Gauging the Impact of Power Generation from Fossil Fuels on CO_2 Level in Atmosphere

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Abstract: ***Energy and environment have always been closely related to one another. In the past few decades, the implications of this close association have become more noticeable, as the sustainable development of regions across the world is being adversely affected. To consider the specific instance of India, the total power installed capacity in the country is presently about 2, 58,700 MW. India has largely relied on fossil fuels namely coal, natural gas and oil which are depleting at a rapid rate. It may be noted that 69% of power in India is presently being generated by thermal power plants with adverse effects on environment due to addition of CO_2. The extent of CO_2 presence in atmosphere in the context of grid electricity is determined by the fuel mix used in power generation. The negative impact of increasing CO_2 levels may be avoided to some extent through the use of renewable energy sources, especially via decentralised power systems. In any case, energy demand is going to rise with increasing population and one must search for new resources. In this study, an attempt has been made to estimate the effects of power generation in India on CO_2 content of the atmosphere. One usually assumes that the maximum safe level of CO_2 concentration in the atmosphere is 350 ppm. This level may be maintained in the year 2050 by adoption of four-fold strategy (i) the use of carbon-free or low-carbon energy sources (ii) emphasis on forestation (iii) stabilization of population growth and (iv) use of energy efficient equipment. We investigate the first strategy.***

Keywords: energy demand, fossil fuels, renewable energy sources, CO_2 emissions, environment, development

1. Introduction

Human beings are the main agent of change in Earth's atmospheric composition and their activities affects the direction of future climate change. The inevitable increase in global population and the need of economic development obviously demand greater energy expenditure; with serious implications for environment. Experience shows that there is a strong association between economic development and energy consumption. In the specific instance of Indian power sector, numerous challenges will emerge over the next few decades. Currently one third of India's population does not have access to electricity [1]. The present energy supply and demand shows wide disparity and imbalance at national level. The present installed capacity in India is around 2, 58,700 MW [2]. In spite of this, there is a daily outage of more than 30,000MW of power [3]. Urgent action is therefore needed to overcome the problem of energy poverty. At the same time rapid economic growth is projected to increase electricity demand itself by five-fold to six-fold in the 2050. India's per capita annual consumption is around 1000 kWh, which is lower compared to many countries. In comparison, China has a per capita consumption of 4,000 kWh, with the developed countries averaging around 15,000 kWh of per capita consumption [3]. Nowadays, energy planning demands not only an adequate energy supply, but greater sensitivity towards environmental pollution. It is essential that future energy supply resources should either be more efficient or least based hydrocarbons. It is possible to study this effect from the point of view of CO_2 mitigation strategies. In the present study, an attempt has been made to predict the power demand and the optimum CO_2 level 350 ppm can be maintained by using renewable energy sources or less polluting energy sources [4].

2. India's Energy Scenario

In order to meet the ever increasing power requirements, huge amount of power needs to be generated. According to Indian Ministry of Power data, the peak power shortage in India is around 10% [2]. However, per capita energy consumption in India is 1000 kWh per year [3]. The demand of electricity has been increasing continually due to increasing population, urbanization and use of technology to access comfortable life. The present scenario indicates that India's future energy requirements are going to be extremely high. The loss due to transmission and distribution along with the problem of power theft in rural and urban areas are the areas of major concern of the present power system. Keeping in view the aforesaid concerns, an intelligent and reliable power system is urgently required which can prevent the power theft problem and transmit the power at maximum effectively and efficiently. The electricity installed capacity in India from different sources is shown in Figure 1.

Some of the basic features of the current power production status in India [2]:

- India's current installed capacity (As on 31 January, 2015): 2, 58,700 MW, from all sources.
- Power generation is mainly based on thermal and hydro, with about 12% from renewable energy.
- In 2014, peak power shortage was over 10 %.

- 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.

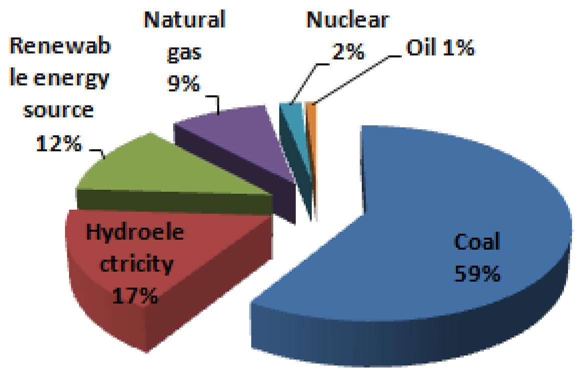

Figure 1: Electricity installed capacity in India by source

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.

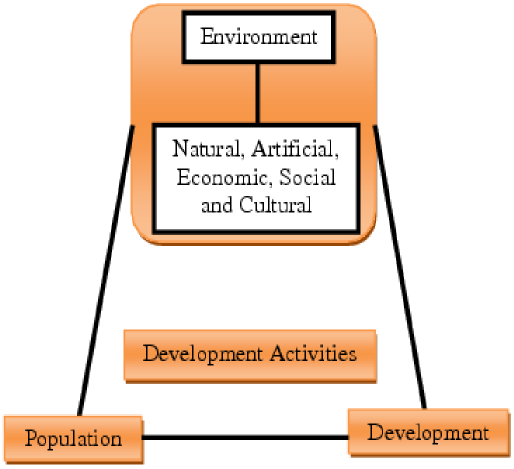

Figure 2: Interrelationship among population, environment and development

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 $\eta_i^{'}$; 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 $\eta_i^{'}$ (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 $(\eta_i^{'})$
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.

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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.

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

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