry provides medical facilities and also educational facilities. Thus coal industry is contributing immensely to social development and advancement.

The lowest fatality rates occur in countries where there is a strong commitment to health and safety standards and where large scale modern operations dominate production.

1·7. Cogeneration for Protection of Environment

Cogeneration is deined as the production of electric power and other forms of useful energy such as heat or process steam from the same facility or the simultaneous production of two forms of energy *e.g.* steam and electricity from a single power plant. Cogeneration is also known as combined heat and power (CHP). It is an economically sound method for the conservation of resources and pollution mitigation. The efficiency of cogeneration plant can reach 80% or more and it offers energy savings, enery conservation, environmental benefits through using fossil fuels more efficiently.

Benefits of Cogeneration. The following benefits occur in cogeneration process.

—Higher efficiency of energy conversion and use.

—Lower emissions to the environment, (CO_2, the main greenhouse gases).

—Biomass fuels and agricultural waste can be used as fuels for cogenertion schemes.

—Large cost savings.

—Offering affordable heat for domestic users.

—Decentralised generation of electricity, avoiding transmission losses.

—Improved local and general security of supply.

Usually a variety of fuels such as high sulphur and high ash coal, rice husk, rice straw and coal washery rejects are available locally and these can be burnt in fluidised bed combustion boilers.

Waste heat boilers of ratings up to 60 tph with single pressure and 100 tph with dual pressures are available. These are available in small sizes also.

Cogeneration is ideally suited in the paper and bulk chemicals industries, which have large concurrent heat and power demands. The greater availability and wider choice of suitable technology has made cogeneration as an attractive and practical proposition for a wide range of applications like process industries, commercial and public sector buildings and district heating schemes.

A cogeneration plant is best suited where there is inaccessibility to the grid or high price of grid electricity, a reliable power is needed, where there is higher thermal energy demand than electricity and there is relatively steady electrical and thermal demand patterns, etc.

Heat-electrical power ratio in cogeneration plant vary from site to site. The type of plant has to be selected carefully and an appropriate operating regime must be established to match demands as closely as possible. The plant may therefore be set up to supply part or all of the site heat and electricity loads, or an excess of either may be exported if a suitable customer is available. Cogeneration plant consists of a prime mover (engine), an electricity generator, a heat recovery system, and a control system. Depending on site requirements, the prime mover may be a steam turbine, reciprocating engine or gas turbine and combined cycle (gas and steam turbines), micro-turbines, stirling engines, and fuel cells.

The choice between backpressure turbine and extraction condensing turbine depends mainly on the quantities of power and heat, quality of heat, and economic factors. The extraction points of steam from the turbine could be more than one, depending on the temperature levels of heat required by the processes.

Another variation of the steam turbine topping cycle cogeneration system is the extraction-back pressure turbine that can be emploiyed where the end-user needs thermal energy at two different temperature levels. The full-condensing steam turbines are usually incorporated at sites where heat rejected from the process is used to generate power.

Gas turbine cogeneration systems can produce all or a part of the energy requirement of the site, and the energy released at high temperature in the exhaust stack can be recovered for various heating and cooling applicattions. Though natural gas is most commonly used, other fuels such as light fuel oil or diesel can also be employed.

Trigeneration and Vapour Absorption cooling. Trigeneration is the concept of deriving three different forms of energy from the primary energy source, namely, heating, cooling and power generation. This is applicable where buildings need to be air-conditioned and many industries require process cooling. A typical trigeneration facility consists of a cogeneration plant, and a vapour absorption chiller, which produces cooling by making use of some of the heat, recovered from the cogeneration system.

Low qualtiy heat (*i.e.* low temperature, low pressure) exhausted from the cogeneration plant can drive the absorption chillers so that the overall primary energy consumption is reduced. Absorption chillers have widespread usage due to their capability of integrating with cogeneration system and they can operate with industrial waste heat streams also.

Many industries and commercial buildings in tropical countries, like India and other South Asian countries, need combined power and heating/cooling. Cogeneration systems with absorption cooling have very high potentials for industrial and commercial application in suh places.

Stirling Engines. The Stirling engines is an external combustion device and therefore differs substantially from conventional combustion plant where the fuel burns inside the machine. Heat is supplied to the Stirling engine by an external source, such as burning gas, and this makes a working fluid, *e.g.* helium, expand and cause one of the two pistons to move inside a cylinder. This is known as the working piston. A second piston, known as a displacer, then transfers the gas to a cool zone where it is recompressed by the working piston. The displacer then transfers the compressed gas or air to the hot region and the cycle continues. The Stirling engine has fewer moving parts than conventional engines, and no valves, tappets, fuel injectors or spark ignition systems. It is therefore quieter than normal engines, a feature also resulting from the continuous, rather than pulsed, combustion of the fuel. Stirling engines also require little maintenance and emissions of particulates, nitrogen oxides, and unburned hydrocarbons are low. The efficiency of these machines is potentially greater than that of internal combustion or gas turbine devices.

The ratio of heat to power required by a site may vary during different times of the day and seasons of the year. Importing power from the grid can make up a shortfall in electrical output from the cogeneration unit and firing standby boilers can satisfy additional heat demand. Many large cogeneration units utilize supplementary or boost firing of the exhaust gases in order to modify the heat to power ratio of the system to match site loads. Higher the heat to power ratio, greater the environmental benefits.

The high efficiency of cogeneration and efficient use of fuel guarantee a significant reduction of CO_2 emission. The quantity of each of the pollutant generated (CO_2, SO_x, NO_x etc.) depends largely on the type of fuel used and the characteristics of the cogeneration technology adopted.

1·8. Technologies for zero emission

Green House gases in desired quantity are necessary for maintaining the moderate temperature on Earth but too much of it is responsible for increase in Mean Surface Temperature and climate changes.

In 1992 the First Convention on Climate Change was held at Rio called the Rio Earth Summit. This was done under the auspices of UNDP. It was then decided to roll back the GHG emission levels as that prevailing in the year 1990, thus setting a Bench Mark for GHG emission in future. A time frame of 2012 was fixed for achieving this. Collective wisdom and a sense of self preservation brought about another land mark in the form of Kyoto Protocol in the year 1998. This protocol proposed a regime of rewards and punishments to ensure a roll back in the GHG emissions. These would be in the form of damages to be paid by the polluters and credits for those preventing these emissions.

The biggest threat and challenge is for the coal based power plants which account for 46% of the total GHG's due to human activity. The second biggest threat is from the transport sector, which accounts for more than 30% of all the GHG's. These are also dangerous as their emissions are tetratogrens and carcinogens and mutagens and these originate from petroleum as feed stock.

A recent study published has stated that diesel emission has more than 476 compounds, which are dangerous. CNG exhausts also have some of these agents.

Petroleum resources are not easily replenished, and these are natural resources. These could be used to produce far greater and better value added chemical molecules and drug molecules and useful fiber supplement instead of their being burnt as fuel and cause health problems for the present and future generation.

At present CO_2 is consumed by the sinks present in the atmosphere in the form of vegetation, which is used up in the photosynthesis for the plant growth. It has become imperative to develop technologies which have the potential to reduce the level of the GHG's so that we do not limit the growth of our economic development or energy consumption.

There are a number of methods like sequestration of CO_2, *i.e.* liquefaction of CO_2 and dumping it at the sea where there is an earth fault and here the CO_2 could be absorbed naturally.

Various technologies which could lead to zero emission are as under :

(*a*) Clean Coal Technologies.

(*b*) Solid to liquid and solid to gas fuel technology.

(*c*) GHG mitigation technology.

(*d*) Clean Development Mechanism.

(*e*) Clean fuel technology for automobiles.

(*f*) Non-CFC Refrigerant and Non-CFC Aerosol Propellent Technology.

(*g*) Clean Aviation Fuel or ATF for aircraft.

(*h*) Substitute LPG for domestic use.

The Carbon Recycling Technology or Eco-friendly process of CO_2 recyling could address a large segment of the GHG control in the foreseeable future. This technology could give rise to Zero Emission Power Plants and also produce clean alternate fuel which has CO_2 and water which can be used as an alternative transportation fuel. This would further help to lower pollution of the dangerous emission from the Petroleum based fuels.

'Carbon Recycling Technology' uses the CO_2 from the exhaust of various plants and converts the same into Di-Methyl Fuel (DMF) or fuel grade Di-Methyl Ether in the most cost-effective manner. In this process CO_2, NH_3, coal, steam are the inputs and have cogenerated power and DMF as its output.

Conversion of CO_2 into hydrocarbons is another line of research in the form of conversion of CO_2 into Butane, Propane and other Hydrocarbons by using Hydrogen of the Hydrochloric Acid using Iron as a catalyst. This is a low temperature and pressure reaction but in the process produes Chlroine as a by-product.

Zero emission technology in the power plant uses carbon recycling technology to convert the CO_2 emissions into a useful clean fuel DMF. These technologies have been based on the twin principle of increasing the energy efficiency of the power plant and have been directed at using the IGCC technology for power generation.

Clean Alternate Transportation Fuels (ATF) are an essential link in the chain of strategy for environmentally friendly sustainable economic development. Reduction of the levels of air pollution consisting various components like SPM's, PAH's, NO_x, SO_2, etc. to international accepetable levels of 15 mcg for SPM's. The USEPA standard for RSPM of 15 mcg/cu.m. is more stringent than the Indian standards of 80 mcg/cu.m. by nearly six times for RSPM. Cities exposed to higher values of Respirable Suspended Particulate Matter or RSPM are exposed to and prone to respiratory diseases like Asthma, Bronchitis's, TB or even Cancer. The causes of air pollution are well established.

The main causes of air pollution are the vehicles plying on the roads using petrol and diesel. These vehicles emit various emissions, the petrol vehicle emit lead in the form of Tetra Ethyl Lead or TEL which is added as an anti-knock and ETBE for unleaded petrol and they have a very large emission of aromatics which are either due to the adulteration or negligence.

The other soure of the adulteration is from kerosene to diesel. The kerosene contains about 30% of Aromatic Chain. This results in the increased emission levels of PAH (polycyclic aromatic hydrocarbon) and RSPM and carbon monoxide. The sulfur content in diesel as per Euro-III standards needs to be reduced to 50 PPM. Emission studies have shown diesel emissions to have 476 compounds, which are toxic. No hydrocarbon fuel which is related to the petroleum chain could really be suitable for environment considerations.

Various options to lower emission are :

(*a*) Use as a ATF and solar energy to generate the required hydrogen or the same being extracted from the earth's crust which is supposed to contain an unending supply of hydrogen, only if we knew how to tap this resource in a cost effective manner. The emissions in using H_2 as ATF would only be water.

(*b*) Tap ocean floor for the available Methyl hydrate which is formed at high pressures and low temperatures and which is enough to take care of the global energy needs for a few centuries.

(*c*) Use of electric transportation vehicles making use of non-peak-load power of the power plants. The use of aluminium metal as the accumulator of electricity in an aluminium cell using hydrogen peroxide to reverse the reaction to get electricity and aluminium oxide promises to be the most efficient system.

(*d*) Hydrocraking of the aliphatic hydrocarbon chain from petroleum feedstock used to produce diesel and naphtha to get a mixture of various petrochemical feedstock gases like Methane, Ethane, Propane, Butane, Pentane, Hydrogen, etc. This process would increase the heat value by three times and produce a clean gas mixture, which could be called substitute LPG. It has its principal component as Butane.

(*e*) Use of Methanol as a fuel for vehicles. The fuel of 85% Methanol and 15% gasoline has high burning rate and has better utilisation of the air.

(*f*) Use 'Carbon Recycling Technology' which uses CO_2 to produce a clean fuel called Di-Methyl Fuel. This fuel has virtually zero emission as this fuel breaks-down into water and CO_2. The fuel DMF which uses 'Carbon Recycling Technology', can be used by almost any type of engine, by making suitable modifications to the engine or additives to the fuel to suit the vehicle type, and would generate optimum power, efficiently with zero pollution as in the case of hydrogen used as a transportation fuel. Any emissions that may result would result from the use of the additives to make this fuel suit to the engine type.

1·9. Energy Security

Energy security is defined as ability to supply lifeline energy to all citizens irrespective of their ability to pay for it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected.

India has to face three major risks in regard to energy security risks.

(*i*) **Supply Risk.** This is concerned with supply disruption due to events outside our control. The threat of energy security arises not just from the uncertainty of availability and price of imported energy, but also from the possible disruption or shortfalls in domestic production. A strategy needs to be developed to counter disruption of supply risk.

(*ii*) **Market Risk.** This is concerned with a sudden increase in oil price. A high oil price can cause inflation, slow down the economy and impose hardship on the common man.

(*iii*) **Technical Risk.** Even when the country has adequate energy resources, technical failures may disrupt the supply of energy. Accidents can also disrupt the supply of energy. Such risks can be dealt by having enough redundancy in system, having spinning reserve, etc.

Energy Independence. It implies augmentation of total domestic energy supply. India could eliminate its oil dependence over the next 40-50 years by :

— Developing cheap batteries with high storage density for hybrids/electric vehicles.

— Developing solar power. If efficiency of solar photovoltaic can be increased from the current 15% to 50%, without increasing the cost, we can have all the power we need at competitive costs by covering a small fraction of our land (the land required can be further reduced by putting photovoltaic cells on all roof tops). The surplus solar power during daytime can be used to split water to produce hydrogen that can provide electricity at night and can also be used to run motor vehicles using fuel cells.

— Developing nuclear power based on thorium.

Various policy options for energy security are :

(*i*) Attempting efficiency improvements in energy extraction, conversion, transmission, distribution and end-use of energy.

(*ii*) Reducing the need for imported energy sources by other forms of energy. If the domestic substitutes increase dependence on one particular fuel, it can increase domestic supply risk. Therefore, efforts should be to diversify the domestic energy mix.

(*iii*) Diversification of sources of import of a particular fuel and diversification of energy mix by using different types of fuels can lead to energy security. The security provided by such diversification is enhanced when the ability of the users to switch among fuels increases.

(*iv*) Expand the resource base in many ways like enhancing recovery from existing resource bases, exploring to find new reserves, developing new sources of energy mainly through R&D.

(*v*) The shortage due to disruption of supply from any country will be small if the import dependence is reduced. This can also be dealt with by maintaining a strategic reserve.

(*vi*) The market risk of a sudden price increase can be guarded by keeping the import bill as a small proportion of the foreign exchange earnings or by maintaining a stock of foreign exchange to address volatility.

1·10. Energy Efficiency Strategies

Energy efficiency does not only imply technological efficiency but encompasses all changes that result in decreasing the amount of energy used to produce one unit of economic activity. It is concerned with both 'conversion efficiency and 'use efficiency' and then it slows down the negative impact of energy consumption and other activities on the environment. Energy efficiency includes technological, behavioural and economic changes.

Energy efficiency promotes sustainable and environmentally sound economic growth and development, helps in the conservation of scarce and finite fossil fuels, enables to reduce dependence on imported fuels.

Lowering energy intensity through higher efficiency is equivalent to creating a virtual source of untapped domestic energy. It may be noted that a unit of energy saved by a user is greater than a unit produced, as it saves on production losses as well as transport, transmission and distribution losses.

Petroleum Conservation Research Association (PCRA) is entrusted with the task of sponsoring R&D activities for the development of fuel efficient equipment/devices and running of multimedia campaigns for creating mass awareness for the conservation of petroleum products.

The Bureau of Energy Efficiency was established (under the Energy Conservation Act 2001) with the mission to develop policies and strategies on self-regulation and initiate market interventions aimed at reducing the energy intensity of the Indian economy. It provides policy framework and direction to national energy conservation and efficiency efforts and programmes.

Various measures being taken to achieve energy efficiency are :

—Improving efficiency of industrial, municipal and agricultural water pumping.

—Promoting solar hot water systems.

—Promoting variable speed drives in industries and process plants.

—Undertaking efficient lighting initiative.

—Improving cooking efficiency.

—Making energy audits compulsory for all loads above 1 MW.

—Reaping daylight savings.

— Large scope exists to make buildings energy efficient. Construction materials are energy intensive and the use of appropriate materials and design can save a significant amount of energy not only in construction but also during use by building occupants. Innovative and energy efficient building technologies should be widely publicized through an annual prize. Reducing energy needs for heating and cooling by orientation, insulation could also be significant.

Energy efficiency and thereby energy conservation is considered as a major instruemnt for augmenting energy supplies contributing to energy security. Energy efficiency improvement may also lead to climate security by reducing the emissions. Whereas efficiency improvement will make industry more competitive in a market oriented economy, it can not substitute for additional supplies of energy resources. It will no doubt take away the pressure from the quantities of energy sources required by the country, and thereby bringing in a cost-effective option for economic and social development.

1·11. Salient features of Energy Conservation Act, 2001

Policy Framework. Government of India enacted the Energy Conservation Act, 2001 with a view to saving energy on large scale, bridging the gap between demand and supply and reducing environmental emissions through energy saving. The Act provides the much-needed legal framework and institutional arrangement for embarking on an energy efficiency drive. Bureau of Energy Efficiency has been established with a view to implement policy programmes and coordination of implementation of energy conservation activities.

Important features of the Energy Conservation Act are :

Standards and Labeling. Standards and Labeling (S & L) has been identified as a key activity for energy efficiency improvement and to ensure that only energy efficient equipment and appliance would be made available to the consumers. It aims to (*i*) evolve minimum energy consumption and performance standards for notified equipment and appliances, (*ii*) probihit manufacture, sale and import of such equipment, which does not confirm to the standards, (*iii*) introduce a mandatory labeling scheme for notified equipment appliances to enable consumers to make informed choices, and (*iv*) disseminate information on the benefits to consumers.

Designated Consumers. It is envisaged that :

— The government would notify energy intensive industries and other establishments as designated consumers;

— Schedule to the Act provides list of designated consumers which covered basically energy intensive industries, Railways, Port Trust, Transport Sector, Power Stations, Transmission and distribution companies and commercial buildings or establishments;

— The designated consumer to get an energy audit conducted by an accredited energy auditor;

— Energy managers with prescribed qualification are required to be appointed or designated by the designated consumers;

— Designated consumers would comply with norms and standards of energy consumption as prescribed by the central government.

Certification of Energy Managers and Accreditation of Energy Auditing Firms. A cadre of professionally qualified energy managers and auditors with expertise in policy analysis, project mangement, financing and implementation of energy efficiency projects would be developed through certification and accreditation programme. BEE will design training modules, and conduct a national level examination for certification of energy managers and energy auditors.

Energy Conservation Building Codes. The main provisions of Energy Conservation Building Codes are :

— The BEE to prepare guidelines for Energy Conservation Building Codes (ECBC);

— These would be notified to suit local climate conditions or other compelling factors by the respective states for commercial buildings erected after the rules relating to energy conservation building codes have been notified.

— Energy audit of specific designated commercial building consumers.

Bureau of Energy Efficiency (BEE)

— The mission of Bureau of Energy Efficiency is to institutionalise energy efficiency services, enable delivery mechanisms in the country and provide leadership to energy efficiency in all sectors of economy. The primary objective would be to reduce energy intensity in the Indian Economy.

— The role of BEE would be to prepare standards and labels of appliances and equipment, develop a list of designated consumers, specify certification and accreditation procedure, prepare building codes, maintain Central EC fund and undertake promotional activities in co-ordination with center and state level agencies. The role would include development of Energy Service Companies (ESCOs), transforming the market for energy efficiency and create awareness through measures including clearing house.

Role of Central and State Government

Central Govt. will notify rules and regulations under various provisions of the Act, provide initial financial assistance to BEE and EC fund, coordinate with various state governments for notification, enforcement, penalties and adjudication.

State Govt. will amend energy conservation building codes to suit the regional and local climate condition, designate state level agency to coordinate, regulate and enforce provisions of the Act and constitute a State Energy Conservation Fund for promotion of energy efficiency.

Enforcement through Self-Regulation. The following procedure of self-regulation is proposed to be adopted for verifying areas that require inspection of only two items that require inspection.

— The certification of energy consumption norms and standards of production process by the Accredited Energy Auditors is a way to enforce effective energy efficiency in Designated Consumers.

— For energy performance and standards, manufacturers declared values would be checked in Accredited Labortories by drawing sample from market. Any manufacturer or consumer or consumer association can challenge the values of the other manufacturer and bring to the notice of BEE, BEE can recognise for challenge testing in disputed cases as a measure for self-regulation.

Penalties and Adjudication. Penalty for each offence under the Act, after initial promotional period of 5 years would be in monetary terms *i.e.* Rs.10,000 for each offence and Rs.1,000 for each day for continued non compliance.

1·12. Integrated Energy Policy

This policy recommends measures aiming to bridge the prevailing gap in the demand and supply of energy in short, medium and long term perspective.

The broad vision behind the Energy Policy is to reliably meet the demand for energy services of all sectors at competitive prices. The demand must be met through safe, clean and convenient forms of energy at the least-cost in a technically efficient, economically viable and environmentally sustainable manner. Considering the shocks and disruptions that can be reasonably expected, assured supply of such energy and technologies at all times is essential to providing energy security for all. To meet this vision, it is necessary to pursue all available fuel options and forms of energy, both conventional and non-conventional. There is need to expand energy resource base and seek new and emerging energy sources, and also pursue technologies that maximize energy efficiency, demand side management and conservation. Coal shall remain India's most important energy source till 2031-32 and possibly beyond. Thus, India must seek clean coal combustion technologies and, given the growing demand for coal, also pursue new coal extraction technologies such as in-situ gasification to tap its vast coal reserves that are difficult to extract economically using conventional technologies.

Other important areas covered are :

— **Ensuring availability of gas for power generation.**

— **Power sector reforms** by focussing on controlling the aggregate technical and commercial losses of the state transmission and distribution utilities.

— **Reduction in cost of power.** It is important to reduce the cost of power to increase both the competitiveness of the Indian economy and also to increase consumer welfare.

— **Rationalization of fuel prices.**

— **Energy efficiency and demand side management.** Efficiency can be increased in energy extraction, conversion, transportation, as well as in consumption. There is need to enforce truthful labelling on equipment, and impose major financial penalties if the equipment fails to deliver stated efficiencies, establishing benchmarks of energy consumption for all energy intensive sectors.

— **Augmenting of resources for increased energy security.** India's energy resources can be augmented by exploration to find more coal, oil and gas, or by recovering a higher percentage of the in-place reserves. Developing the thorium cycle for nuclear power and exploiting non-conventional energy, especially solar power, offer possibilities for India's energy independence beyond 2050.

— **Role of Renewables.** From a longer-term perspective and keeping in mind the need to maximally develop domestic supply options as well as the need to diversify energy sources, renewables remain important to India's energy sector. It would not be out of place to mention that solar power could be an important player in India attaining energy independence in the long run. With a concerted push and a 40-fold increase in their contribution to primary energy, renewables may account for only 5 to 6% of India's energy mix by 2031-32. While this figure appears small, the distributed nature of renewables can provide many socio-economic benefits.

— **Ensuring Energy Security.** India's energy security, at its broadest level, is primarily about ensuring the continuous availability of commercial energy at competitive prices to support its economic growth and meet the lifeline energy needs of its households with safe, clean and convenient forms of energy even if that entails directed subsidies. Reducing energy requirements and increasing efficiency are two very important measures to increase energy security. However, it is also necessary to recognise that India's growing dependence on energy imports exposes its energy needs to external price shocks. Hence, domestic energy resources must be expanded. For India it is not a question of choosing among alternate domestic energy resources but exploiting all available domestic energy resources to the maximum as long as they are competitive.

— **Boosting Energy Related R&D.**

— **Household Energy Security.** Electricity and Clean Fuels for All : Electrification of all Households.

1·13. National Electricity Policy

The Government of India decided and notified the National Electricity Policy in February 2005. The policy aims at accelerated development of power sector, providing supply of electricity to all areas and protecting interests of consumers and other stakeholders.

The Policy prescribes development of Rural Electrification Distribution backbone, village electrification and household electrification to achieve the target of completing household electrification in next five years, financial support in terms of capital subsidy to States for rural electrification and special preference to Dalit Bastis, Tribal Areas and other weaker sections for rural electrification. REC to be nodal agency for rural electrification at Central Government level.

The policy emphasizes :

(*i*) Creation of adequate generation capacity with a spinning reserve of at least 5% by 2012 with availability of installed capacity at 85%.

(*ii*) Full development of hydro potential.

(*iii*) Choice of fuel for thermal generation to be based on economics of generation and supply of electricity.

(*iv*) Nulear Power is an established source of energy to meet the base load demand. Share of nuclear power in the overall capacity profile will need to be increased significantly.

(*v*) Development of National Grid.

(*vi*) Cost of recovery of service from consumers at tariff reflecting efficient costs to ensure financial viability of the sector.

(*vii*) Provision of support to lifeline consumers (households below poverty line having consumption of 30 units per month) in terms of tariffs.

(*viii*) Availability based tariff (ABT) to be extended to State level for better grid discipline through economic signalling.

(*ix*) Special emphasis on time bound reduction of transmission and distribution losses.

(*x*) Measures to promote competition aimed at consumer benefits.

(*xi*) Reliability and quality of power supply to be monitored by State Electricity Regulatory Commissions.

(*xii*) Exploitation of non-conventional energy sources such as small hydro, solar, biomass and wind for additional power generation capacity. Required encouragement through suitable promotional measures.

(*xiii*) Emphasis on achieving higher efficiency levels of generating plants through necessary renovation and modernization.

(*xiv*) Central Government to facilitate the continued development of national grid. Central Transmission Utility and State Transmission Utility to undertake coordinated planning and dvelopment.

(*xv*) Transmission capacity to have redundancy level and margins as per international standards.

(*xvi*) Adequate transitional financial support for reforming power utilities. Encouragement for private sector participation in distribution.

(*xvii*) The State Regulatory Commissions to put in place independent third party meter testing arrangement.

(*xviii*) Support for adoption of IT system for ensuring correct billing to consumers.

(*xix*) Speedy implementation of stringent measures against theft of electricity.

(*xx*) Full emphasis on augmentation of R&D base. Mission approach for identified priorities areas.

(*xxi*) Demand side management through energy conservation measures. Labels regarding energy efficiency to be displayed on appliances. Efficient agricultural pumpsets and efficient lighting technologies to be promoted. Appropriate tariff structure for managing the peak load.

(*xxii*) Special attention for developing training infrastructure in the field of regulation, trading and power market.

(*xxiii*) For giving boost to renewable and non-conventional energy sources, a prescribed percentage of power, as specified by State Regulatory Commissions, to be purchased from such sources of energy at the earliest.

1·14. National Tariff Policy

The key highlights of the National Tariff Policy are :

— The aim of the policy is to ensure financial viability of the sector and attract investments, promote competition and efficiency, ensure availability of electricity to consumers at reasonable rates and promote transparency, consistency and predictability in regulatory approaches. The policy provides clarity on determination of cross-subsidy and additional surcharges for open access to consumers.

— To promote competition aimed at benefiting consumers, the policy provides that all future requirements of power should be procured competitively except in case of a one-time expansion of existing projects where a state-controlled public-owned company has been identified as the developer. A transition period of five years has been indicated for achieving the goal of developing generation and transmission projects in the public sector through competitive bidding only.

— The Forum of Regulators (constituted by the central government for consistency in regulation in the area of distribution) has been asked to decide the basic framework of service standards so that the standards regarding quality, continuity and reliability of service can be enforced. Licensees failing to meet this standard will face penalties.

— A multi-year tariff (MYT) framework is to be adopted for any tariffs to be determined from April 1, 2006 along with incentives and disincentives for incentivising better performance. Gains from efficient operations are to be shared with consumers. Continued and proven inefficiency must be controlled and pnalised.

— The regulatory commissions would put a system of independent scrutiny of financial and technical data submitted by the licensee in place. They have also been called upon to encourage suitable local area based incentive and disincentive schemes for the staff of the utility linked to reduction in losses. Third party verification of energy audit results are to be used to impose area-specific surcharge for larger losses. Greater transparency and nurturing of consumer groups will be the key feature of regulatory processes.

— The policy lays down a timeframe for rationalisation of electricity tariffs and reduction of cross-subsidies within band of ± 20 per cent by the end of year 2010-11. It also lays down the formula for computation of cross-subsidies. Consumers below the poverty line and consuming a small quantity of electricity shall continue to receive special support through cross-subsidised tariffs.

— The tariffs for agricultural use are to be fixed so as to address concerns about sustainable use of ground water resources. The provision of free electricity is not desirable as it encourages wasteful consumption of electricity and in most of the cases, depletion of the water table. To promote energy efficiency, time-differentiated tariffs are to be put in place within one year for large consumers of 1 MW and above.

— For projects whose tariff is determined through performance-based cost of service regulation, the benefit of reduced tariff after full depreciation of assets is to be made available to the consumers. Similarly, for avoiding front loading of tariff, debt of longer tenor and adoption of mechanisms like take-out financing are to be considered. Restructuring of debt is to be incentivised keeping in view the interest of consumers.

— Any additional capital investment for renovation and modernisation is to be linked with pre-determined efficiency gains or for sustaining high level performance.

— To promote non-conventional sources of energy, a minimum percentage of energy, as specified by the regulatory commission, is to be purchased from such sources by April 1, 2006. The developers of the project are to be given adequate incentive to avail of benefits of the clean development mechanism (CDM). The cost of the project will also allow reasonable cost of setting up coal washeries, coal beneficiation systems and ash handling and disposal systems.

— To improve grid discipline, the availability-based tariff system is to be extended to the state level within the next one year. This will also facilitate integration of captive generation plants with the grid.

— To give a choice of supply to the consumers, the tariff policy enunciates a facilitative framework for calculating cross-subsidy surcharge. It also lays down a mechanism for arranging backup supply for such consumers.

1·15. Global Environmental Concerns

Global Environmental Issues. Environment is a global issue since there are no boundaries for it. Advanced countries have released considerable greenhouse gases and other toxic gases into environment. We have reached alarming limits. To avoid further degradation several treaties, conventions and protocols in the field of environmental protection have taken place in recent past. It is being realised that present human activities are interfering with the way the sun interacts with the earth, resulting in global warming and climate change. Environmental degradation affects all mankind on a global scale - without regard to any particular country, race, or region. The whole world is therefore a stakeholder and this raises issues on who should do what to combat environmental degradation. Global environmental stability is a serious concern for future of human mankind.

The environmental issues of global significance are :

(*i*) Ozone layer depletion, (*ii*) Land degradation, (*iii*) Air and water pollution,
(*iv*) Sea-level rise, and (*v*) Loss of biodiversity

Ozone Layer Depletion

Three zones of atmosphere on earth are troposphere, sonosphere and stratosphere.The stratosphere extends from 10 to 50 kms. from the Earth's surface. Stratosphere contains a layer of a slightly pungent smelling light bluish gas made up of Ozone molecules. This layer acts as an efficient filter for harmful solar Ultraviolet B rays. Ozone layer is highly beneficial for human, animal and plant life on earth. Any disturbance/depletion of ozone layer will allow harmful radiation to reach earth and have grave consequences. Ozone is a very unstable molecule and exists due to high intensity ultra violet rays of the sun. The amount of ozone in the upper atmosphere and in the stratosphere formed during millions of years is in a continuous state of equilibrium. Ozone is constantly formed and destroyed also by sun's rays as well as other substances drifting up in the Stratosphere but overall amount of ozone has been essentially stable. Ozone is highly reactive and easily broken down by man-made chlorine, bromine compounds, CFCs (used in refrigerator and air conditioners) and other ozone-depleting substances. These compounds after several years, reach the stratosphere by diffusion. Strong UV light breaks these molecules to release chlorine atoms, and halons and methyl bromide release bromine atoms. These atoms destroy ozone.

Increased penetration of solar UV-B radiation has potential risks of eye disease and skin cancer. It could also alter the biodiversity in diferent ecosystems. High levels of exposure in tropics and subtropics may affect the distribution of phytoplanktons, which form the foundation of aquatic food webs. It can also cause damage to early development stages of fish, shrimp, crab, amphibians and other animals.

Increased solar UV radiation could affect terrestrial and aquatic bio-geo-chemical cycles thus altering both sources and sinks of greenhouse gases. Reduction of stratospheric ozone and increased penetration of UV-B radiation result in higher photo dissociation rates of key trace gases that control the chemical reactivity of the troposphere.

Q. 1·1. What is the difference between primary energy and secondary energy ?

Ans. Primary energy sources are either found in nature or are stored in nature. Common primary energy sources are coal, oil, natural gas, and biomass. Primary energy sources are mostly converted in industrial utilities into *secondary energy* in the form of electrical energy.

Q. 1·2. Explain the difference between renewable and nonrenewable energy briefly.

Ans. Renewable energy sources are essentially inexhaustible like wind power, solar power, geothermal energy, tidal power and hydroelectric power. Renewable energy can be harnessed without the release of harmful pollutants.

Non-renewable energy is the conventional fossil fuels such as coal, oil and gas, which will deplete with time and these emit harmful pollutants.

Q. 1·3. How much coal reserves are estimated in earth ? What is the rough percentage of reserve of coal in earth in India ?

Ans. The global coal reserves are estimated to be 10×10^5 million tonnes (approx). India is 4th largest in world and it has approximately 9% share.

Q. 1·4. What is the share of India in terms of primary consumption of fuel in world ?

Ans. Around 3·5%.

Q. 1·5. What is the approximate sectorwise energy consumption pattern in India?

Ans. Industry is the biggest consumer (50%) followed by transport (22%), residence (10%), agriculture (5%), etc.

Q. 1·6. What is energy intensity ?

Ans. Energy intensity is energy consumption per unit of GDP. Energy intensity indicates the development stage of the country.

Q. 1·7. What do you understand by global warming and climate change ?

Ans. Global warming refers to the long-term fluctuations in temperature, precipitation, wind and other elements of the earth's climate system. Increasing fossil fuel use has led to increasing carbondioxide emissions leading to green house effect and global warming. The energy use has attracterd huge attention due to its associated global climatic impacts. The heating up of earth's atmosphee the to trapping of long wavelength infrared rays by the carbondioxide layer in the atmosphere is called green house effect. It is generally believed that the combustion of fossile fuels and other human activities are the primary reason for the increased concentration of carbon dioxide.

Q. 1·8. What are the key greenhouse gases (GHG) driving global warming ?

Ans. Carbon-dioxide is the primary global warming gas. CFC's are also significant contributors to global warming. Other sources are methane, ozone, nitrous oxide. In addition perfluorocarbons (PFC's), sulfur hexafluoride (SF_6) and hydro fluorocarbons (HFC's) are also growing contributors.

Q. 1·9. Carbondioxide is one the most prevalent greenhouse gas in the atmosphere, who are major contributors to this ?

Ans. 80% of CO_2 is released by burning of fossil fuels - coal, oil, and gas and around 20% by cutting down forests.

Q. 1·10. How acid rain is caused and what are its harmful effects ?

Ans. Acid rain is caused by release of SOx and NOx from combustion of fossil fuels, which then mix with water vapour in atmosphere to form sulphuric and nitric acids respectively. The effects of acid rain are as follows :

(*a*) Health problems (respiratory, burning-skin and eyes)

(*b*) Killing of wildlife (trees, crops, aquatic plants, and animals)

(*c*) Acidification of lakes, streams, and soils

(*d*) Decay of building materials and paints, statues, and sculptures.

Q. 1·11. What is energy security and what are the strategies to be adopted for it ?

Ans. To reduce dependence on the imported energy sources for economic growth is the basic aim of energy security. Import of coal, oil, LNG, etc. implies vulnerability to external price shocks and supply fluctuations, which threaten the energy security of the country. Some of the strategies that can be used for energy security are :

(*a*) Diversification of energy supply sources.

(*b*) Reducing demand through persistent energy conservation efforts.

(*c*) Increased capacity of fuel switching.

(*d*) Building stockpiles.

(*e*) Demand restraint by energy management.

(*f*) Development of renewable energy sources.

(*g*) Greater focus on engegy efficiency and sustainable development.

Q. 1·12. What is the difference between energy conservation and energy efficiency ?

Ans. Energy conservation implies utilising energy in most optimum manner so that quality does not suffer. It thus results in reduction of growth of energy consumption and conservation of fossil fuels. Energy Conservation is thus possible with productivity increase or technological progress. Energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels. Promotion of energy efficiency will contribute to energy conservation. Energy efficient equipment uses less energy for same output and reduces CO_2 emissions.

Energy efficiency provides additional economic value by preserving the resource base and reducing pollution. Energy efficiency does not lie in cutting down comfort level but it means using less energy to perform the same function. Energy efficiency is the most cost-effective and reliable means of mitigating the global climatic change.

Energy efficiency for industries results in increased competitiveness, increased productivity, improved quality, increased profits and reduced energy bills.

Q. 1·13. What are clean coal technologies ?

Ans. Clean Coal Technologies (CCTs) are defined as 'technologies designed to enhance both the efficiency and the environmental acceptability of coal extraction, preparation and use'. These technologies reduce emissions, reduce waste, and increase the amount of energy gained from each tonne of coal. Coal contributes to the energy security, economic prosperity and social development. It meets all the environmental regulations and competes with oil and natural gas for power generation. Coal is produced, transported and used in ways that fully protect the environment.

To meet environmental concerns, clean coal technologies are applied at the three stages in fuel chain i.e. precombustion, during the combustion and post combustion.

Q. 1·14. List various technologies to control pollution, viz particulate matter, SO_x and NO_x and how much these technologies control the pollutants ?

Ans. Refer table given below for pollution control/reduction technologies for SO_2, NO_x and particulate matter :

Technology for control of pollution	*Pollutants controlled and reduction efficiency, %*		
	SO_2	*NO_x*	*Particulate Matter*
Physical coal cleaning	10-40	N/A	30-60
Advanced coal cleaning	30-70	N/A	Up to 70
Low-NO_x burner	N/A	30-60	N/A
Sorbent injection	30-60	None	N/A
Duct injection			
Pre-ESP	30-70	N/A	N/A
Post-ESP	70-90	N/A	N/A
Wet FGD	90-99	N/A	
Dry FGD	70-90	N/A	N/A
SNCR	None	35-60	N/A
SCR	None	70-90	N/A
Combined SO_x/NO_x	80-95	80-90	Possible
Advanced ESP	N/A	N/A	Up to 99·9
Bagfilters	N/A	N/A	Up to 99·9
Hot gas cleanup	N/A	N/A	Up to 99·9

ESP = electrostatic precipitator; FGD = flue-gas disulfurisation, SNCR = selective noncatalytic reduction; SCR = selective catalytic reduction.

Q. 1·15. What are the advantages of Integrated Gasification Combine Cycle (IGCC) ?

Ans. (*i*) IGCC systems can achieve efficiencies close to 45% and with recent advances in gas turbine technologies these systems can attain efficiencies above 50% (*ii*) IGCC systems produce less solid waste and lower emissions of SO_x, NO_x and CO_2 (*iii*) Over 99% of the sulphur present in the coal can be recovered economically for sale as chemically pure sulphur (*iv*) Gasification can also be integrated with fuel cell for most efficient and cleanest power generation, (*v*) Environmental performance and cost optimization is possible through the following areas of technology development; —(*a*) Advanced gasifier and gas separation, (*b*) Hot gas desulfurisation and hot particulate removal, and (*c*) Advanced turbine systems. (*vi*) IGCC operating costs can be lower than those of a PC plant due to reduced fuel use from its low heat rate, by-product sulfur credits and low volume of solid waste (*vii*) Other potential economic advantages of IGCC can be achieved through phased construction, co-production/co-generation and fuel flexibility.