- Electricity demand is expected to rise by 7.4% a year during the next quarter of a century. This will see generation capacity increase five-fold in India is to supply this growing demand.

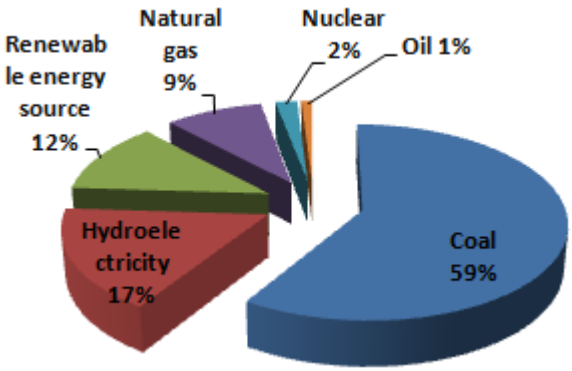

Figure 1: Electricity installed capacity in India by source

3. Prediction of Population, Energy Demand and CO_2 Emissions by 2050

On the basis of "Parabolic Fit" one may predict the population growth and energy demand and also CO_2 emissions due to power generation from thermal power plants; for the year 2050. We begin by predicting the population growth on the basis of the available population data since 1951 onwards. The assumption of parabolic population growth is made in order to find out the average rate of growth and then predict the population for the middle of the century. The equation employed is the following.

Parabolic fit

$$N(z) = N(z_0) + (z - z_0)N'(z_0) + \frac{(z - z_0^2)}{2}N''(z_0)$$

Here, z_0 is regarded as the base year and the above equation may be used to predict the population in a subsequent year z. The symbol N stands for population in a particular year.

Choosing $z_0 = 2001$ and $z = 2051$, we note that $N(z_0) = 1028$ the magnitude of N' is calculated from Table 1.

$$N'(z_0) = \frac{N(2001) - N(1991)}{10}$$

$$= \frac{1028 - 684}{10}$$

=16.4

Similarly, $N'(1991) = 18.1$

Further $N''(z_0) = \frac{N'(2001) - N'(1991)}{10}$

$$= \frac{16.4 - 18.1}{10}$$

$= -0.17$, Substituting, we get

$$N(2051) = 1028 + 50(16.4) + \frac{50^2}{2}(-0.17)$$

=1636 million

When population grows faster than GNP, the standard of living of the people does not improve. In fact rapid population growth has been obstructing economic growth in developing countries like India where since 1951 population has been growing at a relatively high rate. In Table1 we present the actual population growth in India.

Table 1: India's actual population [5]

Year	*Population (million)*
1951	361
1961	439
1971	548
1981	683
1991	864
2001	1028
2011	1210

4. Impact of Population Growth on Environment

It is important to realise that the relationship between population and the environment is complex. Human impact on environment is a function of three major, interconnected elements: population size, energy consumption, and level of technology. Population is an important source of development, yet it is a major source of environmental degradation also when it exceeds the threshold limits of support systems. Unless the relationship between the increasing population and the life support system can be stabilized, development programs, howsoever, innovative are not likely to yield desired results. Population impact on the environment arises primarily due to the use of natural resources and production of waste. It is associated with environmental stress like loss of biodiversity, air and water pollution and increased pressure on arable land. Human population issues are extremely important when it comes to our way of life and our future on this planet.

Environmental degradation is the result of dynamic inter-play of socio-economic, institutional and technological activities. Environmental change may be driven by many factors including economic growth, population growth, urbanization, expansion of agriculture, rising energy use and transportation. In 2050 India's population is projected to be 1636 million, as calculated above. This dramatic change will coincide with development in all fields. A rapid increase in India's population and simultaneously the misuse of modern technology has created environmental crises which has threatened the future of human beings.

5. Environmental Challenge

Environment constitutes a huge international challenge. Population growth and economic development are contributing too many serious environmental problems in India. These include pressure on land, deforestation, water scarcity and air & water pollution. One of the major causes

of environmental degradation in India could be attributed to rapid growth of population, which is adversely affecting the natural resources and environment.

6. Specific Environmental Issues

Recently human impact on the atmosphere has been enormous, with anthropogenic emissions a prime cause of environmental problems. Emissions of almost all greenhouse gases continue to rise. Major environmental issues are forest and agricultural degradation of land, resource depletion (water, mineral, forest, sand, rocks etc.), environmental degradation, public health, loss of biodiversity, loss of resilience in ecosystems, livelihood security for the poor. The major sources of pollution in India include rampant burning of fuel-wood and biomass such as dried waste from livestock as the primary source of energy, lack of organized garbage and waste removal services, lack of sewage treatment operations, lack of flood control and monsoon water drainage system, diversion of consumer waste into rivers, cremation practices near major rivers, government mandated protection of highly polluting outdated public transport, and continued operation by Indian government of government owned, high emission plants. Air pollution, poor management of waste, growing water scarcity, falling groundwater tables, water pollution, preservation and quality of forests, biodiversity loss, and land/soil degradation are some of the major environmental issues India faces today. India's population growth adds further pressure on environmental issues and burden on its resources.

7. Interrelationship among Population, Environment and Development

The environment is the ultimate reservoir to fulfil the basic need of human beings. Human beings need water, air and food which are obtained from the environment. Unlike other creatures, human beings are not satisfied only with fulfilment of basic needs. They need different other facilities to make their life comfortable and improve their living standard. People conduct a wide variety of development activities for various benefits and improvement in their quality of life. To carry out developmental activities the environmental aspects such as land, forest, water and modern technology are used. Development work is incomplete if the environment is not preserved and conserved. The development activities should be conducts for the welfare of human beings without harming or deteriorating the environment. Natural resources available in the environment are used for the development. Activities aimed at growth cannot be conducted in isolation without regard to depleting natural resources. Therefore, development of the nation is not possible without attention to environment. Hence, there is close interrelationship among population, environment and development. Figure 2 indicates this versatile relationship. These all are modify by using the natural resources according to the wish of people. The environment provides the raw materials required to run the industries. Various aspects of development are associated with agriculture, industry, health, transportation, security and communication. Development programmes should be formulated with the aim of conserving animal and plant diversity. Hence, healthy environment and development are both essential to human beings for growth of human civilization and happy and prosperous life.

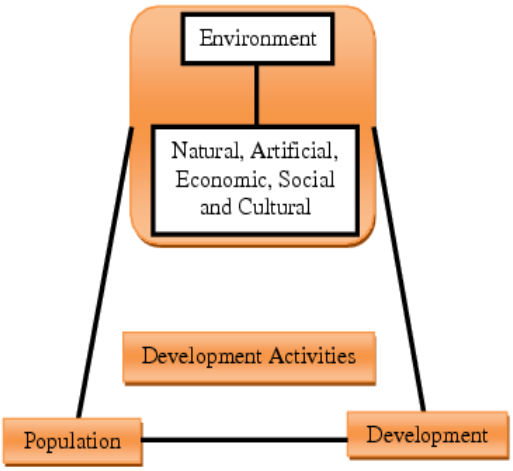

Figure 2: Interrelationship among population, environment and development

8. Energy Demand

The population of India has already been predicted in an earlier section. Now we assume that the electric power generation will be directly proportional to the population. The norms vary from country to country. While in India per capita energy consumption is estimated to be 1000 kWh per year. This figure becomes 4000 kWh in China. We may predict the energy generation by 2050 taking India's present per capita energy consumption to be applicable. We also calculate energy generation assuming that India's consumption norm will become at par with that of China in the year 2050. China is also a developing country as India, and its population is large and in this respect it resembles India. Therefore, it is not unrealistic to apply the norms of China to India. Accordingly we predict the energy demand for both these norms. To reach the level of 4000 kWh (in the year 2050); the energy demand in India (which is presently 1000 kWh) should grow at the annual rate of 4%.

9. Amount of CO_2 Generated

Electrical energy is to be generated by consumption of fossil fuels (coal, natural gas and oil) and also by other means (hydro, nuclear and renewable energy sources). Share of these sources is denoted by η_i where i =coal, gas, oil. Thus the symbols for shares are:

Coal: η_c (present value is 59%)

Natural gas: η_g (present value is 9%)

Oil: η_o (present value is 1%).

Similarly we denote the amount of CO_2 emitted (in kg) due to fossil fuel consumption, by the symbol a_i; when any of

the above fuels is used to generate 1 kWh of electrical energy. Thus the symbols are:

Coal: a_c (present value is 0.98 kg/kWh) [10]

Natural gas: a_g (present value is 0.52 kg/kWh) [10]

Oil: a_o (present value is 0.77 kg/kWh) [10]

Total amount of CO_2 produced (in kg) for each kWh of generated electrical energy is therefore given by

$A = \sum \eta_i a_i$; i =coal, natural gas and oil.

If the shares of these fossil fuels (which are presently η_i) are varied to new values η_i'; then the amount of CO_2 emitted will corresponding change. Thus the amount of CO_2emitted will become

$$A' = \sum \eta_i' a_i$$

These ideas may be expressed in the form of percentage change or relative change. Suppose a particular share η_i (of i^{th} source) is sought to be changed and the relative change is α_i.

Then $\eta_i' = (1+\alpha_i)\eta_i$; where α_i may be positive or negative. This means that the relative difference between η_i' (new share) and η_i (old share) is α_i. Hence the relative change in (overall) CO_2 emission will be

$$\frac{A' - A}{A}$$

We now calculate the amount of CO_2 added to the atmosphere, taking into consideration the whole population of the country.
Total amount of CO_2 added annually= (A) × (per capita energy consumption in kWh) × (Population of the country)

10. Example of CO_2 Reduction

The present and suggested shares of fuels are given in Table 2

Table 2: Fuel share

S. No.	Fuel	Present Share (η_i)	Suggested Share (η_i')
1.	Coal	59%	54%
2.	Natural gas	9%	13%
3.	Oil	1%	2%

Relative change in CO_2 emission is

$$\frac{A' - A}{A} = \frac{[(59\times0.98)+(9\times0.52)+(1\times0.77)]-[(54\times0.98)+(13\times0.52)+(2\times0.77)]}{[(59\times0.98)+(9\times0.52)+(1\times0.77)]}$$

= 3.24%

Then CO_2 emitted will reduce from 2062 million ton to 1995 million ton (as per India norms).

CO_2 emitted will reduce from 8246 million ton to 7979 million ton (as per China norms).

11. Prediction of Electric Power Generation

As we know that at present energy consumption in India per capita is 1000 kWh. Considering plant load factor (PLF) i.e. 65.09 [7] and transmission & distributed losses (TDL) i.e. 23% [8].

Let actual power generation capacity = P
Plant load factor =65.09
Transmission & distribution losses = 23%
Power actually available = 0.6509P (1-0.23)
= (0.6509×0.77) P
=0.501P
Calculations are shown in Appendix-I

12. Environmental Effects of CO_2

Carbon dioxide is not normally considered a pollutant because it is a normal constituent of air. However, excess of carbon dioxide is considered a pollutant because it leads to adverse effects on the environment as a result of green house effect. Green house effect is a natural phenomenon to keep the earth warm, which will affect all the living beings. According to an estimate, the average temperature of the earth has increased by 1^0 C in the last 50 years. It is predicted that if the global temperature rises by 3.6^0 C, the polar ice caps and glaciers would melt. This would increase the water level of oceans by about 20 cm and hence lead to the flooding of low-lying coastal areas of the earth [9].

13. Results

We have calculated the CO_2 emissions (in million) due to power generation from thermal power plants. The net increase in the amount of CO_2 emissions up to year 2050 would be1995 million ton as per India's energy consumption norm and 7979 million ton as per China's energy consumption norm.

14. Conclusion

Presently coal is the preferred conventional fuel for electricity generation in India but it is also a depleting source of power. Its use has negative impact on environment; its use is a severe threat for posterity. As a potential alternative, the development, promotion and commercialization of renewable energy sources will be essential for sustainable and eco-friendly economic and social development; which may also fulfil energy demand. One must aim at a turn around to CO_2 level below 350 ppm in this century. Otherwise we risk triggering tipping

points and irreversible impact that could send climate change spinning truly beyond human control.

The present generation has a duty of solidarity towards the next generations. We have to accept our prime responsibility in the current situation. We have no right to leave our children to suffer from the results of our mistakes. If we don't take immediate action, we will be guilty of inaction while humanity is in danger.

15. Suggestions

In order to reduce CO_2 emissions nationwide the following measures should be taken:

i. The most effective way to reduce CO_2 emissions is to reduce fossil fuels consumption.
ii. Carbon-free or low-carbon sources of energy i.e. renewable energy sources (solar, wind, geothermal, small hydropower, biomass and biogas), hydrokinetics (e.g., wave and tidal power), and nuclear power should be used.
iii. Tree plantation should be launched at national level in a massive way through state governments and gram panchayat (local bodies) with incentives to farmers and villagers.
iv. Control of population growth should be emphasized.
v. Improving efficiency of currently used energy producing and energy consuming devices, should be a priority.
vi. Less polluting fuel such as natural gas/LPG and biogas should be used.

References

[1] Technological Development Prospects for Indian Power Sector, *www.iea.org>Publications>Free publications*
[2] Power Sector at a Glance-ALL INDIA: 2014, powermin.nic.in/Indian-electricity-scenario/introduction.htm
[3] India faces daily outage of 30000MW-livemint, *www.livemint.com/...India-faces-daily-power-outage-of-30000-MW-ht*
[4] Press Release: Revised theory suggests carbon dioxide levels already in danger zone. November 10, 2008.
[5] Population and its Growth, India: 1901-2011 - ENVIS Centre on Population and Environment. Ministry of Environment and Forests, Govt. of India *www.iipsenvis.nic.in/Database/Population_4074.aspx*
[6] 20 Most Populous Countries in 2050-Geography-About.com (United Nations Population Division)
[7] All India plant load factor *www.cea.nic.in/reports/monthly/executive_rep/dec12/7.pdf*
[8] Print release, Press Information Bureau, Government of India, Ministry of Power as on14.7.2014.
[9] Climate Change and Sea Level Rise-The Climate Institute. *www.climate.org/topics/sea-level/*
[10] Electricity emissions around the world, *Shrinkthatfootprint.com/electricity-emissions-around-the-world*

Appendix-I

Note 1: As per India energy consumption per capita per year is 1000 kWh. Considering PLF 65.09 and TDL 23%, we get actual power generation P.

$$P = \frac{1000}{0.6509 \times 0.77} = 1995 \text{ kWh}$$

Since, 1mkWh=0.114 MW

Therefore, actual power generation per capita (P)

$$= 1995 \times \frac{0.114}{10^6} = 2.27 \times 10^{-4} \text{MW}$$

Total actual power generation (P) $=2.27\times10^{-4}\times$poputation
$=2.27\times10^{-4}\times1636\times10^{6}$
=3, 72,120MW

Note 2: Let, as per China energy consumption per capita per year is 4000 kWh. Considering PLF 65.09% and TDL 23%, we get

$$P = \frac{4000}{0.6509 \times 0.77}$$

= 7981 kWh

Therefore, actual power generation per capita (P)

$$= 7981 \times \frac{0.114}{10^6} = 9.10 \times 10^{-4} \text{MW}$$

Total actual power generation (P) = $9.10\times10^{-4}\times$population

$=9.10\times10^{-4}\times1636\times10^{6}$
=14, 88,480MW