APPENDIX I. PRESENTATIONS AT THE MEETING

(10) **Environmental Impacts of Energy Alternatives**,
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Environmental Impacts of Energy Alternatives - Indian Scenario

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INTRODUCTION

The generation of electricity by any energy source usually entails emissions and disposal of waste products to air, water and land, giving rise to potentially short or long term impacts, either immediately or after a considerable time has elapsed. At present there are economical and technological limitations to the elimination of these emissions and wastes. Thus, there will always be environmental impacts with the present day commercially available electricity generation technologies. The nature and extent of environmental impacts depend on the nature and the quantity of the fuel used, the method of conversion, the level of pollution control technology and the efficiency of the pollution control unit's operation. The environmental impacts of alternative energy systems available at present are not fixed, but are dependent on the resource employed to curtail them. Although waste discharge during electricity generation depends to a large extent on the pollution control technology employed for the purpose, there are emissions, which are in a sense, intrinsic with the fuel used. The examples include carbon dioxide emissions from fossil fuels and radioactive releases from nuclear fuel cycle.

To-day some people are more concerned about the environmental risks from technologies. The power generation from nuclear plants might have inspired this awareness for it is only in nuclear power plants an effort is made to identify the hazards and to quantify the risks. The necessary adequate consideration was given from the very beginning to the total protection of the environment in case of power generation based on nuclear fuel cycle in India. This can be aptly illustrated by quoting a portion of the Office Order issued by the Father of the India's nuclear power programme, Dr. Bhabha. "Radioactive substances and source of radiation should be handled not only in a manner which fully ensures that no harm can come to workers in the establishment or any one else but also in an exemplary manner so as to set a standard which other organisations in the country may be asked to emulate....." In any nuclear power plant in India at the time of design and construction appropriate measures have been taken to fulfil these objectives. Twenty five years of operating experience and the environmental effects of the nuclear power plant indicates negligible amount of additional radiation level compared to the natural radiation background in the immediate vicinity of the power plant. Therefore it can be conclusively said that there is hardly any radiological impact. In considering the overall impact of any industry on the environment other effects may also become important. These include aesthetics, effects of flora and fauna, land use change, depletion of natural resources, materials used, waste disposal and social impacts etc.

In this paper, a few of the effects mentioned above, arising out of energy alternatives have been considered.

MAJOR ENVIRONMENTAL ISSUES OF ELECTRICITY GENERATION

AIR POLLUTANTS

Fossil Fuelled Technologies

Most fossil fuelled technologies produce air pollutants - like nitrogen oxides, sulphur dioxides and carbon dioxide - those are believed to contribute to acid rain and global warming. Reductions in carbon dioxide emissions can be achieved by switching fuel from high to low carbon sources or

alternatively changing the source of fuel to non carbonaceous. Sulphur dioxide emissions can be reduced by switching to desulphurisation process.

Nuclear Technologies
The nuclear power plant is inherently free from emissions of carbon dioxide, nitrogen oxides, sulphur dioxides, and other greenhouse gases; however, considering total energy cycle approach some amount of such emissions have to be accounted to fossil fuels utilised during construction of nuclear power plants and mining and processing of nuclear fuel materials. The main environmental impact from nuclear power plants is due to emissions of very low level radioactive gases and low level radioactive liquids which are however, controlled so as not to increase the radioactivity in the environment to any significant level beyond the background.

Renewable Energy Systems
Some renewable technologies offer an alternative path for reducing pollution at the plant level, e.g. solar, wind, wave, ocean thermal and tidal power. Airborne emissions from geothermal energy using such technologies are CO2, as exhaust of the spent steam into the atmosphere.

SOLID WASTE

Fossil Fuelled Technologies
Solid waste production from fossil fuel fired power plants and their fuel cycle is a wide ranging subject. This paper focuses on the coal fuel cycle since the related solid waste problems are more serious than those of the natural gas and oil cycles.

Nuclear Technologies
Nuclear power and its fuel cycle produce radioactive wastes in which there are varying degrees of a range of radioactive isotopes. The problems of managing and disposing of this waste are most demanding for high level waste which results from the reprocessing of spent fuel.

Renewable Energy Systems
On the whole the amount of solid waste produced by renewable energy sources at the plant level is very limited compared with fossil fuelled power plants.

In densely populated areas the comparative assessment of alternative electricity supply options is increasingly determined by the land requirements for the technologies. Economic criteria such as acquisition costs, environmental impacts such as land degradation or diminishing habitat for flora and fauna and such other aspects gain importance in the choice of electricity generation options. Land requirements receive special importance when electricity plants or systems are in direct competition with agricultural land usage. In evaluating the land requirements conditions need to be addressed are: the physical space requirement of the plant itself, the net land requirement and the gross land requirement. Comparative assessment of specific land requirements for the different electricity generation technologies discussed in this paper restricts itself to those necessary for plant operation.

For the fossil fuels, some of the local and regional impacts are ground and surface water contamination, forest degradation from sulphur dioxide and nitrogen oxides emissions. With respect to the nuclear cycle, some of the local and regional impacts are ground and surface water contamination, radiation effects, and land/water contamination under accident conditions. As for the renewable energy sources, some of the local and regional impacts are atmospheric pollution during construction and changes to the hydrological patterns and water quality. Only in the case

of fossil fuel, there could be long term global impacts like climate change from carbon dioxide and other greenhouse gas emissions.

Three main categories of pollutants are evident. The first consists of gases that have long residence time globally i.e. carbon dioxide emissions. The second comprises emissions or effluents with shorter residence times leading to regional impacts. The acid depositions with characteristic residence times of a few days and transport potential of a few thousand kilometres exemplified by sulphur dioxide, fall under this category. The third category of predominantly local impact is composed of heavy hydrocarbons and particulate which are deposited in hours and travel less than 100 km from their source.

Examples of largely local impacts from electricity generating facilities can be found world-wide in many urban situations and in other areas where large facilities are sited. They include emissions to the atmosphere, via cooling towers, stacks, venting ducts, fuel handling or ash disposal activities. Fuel combustion, particularly that of fossil fuel, has resulted in significant emissions of sulphur dioxide and nitrogen oxides to the atmosphere over recent decades leading to regional impacts

An attempt is being made in this paper to analyse the effect of increasing power generation on the environment. Based on the present day technology it is not possible to make reasonably accurate predictions on the effect of the present day pollution discharges leave alone the increased level in the years to come, the green house effect, the problem of radioactive waste or the effect of impounding large volumes of water though the qualitative effects can be studied on the basis of relative undesirability. As such the analysis given here are either qualitative in nature or indicative of trends only.

ENVIRONMENTAL IMPACTS OF ELECTRICITY GENERATION

COAL FUEL CYCLE

The coal based fuel cycle contains the following stages: mining, transportation, combustion, power transmission and solid waste disposal. Mining activities, particularly open cast mining operation result in the deterioration of air quality and degradation of land and soil erosion. The main air pollution effects for the coal fuel cycle are acid rain and the greenhouse effect. The former is due to sulphur oxides and latter is due to carbon dioxide. The acid rain has caused severe damage to the flora and fauna in many parts of the world. Carbon dioxide is transparent to incoming solar radiation but retains the longer wavelength heat back near the earth's surface. This trapping of the heat near the earth's surface is known as the greenhouse effect. The pre-industrial level of carbon dioxide was 280 PPM and the 1990 value is 353 PPM. The rate of carbon dioxide increase is 0.5% per year due to anthropogenic emissions. The rate of accumulation from fossil fuel burning and deforestation is 4% per annum .As per estimates a doubling of carbon dioxide content from the pre-industrial level will cause an increase in temperature of 4-6 deg.C which will result in the melting of the ice sheets in Antarctica.

Burning of coal results in vitrification of ash, 20% of which is heavy and appears as slag. The balance is a light fraction particulate with sizes ranging from 1/1000 of a micron to 1 micron. Coal contains significant quantities of naturally occurring radionuclides such as K-40, U-238, Th-232 and their decay products whose concentration gets enhanced in burning process. The trace elements found in coal are arsenic, cadmium, cobalt, chromium, mercury, etc.

Indian coal has a very high ash content (30 - 50 %) and hence the fly ash problem in India is very severe. Based on coal consumption during the year 1993-94 approximately 33 million tonnes of fly ash was generated in India from the coal fired thermal power stations. The land requirement for disposal of this ash is continuously increasing and use of this conventional system also causes air, soil and water pollution. The disposal of fly ash near water bodies will also create difficulties as in addition to radionuclides, toxic trace elements may also get washed out. Alternate use of ash in road buildings, bricks etc. are being pursued in India to some extent.

OIL FUEL CYCLE

The major emissions and solid and liquid waste streams associated with the oil cycle are generated during extraction, transportation, refining, construction and combustion at a power plant. In the refinery, liquid effluents contain grease, phenol, chromium, lead, and numerous dissolved and suspended organic and inorganic chemicals in lesser amounts. The releases to the air in the refinery as well as in the power plant include carbon dioxide, nitrogen oxides, sulphur dioxide and organic chemicals. Oil is also lost by blowouts or spills at wells. The waste heat and boiler-wash waste effluents are also discharged to water.

NATURAL GAS CYCLE

The emissions and waste streams arise from extraction, processing, transmission and combustion at a power plant. The flue gas emissions include sulphur dioxide, nitrogen oxides, various organic chemicals and particulate. In addition, there is methane loss during gas transmission to the plant.

NUCLEAR FUEL CYCLE

The uranium mining and milling, fuel fabrication, power plant operation, spent fuel reprocessing and management of high level wastes are the components of a nuclear fuel cycle. The main environmental impact from nuclear power plants is due to emission of very low level radioactive gases and low level radioactive liquids. These emissions are strictly regulated and controlled, with the discharge limits set such that even the most exposed persons living in the vicinity of the nuclear power plant are subjected only to very small risks to health. For the nuclear cycle, the emissions are generated mainly during uranium milling and reactor operation. The atmospheric releases are radon and gaseous fission product radionuclides. The liquid releases in milling contain small amounts of uranium, thorium and radium and in power plant operation, releases contain radioactivity due to fission products.

RENEWABLE ENERGY CYCLE

Airborne emissions from geothermal energy are carbon dioxide, exhaust of the spent steam into the atmosphere, hydrogen sulphide, mercury, ammonia and radon. Wastes are generated during dam construction, extraction of geothermal fuel, fabrication of fuel cell, collector panel and wind mill and biomass production.

HYDROELECTRIC CYCLE

Some of the important environmental consequences of hydroelectric stations are loss of vast areas of habitat for the people, impoundment of large mass of water which may induce seismic activity as in the case of dam induced Koyna earthquake of 1967 which caused 200 deaths and destruction of houses. The evaporation losses in a reservoir are higher than in the original river system which

leads to increase in concentration of dissolved solids. pH & oxygen are lower at greater depths in reservoirs; carbon dioxide and inorganic nutrients register increased levels and these conditions favour growth of macrophytes and phytoplankton which provide the much needed habitat for diseases such as malaria. The severest of the social impact of hydroelectric projects is perhaps the land submergence and the displacement of large populations.

ENERGY SCENARIO IN INDIA

India saddled with high population density and low standard of living faces an uphill task.

As mentioned earlier all transformation of energy to useable form have environmental impact. In India, from all sides be it written media, electronic media or learned publications, it is being emphasised that something radical has to be done about pollution control.

To some it has assumed a significance almost amounting to opposing any development and a review of the population growth from 1972 and its projection unto the year 2020 AD indicates that global population is expected to increase from a figure of 3760 millions in 1972 to a figure of 6193 millions by the year 2000 AD and is projected to reach a staggering figure of 8000 millions by the year 2020 AD. India contributes 16% of the total population as per 1991 census and this figure is expected to rise to 25% by 2020 which means in less than 25 years one person in every four will be from Indian sub-continent. One also notices with a high degree of apprehension that the time of doubling the population has become slightly more than 35 years and all these directly reflect on the efforts necessary for electricity generation.

Availability of per capita power in India was almost negligible and was of the order of 15 kWh in 1950 which increased to 300 kWh presently which is 40 times less than the consumption by the North American countries and 15 times less than that of Singapore and 8 times less than that of the average consumption of that of the world. Due to very low industrial growth in spite of high growth rate of population the industrial pollution created by India has been moderate. The present installed capacity of electricity generation in India is 61,000 MW thermal, 21,500 MW hydroelectric and 1640 MW nuclear. Utilisation factor of installed capacity based upon the figure of gross generation of energy works out to be slightly above 50%. The planners are now aware of the importance of the problem of meeting the peak demand. The estimate of required energy consumption in a developing country like India in a warm climatic zone for maintaining a decent standard of living has been worked out as 210 watts of electricity & 839 watts of fuel in a total of 1049 watts. The break-up is given in the table below:

Activity	**Electricity (watts)**	**Fuel(watts)**	**Total(watts)**
Residential	51	34	85
Commercial	22		22
Transportation	12	276	288
Manufacturing	121	429	550
Agriculture	4	41	45
Mining		59	59
Total	210	839	1049

Based on the above to support a population of 1000 million the annual demand for energy works out as given below and can be considered as a conservative estimate of the future energy demand.

A. Fuel

a) Oil equivalent of liquid and gaseous fuels - 260 x 10E6 Te
b) Coal equivalent (HCV of 3000 Kcal /kg of other fuel) - 1260 x 10E6 Te

B. Electricity

a)Total electrical energy - 1840 x 10E9 kWh
b) Coal equivalent of fuel at 40% efficiency of conversion - 1300 x 10E6 Te
c) Installed capacity 368,000 MW

This installed capacity will require major addition to the existing capacity and the environmental impacts are highlighted subsequently.

COAL CYCLE :

The effect of environment may be divided into following categories:

1) Effect on vicinity

2) Effect within the political boundary of the country

3) Effect on adjacent regions

4) Effect on earth environment as a whole

Each of the above mentioned categories can be sub-divided into (a) short and (b) long term effect.

On the basis of average coal having a calorific value of 3800 Kcal/kg and weighted heat rate of 2065 Kcal/kWh for the power cycle fuel consumption will be of the order of 640 Kg/MWh and if the following assumptions are made

a) Sulphur content - 0.6%
b) NOx - 200 mg/Nm3 of flue gas
c) Ash content - 40%
d) 80% Carbon in ash free coal
e) 80% of the ash generated will be fly ash
f) Electrostatic precipitator efficiency - 99.75%

Emission of gaseous pollutant per MWh generated will be approximately as follows:

a) SO2 - 7.67 Kg
b) NOx - 0.76 Kg
c) Fly ash through stack - 0.51 Kg
d) CO2 - 1124.00 Kg

For the fossil fuel field power station only CO2 missions will have any global significance. The other gaseous pollutants will have significant effects within the country causing respiratory problems and affecting the flora and fauna. However, significant increase in generation of electrical power in the eastern region may lead to these pollutants to having an impact on the neighbouring countries of Bhutan and Bangladesh. As regards its effect within the country almost all the pollutants have adverse effect on human health as they all causes respiratory troubles. India which hardly contributed 1% of the global pollution in the year 1950 contributes less than 2.5% now, Large areas will be required to impound the ash and leaching of heavy metals may lead to poisoning of

the lakes and rivers over a length of time and may also adversely affect the underground water. Liquid pollutants generated by power generation are primarily from treatment of water. For the future installed capacity of 368,000 MW the Indian contribution to the global emissions is given below assuming that 70% of the power generated would be contributed by coal. To achieve this targeted increase of power generation India may become a sizeable contributor of CO2 and SO2 to the atmosphere in the future.

Gas	Emission per year (MT.)	Residence time
Carbon dioxide (CO2)	1450	100 yr.
Sulphur dioxide (SO2)	10	Days to weeks
NOx	1	Days
Fly ash through stack	0.65	hours
Total ash	330	-

The environment impact from a coal based power station based on present day technology is given below. The total installed capacity of the plant is 2100 MWe with 3 units of 200 MWe and 3 units of 500 MWe each. The daily coal requirement is of the order of 32000 - 35000 Te's. The ash content varies from 37.6 % to 44.1 % and the calorific value coal is approximately 3500 Kcal/kg. Particulate matter, SO2 & NOx are the main pollutants through stacks as given below.

Unit No	Diam. (m)	Height (m)	Load (MW)	Velocity (M/sec)	Temperature (oC)	Particulate (mg/m3)	SO2 (mg/m3)
1	5.0	200	200	19.45	110	146	536
2	5.0	200	204	16.67	110	145	525
3	5.0	200	210	18.33	110	142	542
4	6.75	220	500	16.11	105	135	528
5	6.75	220	468	13.33	110	148	516
6	6.75	220	386	14.72	120	122	538

The quality of the three main effluents from the plant are given in the Table shown below:

Parameter	Plant effluent	Cooling water	Ash pond effluent
Quantity (m3/hr)	1000	240,000	2,500
pH	7-7.5	7-8.5	6.5-7.1
Temperature (oC)	28-32	23-30	22-33
TSS (mg/1)	60-250	135-250	500-1800
B.O.D (mg/1)	5-15	10-16	-
Iron (PPB)	170	150	580
Cu (PPB)	<20	<20	<20
Cd (PPB)	<20	<20	<20
Cr(PPB)	<25	<25	<25
Pb (PPB)	< 50	<50	<50

The total quantity of ash produced is 12,700 Te's/day of which about 2540 Te's/day is bottom ash. Out of 10160 Te's/day of fly ash 10,109 Te's/day is collected in ESP's. The total quantity of ash disposal as solid waste is 12,649 Te's/day. The area of the ash pond is 390 ha and an additional area of 445 ha is being acquired for future expansion. The composition of the fly ash is given below. The units are PPM except where especially mentioned as %

Element	Concentration	Range	Mean
Na	165.87	298-2200	811
K	2264	0.37-1.60(%)	0.88(%)
Mn	213.84	180 -1000	410
Fe	21500	2.60-15.0(%)	4.7(%)
Cu	NA	43.0 - 190	100
Zn	20.61	7.9 - 300	100
Cr	71.69	58.8 - 222	120
Ni	17.13	56 - 290	150
Pb	NA	5.3 - 85	35.0

The fly ash problem in India is quite severe and it is essential to set up coal washeries.

	India	USA/Germany etc.
Power Plant	210 MW	210 MW
Heat duty MK Cal/hr	454	454
Fuel fired MK Cal/hr	520	520
Heat value K. Cal/kg	3800	6000
Coal t/hr	137.5	87.5
Ash Content %	40	8
Ash generated t/hr	55	7

NUCLEAR CYCLE:

For the nuclear fuel cycle in the Indian context, the environmental impact due to radiation from the different stages of the fuel cycle is given below:

Uranium Mining & Milling :The radiological impact in the public domain arises out of environmental radon inhalation and radon releases from the tailings pond. The regional collective dose due to radon inhalation is estimated at 3 person - Sv/GWe year and that from the tailings pond 2.2 person-Sv/GWe year.

Fuel Fabrication: The collective dose in the public domain is virtually nil.

Power Plant Operation: The Atomic Energy Regulatory Board has stipulated that exposure to an individual member of the public from power plant releases shall not exceed 1 mSv/year.

The environmental radiation doses at nuclear power plant sites are given below in mSv/yr.

	TAPS	RAPS	MAPS	NAPS
Natural background radiation	1.96	2.12	2.40	3.22
Dose limit from man-made sources	1.00	1.00	1.00	1.00
Technical Specification limit	0.35	0.18	0.27	0.45
Actual dose to public at boundary	0.048	0.055	0.044	0.0009

Fuel Reprocessing :The environmental release from the facility is insignificant.

High level Waste Management : For the Tarapur Waste Management Facility the future projections are 0.5 person-Sv/GWe year in the public domain.

HYDROELECTRIC CYCLE

In the context of the hydroelectric cycle in India 1554 dams are estimated to have caused the displacement of 6.5 - 7 million persons. The Narmada project will displace about 67,000 persons. The displacement of human settlement results in severe social impacts such as obtaining less productive land, psychological stresses due to unfamiliar environment etc. One estimate indicates that an average hydel project in India needs 0.186 sq. km/MWe compared to 0.0006 sq. km/MWe for a nuclear plant. Data on land needs of major nuclear and hydroelectric projects is given below:

Project	Plant Type	Capacity MWe	Submergence area sq.km	Rehabilitation involved
Sharavati	Hydroelect	946	274	12000 persons
Bhakra	Hydroelect	1200	256	36000 persons
Tehri	Hydroelect		870	20 villages
Iddikki	Hydroelect	780	64	unknown
Damodar	Hydroelect			93000 persons
Narmada	Hydroelect	1450	348	67000 persons
Kalinadhi	Hydroelect	910	108	
Varahi	Hydroelect	239	60	
Kadra	Hydroelect	150	29	
Gandhi sagar	Hydroelect	120	653	70 villages
Tarapur	Nuclear	2 x 160	4*	200 families
Rajasthan	Nuclear	2 x 200	15*	None
Madras	Nuclear	2 x 170	4*	700 persons, 3 villages
Narora	Nuclear	2 x 220	4*	2000 persons,6 villages
Kakrapar	Nuclear	2 x 220	8*	None
Kaiga	Nuclear	2 x 220	10*	320 persons

* Including land for exclusion zone.

CONCLUSION

Indian society today is concerned about the health and environmental risks of technologies. The major environmental issues of concern for technologies available for electricity generation are air emissions, management of wastes generated and land requirements. The production of electricity in India is primarily composed of a mix of thermal and hydroelectric power plants with nuclear energy currently contributing to an extent of slightly above 2.0%. For maintaining a decent living standard the present electricity generation has to be increased manifold and with the existing commercially available technologies this can lead to a greater impact on the environment in the immediate vicinity of plant unless a judicious mix is chosen. India which hardly contributed 1% of the global pollution in the year 1950 contributes about 2.0% now and with the growth in electricity generation its contribution will also be slightly increasing and hence environment will have to be one of the guiding factors in future choice of technologies for the growth of electric power generation.

Indian coal has a very high ash content (30 - 50 %) and hence the fly ash problem in India can be severe. During the year 1993-94 approximately 33 million tonnes of fly ash was generated in India from the coal fired thermal power stations. The land requirement for disposal of this ash is continuously increasing. The disposal of fly ash near water bodies will also create difficulties as in addition to radionuclides, toxic trace elements may also get washed out. Pollution from the use of coal will have a definite effect on the environment in addition to depletion of the energy source.

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