

Electricity From Nuclear Power: *Is It A Solution To Greenhouse Gas Emissions In India*

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Abstract: If asked, what is the relation between climate change, intense weather and health - probably the answer would be a straight line relation among the three. The earth is getting warmer day by day and global warming has become a major concern in the past few decades. Various research work is going on but so much of carbon dioxide has already been poured into the atmosphere, so that the technology improvement to reduce the Greenhouse gas emissions is the only solution. This study includes (a) the present scenario of nuclear power plant in India (b) electricity generated from different sources of energy and (c) its adverse effects on the global climate change. This study also includes the critical analysis of coal based thermal power plant because the fossil fuels are dominating in the power sector which is not recommended for the sustainable development of the country. The data concludes that Nuclear energy based power plant is the best option since emission can be minimized up to 7 times and also with respect to the amount of electricity generated and resources used. 90% share of each greenhouse gas is from coal based power plant and only 10% from nuclear based power plant.

Index Terms: Climate change, Environmental sustainability, GHG emissions, Nuclear Energy, source of electricity, Energy demand

1 INTRODUCTION

Increased industrialization is associated with rapid economic growth which in turn gives the problem of increased greenhouse emissions. There is no denying the fact that Global warming has become a major concern in the past few decades. For the past few years, the earth is giving us message in different forms either it is through drought or storms or fire. The earth is getting warmer day by day. This is what global warming is! Global temperatures are increasing and the earth is becoming warmer, warmer than at any time before and it is predicted that in coming future this may surpass the levels not seen on the planet ever before. Energy is the basic component for the development of industries, people and in turn the whole country. But at the same time, it is the component which has led to so many environmental problems either in the direct form or in an indirect form. The electricity is the major form of energy which is being used in the country from the earliest times and the thermal power plant based on coal gives rise to some gaseous emissions like sulfur dioxide, nitrogen oxides, CFCs and suspended particles (SPM). [1]. Now it has become a major international concern for the climate change as the demand for electricity is increasing continuously and in order to balance the demand and supply side, generating more and more units are being installed. The percentage of carbon dioxide is only 0.03 % in the atmosphere but due to continuous combustion of fossil fuels it has been increased by about 25% as compared to the pre-industrial times.

China and India are the two major contributors towards the increased total greenhouse gas emission statistics based on power sector unit. Economic growth of any country is decided by its energy consumption and generation technique as well as its share in the market. [2]. Fuel replacements are an alternative in order to reduce the gaseous emissions from the power plant. With the electricity output increasing continuously, the per capita gaseous emissions in India are also expected to increase in 2020. Annual energy based carbon emissions are increased as compared to that in 1990. The trend says 0.2t C/ person has been increased to 0.6 t C/person in between the years 1990 and 2020. [3] According to Environmental impact agency report, [4] the consumption of fuel is increasing continuously which leads to the exponential decrement in the conventional sources of power generation available in India and it's an alarming situation for us to search for the alternative sources of energy in the upcoming future to combat with the energy crisis as well as the climate change issues. **Figure 1.** [5] rightly explains the energy consumption in India for different fuels and the need for the alternative option. The changing climatic conditions and increase in consumption of electricity have grabbed our attention towards the study of relative contribution of electrical energy sources on the global climate change. According to IPCC (International Panel on Climate change (IPCC, 2000), 37% global emissions of carbon dioxide is from the electricity production. The data says that 10 gigatonnes of CO₂ out of total 27 gigatonnes in CO₂ global emissions from all sources of energy are emitted from the power plant. **Figure 2** interprets that more than 37% GHG emissions in India are from the electricity and heat. (EPA 2010) [6].

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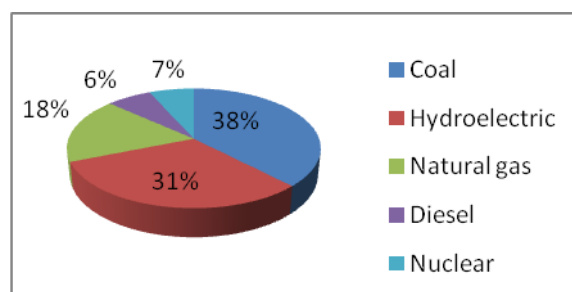


Figure 1. Electricity generation from various sources of energy

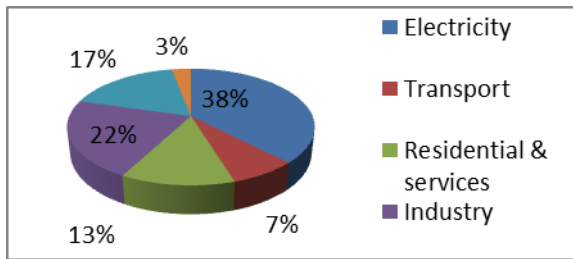


Figure 2: India's GHG emissions from different sector in India

Different power generation sources like coal, natural gases, nuclear power, hydroelectric, wind, solar and geothermal are available in India but the installed capacity of the coal based thermal power plants are incomparable. The figure shown in **Table 1 [7]** clearly depicts the generation of carbon dioxide per kWh is the highest for coal based power plants.

Table 1. Life cycle estimates for electricity generators

Technology	gCO ₂ e/kWh
Wind	19
Hydroelectricity	169
Solar	45
Geothermal	38
Nuclear	66
Natural gas	443
Fuel Cell	664
Oil	1556
Coal	2010

Installed capacity of Indian power sector has been increased to a greater extent as compared to the 20th century and the scenario for thermal power plant in 2010 is 102453.98 MW for the whole country and out of which 84198.38 MW from the coal based thermal power plant. Thus the coal is the highest contributing fossil fuels toward the total carbon dioxide generated in the country. While the installed capacity of nuclear based power plant is 4560 W only out of total 159398.49 MW installed capacity of energy sector in India till 2010. [7]. According to the study conducted by the World Nuclear Association, the Lifecycle GHG emissions intensity from different source of electricity gives a range which has been graphically represented in the Figure 3. [8] [9] and this is an inference based on data analysis, why Nuclear power seems to be one of the best alternatives for the near future. The nuclear energy gives answer to all the concerns, either it is the concern for climate, Indian economy demand or the energy crisis due to unbalanced demand-supply. Nuclear reactors are the best alternative since it generates electricity in a large quantity. India's membership of the ITER (International thermonuclear experimental reactor) indicates the seriousness of the country about the problems of energy crisis which it may face in future. The electricity consumption will keep on increasing with developing trend of the nation and as long as we are relying on the conventional energy sources rather chosen for the other option, we may face the electricity crisis very soon. Nuclear energy will not only solve the problem of electricity but is also responsible for creating comparatively less polluted environment. It was calculated that the emissions can be reduced from 4 % to 45% in the upcoming years by

2020 These include up to 14% by replacing coal with renewable energy, 6 % by improvement in transportation - distribution system and 9% of the improvement in efficiency of the Power plant. [3] Being a better source of power generation, installed capacity of Nuclear based power plant must be increased because coal based power plant can only replace if the nuclear plant can generate the energy which can replace the amount of energy which are coming from a thermal power plant in the present scenario of electricity consumption. No technology or source of energy is 100% perfect that it gets accepted easily. Nuclear energy is also one among them. Its uncontrolled nature, radioactive emissions and handling the nuclear waste, are some reasons which put a question mark on the acceptance of nuclear energy as the best alternative option. The debate about the "Nuclear energy is Bane or Boon" is still a burning issue not only in India, but across the whole globe. Over exploitation of the resources on the path of development has made us to think over the option of the nuclear technology Let us see some of the points in favor of Nuclear energy option in India:-

- 1 Nuclear reaction doesn't produce any greenhouse gases (Carbon dioxide, methane chlorofluorocarbons and ozone) which are contributing towards global warming and this way we can save our planet earth.
- 2 Nuclear energy can be produced in large quantity within a short period.
- 3 It is comparatively cheaper the conventional sources and transportation is easy.
- 4 The waste generated after the nuclear reaction is in small quantity and the fossil fuels generating tons of waste including the fly ash.

Some of the accidents were so terrible that it created its imprints on the mind of people and thus the popularity of nuclear energy is very less in positive sense. People consider it as the "dangerous" source of energy and thus it is the one of the major drawbacks which points that the Nuclear energy are 'cursed' to the society. To overcome this drawback, invention and comparatively efficient technology must be encouraged and popularized whenever necessity comes into the picture. Moreover, India is developing country and there are many villages in India where the poor villagers still dream of electricity in their village. Why not to accept such options which give the smile to the no of faces with some precautions and efficient mitigation measures to combat with the radioactive and carcinogenic gases produced during the nuclear reaction.

2. Nuclear power plant-Present scenario

The number of Nuclear Power plants has been increased as compared to the 1990. In the present scenario installed capacity of nuclear power plant has been increased and many future projects for example Jaitapur nuclear plant are planned which can introduce India as a leading country in the field electricity generation by nuclear fuel in the near future. In India NPCIL (Nuclear Power Corporation Of India Limited), a branch of Department of atomic energy is working for the Nuclear Energy option to be implemented in India in the recent decades. NPCIL has total 20 operating reactors which have an installed capacity of 4780 MW. Presently 6 reactors under construction and working with a capacity of 4000 MW out of which Tamil Nadu is generating 1000 MW at Kudankulam. It is working under the guidelines of the Department of public

enterprises (DPE). Different working as well as planned nuclear power plant India is shown in the Figure 4. [3][10]. Nuclear energy is the form of energy which is derived from nuclear atoms by the break up through nuclear fusion. Nuclear is the fourth largest source of energy in India. Nuclear reactors are used for producing steam in a large quantity which is used to drive the turbine for the electricity generation. Since the per capita demand of the Electricity is increased up to 778.63 kWh (Press information Bureau, Ministry of India). [11] Nuclear energy can replace coal if the operation cost and efficiency are higher for the nuclear power generation technique option.

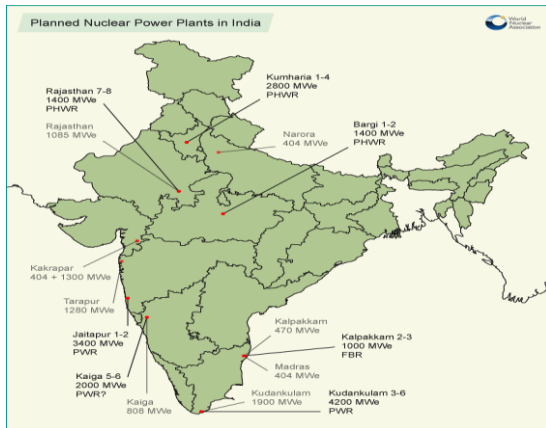


Figure 4. Nuclear power Plants in India

Some of the power plants in India under NPCIL is listed in Table 2. According to the report by Dr. S. K. Jain Chairman, Managing Director Nuclear Power Corporation of India Limited & Bharatiya Nabhikiya Viduyt Nigam Limited [12][13]

Table 2: Nuclear plant working In India

Power station	State	Type	Operator	Units	Total capacity (MW)
Kaiga	Karnataka	PHWR	NPCIL	220 x 3	660
Kalpakkam	Tamil Nadu	PHWR	NPCIL	220 x 2	440
Kakrapar	Tamil Nadu	PHWR	NPCIL	220 x 2	440
Rawatbhatta	Rajasthan	PHWR	NPCIL	100 x 1 200 x 1 220 x 4	1180
Tarapur	Maharashtra	PHWR	NPCIL	160 x 2 540 x 2	1400
Narora	Uttar Pradesh	PHWR	NPCIL	220 x 2	440
Total				19	4560

The energy policy gives an idea of being the nuclear power share to be in between 4.0-6.4% in the year 2013-32. DOE also estimated the percentage share of 8.6% and that of almost double i.e. 16.6% respectively in the upcoming year of 2032 and 2052 as shown in Table 3[14].

Table 3. Future Aspects of Nuclear power in India

Year	Capacity (GWe)	
	Min	Max
2020	48	63
2030	104	131
2040	208	275

In the recent future Indo-US nuclear deal agreement is permitted to carry out international trade of nuclear power and technology so as to increase the power generation growth. Under the safety guidelines of DOE, India has developed some reactors based on Thorium as the uranium is in limited amounts and moreover it can generate electricity 100 times more keeping the mass of fuel constant. Kalpakkam nuclear power reactor is a prototype based on the burning of uranium-plutonium while thorium layer are irradiated at the same time.

3. Thermal vs. Nuclear Power plant

The Nuclear Institute has given a quoted statement which supports our study is that "Nuclear is the best source of electricity" a keen study over the life cycle analysis concludes the fact about the total GHG emissions from the nuclear power sector not only includes its operation but also includes the construction, milling and decommissioning of nuclear power sources. These five activities involved in the functioning of the nuclear power plant were separately observed by Sovacool and the qualitative study concludes that the operation of a nuclear power plant only contributes 18 % of the total carbon dioxide emissions from the whole power generating unit. These results have been shown graphically in Figure 5 [15]. For the coal based power plant LCA was carried out for the mean emissions from operation, mining, transport and preburning on the basis of kgCO_{2eq}/kWh. The study includes 87% emission from the operation. In this regard also coal based power plant is contributing more to GHG emissions as shown in Figure 6.[16] Coal based thermal power plants give 60% of the total greenhouse effect but qualitative study says total CO₂ emitted from the nuclear power plant is only 60g CO_{2e}/KWH [15]. According to Gagnon et al. (2002), nuclear life cycle attributes only 66gCO_{2e}/kWh which is much lower than the value 445 -1050 gCO_{2e}/kWh which was found in the case of coal, oil, diesel and the natural gas based energy generating unit.

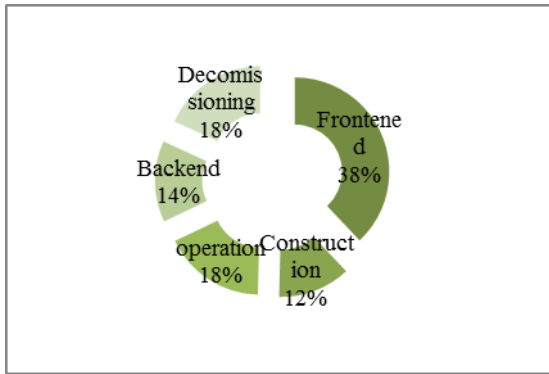


Figure 5. Mean emissions due to all process from nuclear power Plant LCA based on gCO₂/kWh

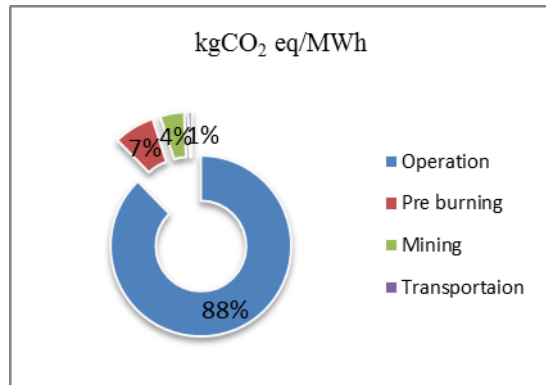


Figure 6. Emissions due to all process in Coal based Power plant in gCO₂/kWh

Thirty nine percent (39%) of these studies is 10 years old and increasing demand for the electricity and continuously increasing installed capacity of the power plant is the evidence that the emissions has been increased much which has been covered in some literature also but are not accessible. The benchmark for the LCA emissions from different sources of power was studied by Miller et al [17] and the result is compared to the nuclear and thermal based power plant over 100 years. The study was carried out for the emissions of GHG gases which includes Methane (CH₄), carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxides (NO_x) and sulfur dioxide (SO_x). Comparative chart is shown in the Figure 7 [17] for these gases. Approximately 90% contribution of each GHG gases which contribute towards the climate change is due to nuclear sources of energy. Replace coal with other renewable sources or nuclear sources are some of the best process technology that can be implemented in India. According to the Sovacool survey 2008, Fighting climate change into consideration the nuclear technology is proven to be 7 to 16 times better than the conventional fossil fuels The Nuclear capacity in India has been increased to 2.2 GW which was only 1.7 in the nineties but the plan is to aim 10 GW in 2020. [15]. The Best practice Technology i.e. By switching fuels from coal to renewable energy sources, nuclear sources and natural gas can reduce the emissions up to 53% by 2020. The life cycle analysis study carried out by the Sovacool concludes that total 6.8g of carbon dioxide emissions per kWh of nuclear energy produced which is much lower than the 9.5 to 38 g carbon dioxide per kWh from the fossil fueled power plant. [18] [19] [20]

4. Results and Discussions:

The emission of greenhouse gases from the power sector in India is expected to increase in the coming two decades. These emissions can be controlled and reduced to a greater extent by improving the technology & efficiency of the existing power plants. It was calculated that the emissions can be reduced from 4 % to 45% in the upcoming years of 2020. These include up to 14% by replacing coal with renewable energy, 6 % by improvement in transportation - distribution system and 9% of the improvement in efficiency of the Power plant. Replacement of BAU (Business as usual) scenario in the future can lower down the range of gas emissions from 4 % to 45% which includes a 14% contribution by replacing the coal by renewable sources presently used for the power generation in Power plant. According to WNA report the emission of GHG which includes mainly CH₄, CO₂ & NO₂ are graphically shown in Figure 8. [17] Since electricity is very important in the household as well as industrial activities, therefore an efficient as well as cheap technology should be adopted for its production. In this regard Nuclear energy is chosen as the best option because the transportation and installation cost is comparatively lower in the Nuclear power plant. The replacement of coal based power plant is required for the sustainable development of India. There are so many points to highlight here which can stop the debate that whether in India nuclear power plant can be chosen as the best option for energy generation over the coal. There are some shortcomings of the coal based power plant which are as listed below:

1. Coal handling is difficult in an operating plant
2. The requirement for a large amount of water
3. maintenance and operating cost is comparatively high
4. Need of a better technology to minimize heat loss.
5. Good quality coal is not available in abundance.
6. Ash removal and disposal problems.
7. More GHG emissions in comparison to Nuclear based unit.

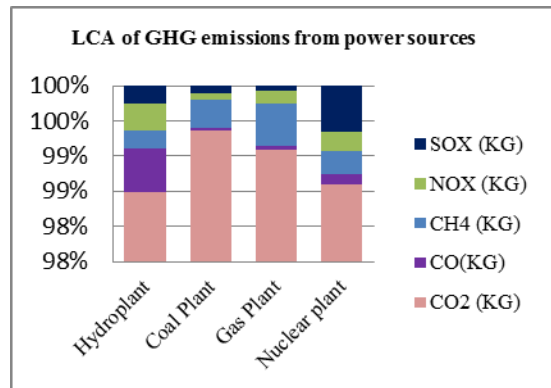


Figure 8.LCA of GHG emissions from different power sources

But the question is whether the nuclear based power plant can reach the requirement of the per capita electricity consumption alone. Due to industrialization, coal consumption has been rapidly increased from 1990 to 2005. Department of Atomic energy has evaluated the total generation of electricity from the installed nuclear plant and it indicates that a total of 48 GWE or 48,000 MW capacities can be achieved in the year of 2020. Center for science and environment report on thermal power plant estimates that up to the year of 2011, the installed

capacity of Thermal power plant was only 99503 MW [21] Definitely the nuclear plant with the projected installed capacity as described by DOE can't replace all the coal based power plant but can minimize the GHG emissions which are increasing due to use of Coal as a major source of electricity in India. For example we can take a case study of coal and nuclear based power plant in India in the region of Maharashtra. There are two major thermal and nuclear plants situated and operating in this region, one is Tarapur Nuclear power plant and the other is Chandrapur. Total capacity of all 23 Coal based power plants in Maharashtra is 21025 MW. Major operating thermal power station in Maharashtra is Parli TPP (Thermal Power Plant) (1130 MW) Chandrapur TPP (2340 MW) and Trombay TPP (1400 MW). [22] According to the survey on air quality monitoring of the Maharashtra region by MPCB, the air quality for two district Parli and Thane was compared where two major power plants, one is based on nuclear and other on coal. Air inventory in the region of the Chandrapur thermal power station of having 2300 MW capacity and Tarapur nuclear plant has the capacity of 1400 MW gives the following emission inventory when monitoring was done for the year of 2006 and 2008. All the glass including particulate matter data was collected and it seems that Chandrapur was declared as the critically polluted area because the SO_x , NO_x and SPM level was $37 \mu\text{g}/\text{m}^3$, $58 \mu\text{g}/\text{m}^3$, $163 \mu\text{g}/\text{m}^3$ respectively in the Chandrapur region where the coal based thermal plant is located at the same time inventory data collected from the air quality of trapper gives the range of $32, \mu\text{g}/\text{m}^3$ $51 \mu\text{g}/\text{m}^3$, $73 \mu\text{g}/\text{m}^3$ as shown in the Table 4 [23] [24]

Table 4. Air quality data for Chandrapur and Tarpur (Maharashtra)

Tarapur	SO_x ($\mu\text{g}/\text{m}^3$)	NO_x ($\mu\text{g}/\text{m}^3$)	RSPM ($\mu\text{g}/\text{m}^3$)	Chandrapur	SO_x ($\mu\text{g}/\text{m}^3$)	NO_x ($\mu\text{g}/\text{m}^3$)	RSPM ($\mu\text{g}/\text{m}^3$)
2006	17	24	86	2006	32	40	103
2007	26	30	77	2007	40	46	143
2008	32	51	73	2008	37	58	163

According to KPMG report on "India Electricity Market Outlook" published in 2008 shows the variation in building and generating cost of different fuel and graphical result interpret that Nuclear power is the one source of electricity whose building cost is much lower as well as the generation time for a large amount of electricity in shorter period is possible. It's one of the best features of the nuclear energy which is an indication of implementing this as a major source of electricity in India.

5. Conclusions

The potential effect of different sources of energy on the increased level of greenhouse gases can be summarized in one sentence as "Nuclear energy is the best option" to control the emissions. This study was carried out for the emission which includes mainly the CH_4 , NO_2 and CO_2 as the major component contributes to global climate change due to electricity generation via different sources of energy. The conclusion based on study carried out on the data included in

this report from IPCC (International Panel on Climate change) is that almost 37% global emissions of carbon dioxide are from the electricity production. The conclusion based on present study gives 10 gigatonnes of CO_2 and emitted from the power plant out of 27 Gigatonnes in total CO_2 global emissions from all sources of energy. Present study concludes the percentage of each greenhouse gases emitted from Coal and Nuclear Plant. It was observed sulfur dioxide (35%) nitrogen oxides (19%), carbon monoxide (34%), carbon dioxides (8%) and methane (4%) in case of nuclear plant and sulfur dioxide (19%) nitrogen oxides (20%), carbon monoxide (19%), carbon dioxides (21%) and methane (21) % emitted from the coal plant when a comparative study was carried with the nuclear plant based on. Life cycle analysis for 100 years and the mean emissions scenario for nuclear and coal plants was depicted as 90% of each of the greenhouse gases was due to nuclear sources. Thus we can conclude that nuclear is better energy source as compared to coal which is a conventional source of energy. But the efficiency of the plant and can be increased by adopting a better technology and minimizing the emissions of gases which causes a global concern of climate change.

6. Acknowledgments

This work has been carried out under the programmed of PGRPE (Post Graduate Research Program in Engineering) of National Environmental engineering Research Institute, CSIR, and Nagpur. The Master degree awarded by ACSIR (Academy of Sciences and industrial Research) to Shilpa Kumari in Environmental engineering is gratefully acknowledged.

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