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# Power Plants: from the perspective of Global Warming

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**Abstract:** Coal is the main fuel used for power generation in India and its consumption is increasing so as to meet the energy requirements of the world. Specific pollutants that are released from burning of coal are sulfur dioxide ($SO_2$), oxides of Nitrogen ($NO_2$) and particulate matter. These emissions not only have the adverse effects on global warming but also have negative health consequences. This paper presents an overview of coal-fired power generation and its emission impacts on the environment. It also considers the other methods of power generation like hydroelectric power plants, gas based power plants and nuclear power plants and their respective GHG emissions. The paper aims in highlighting the emission reduction methods that may be adopted to constrain the global warming to tolerable levels and the technologies potentially available to help in achieving the emission reductions with a special emphasis on renewable energy sources.

**Keywords**: Global warming, GHG emissions, power plants, fossil fuels, renewable energy sources

## I. INTRODUCTION

Global warming implies a gradual increase in the average temperature of the Earth's atmosphere and its oceans. It is a change that is believed to be permanently changing the Earth's climate. Global temperatures are increasing and the earth is becoming warmer and it is predicted that in coming future this may surpass the levels not seen on the planet ever before. The scientific consensus on climatic changes related to global warming is that the average temperature of the Earth has risen between 0.6°C and 1°C over the past 100 years [1]. It is a fact that Global warming has become a major concern in the past few decades. The primary sources of the global warming that has occurred over the past 50 years are believed to be the increased volumes of carbon dioxide and other greenhouse gas (GHG) emissions released by the burning of fossil fuels, development of industries, land clearing, agriculture, and other human activities. Increased industrialization is associated with rapid economic growth which in turn gives the problem of increased GHG emissions.

Electricity is the major form of energy which is being used in the country from the earliest times and most of the electrical energy is generated by the use of conventional energy sources which rely on fossil fuels, particularly coal, to produce energy. The burning of these fossil fuels releases carbon dioxide and other heat-trapping greenhouse gases like sulfur dioxide, nitrogen oxides, CFCs and suspended particles (SPM) into the atmosphere [2]. At present, human life is highly dependent upon electrical energy, we cannot even think of life without electricity. It is scientifically expected that if global warming continues in the same pace then it may deteriorate the life on earth and will lead to bad weather conditions [3].

Because of the increase in the demand for electricity, in order to balance the demand and supply side more and more generating units have been installed. As a result the percentage of carbon dioxide has been increased by about 25% as compared to the earlier times.

Among the many human activities that produce greenhouse gases, the use of energy represents by far the largest source of emissions [4]. Other shares correspond to agriculture (producing mainly $CH_4$ and $N_2O$ from domestic livestock and rice cultivation) and to industrial processes not related to energy (producing mainly fluorinated gases and $N_2O$) as shown in Fig.1.

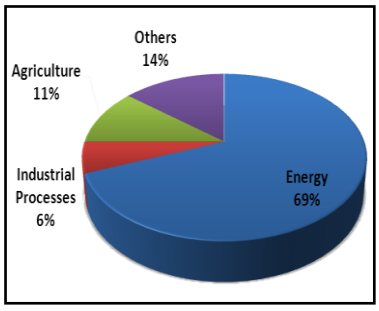


Fig. 1 Sources of GHG Emissions

* Others include large-scale biomass burning, post-burn decay, peat decay and indirect $N_2O$ emissions from non-agricultural emissions of $NO_x$ and $NH_3$.

Fig. 2 interprets that the two major sectors which produced nearly two-thirds of global $CO_2$ emissions in 2012 are electricity and heat generation, by far the largest, accounted for 42%, while transport accounted for 23% [4]. Out of the different power generation sources.

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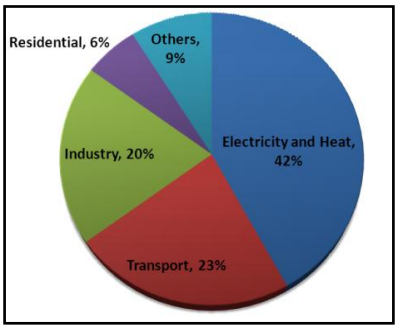


Fig. 2 World's $CO_2$ emissions by Sector in 2012

Coal represented 29% of the world's Total Primary Energy Supply (TPES) in 2012 and it accounted for 44% of the global $CO_2$ emissions due to its heavy carbon content per unit of energy released, and to the fact that 18% of the TPES derives from carbon-neutral fuels as shown in Fig. 3.

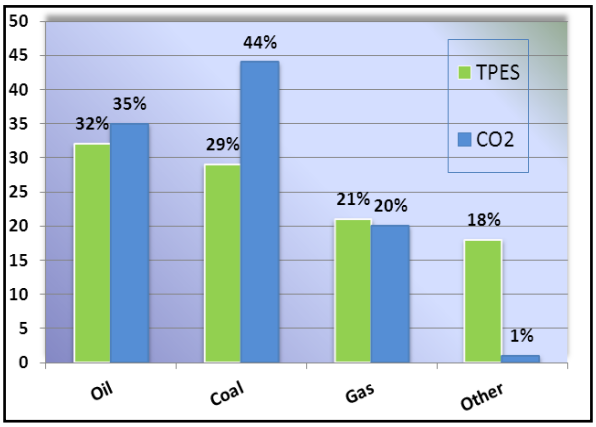


Fig. 3 World's TPES derived from various fuels and their respective contribution to $CO_2$ emissions in 2012 [4]

An increase in the consumption of electricity and subsequent effect on climatic conditions, have grabbed our attention towards the study of relative contribution of electrical energy sources on the global climate change. The need to cut down GHG emissions has become a major concern of energy policy. An energy revolution is therefore necessary to decarbonize the energy supply. According to recent predictions, the average global temperatures could increase between 1.4°C and 5.8°C by the year 2100 and at least 50% of GHG emissions must be cut from 2005 levels by 2050, so as to avoid the worst consequences of global warming [5]. According to IPCC (Intergovernmental Panel on Climate change (IPCC, 2000), 37% global emissions of carbon dioxide is from the electricity production. The data says that 10 gigatonnes of $CO_2$ out of total 27 gigatonnes in $CO_2$ global emissions from all sources of energy are emitted from the power plant [6].

The changes resulting from global warming includes rising sea levels due to the melting of the polar ice caps, as well as an increase in occurrence and severity of storms and other severe weather events.

## II. GLOBAL WARMING SCENARIO IN INDIA

As the electricity output is continuously increasing, the gaseous emissions in India are also expected to increase in 2020. Annual energy based carbon emissions have been increased as compared to those in 1990. As per the calculations, the annual energy related carbon emissions in India may increase from 0.2t C/person in 1990 to 0.5t C/person in 2020 [7]. According to the Environmental Impact Agency report, the consumption of fuel is continuously increasing, which may lead to exponential decrease in the conventional sources of power generation available in India. It is an alarming situation for us to explore the alternative sources of energy in future to cope up with the energy crisis as well as the issues related to climate change.

Fig. 4 shows the energy consumption in India for different types of fuels and the need for the alternative option.

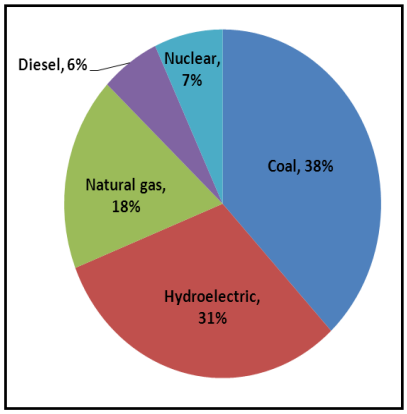


Fig. 4 Electricity generation from various sources of energy in India

The lifecycle estimates for different electricity generators as shown in Fig. 5 clearly shows that the generation of carbon dioxide per unit is the maximum for coal based power plants [8].

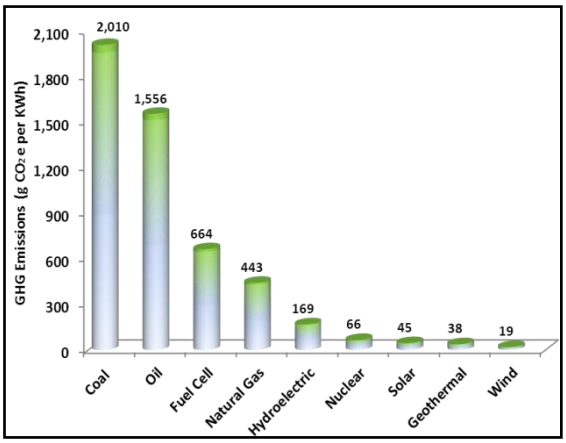


Fig. 5 Lifecycle GHG emissions intensity of electricity generation methods

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## III.POWER PLANTS: IMPACT ON GHG EMISSIONS

Electricity being the key ingredient for the socio-economic development of any country, productivity of the power generation sector has a strong bearing on the competitive advantage other sectors [9]. Cars and other vehicles are often blamed as being the worst polluters but according to U.S. Environmental Protection Agency, power plants are actually responsible for releasing the majority of the greenhouses gases contributing to global warming. Power plants supply the energy needed for heating, cooling and lighting homes. They provide electricity and heat used by people across the globe for powering essential facets of modern life. However, the production and use of this energy contributes significantly to global warming. The vast majority of power plants rely on fossil fuels to produce energy. The burning of these fossil fuels releases carbon dioxide and other heat trapping greenhouse gases into the atmosphere. High carbon dioxide concentrations correlate with warmer average global temperatures. It is a fact that carbon dioxide influences temperature more than any other gas in the atmosphere, according to the National Aeronautics and Space Administration (NASA). Accelerating $CO_2$ emissions from human activities such as the operation of power plants have caused a particularly sharp increase in warming since the mid- $20^{th}$ century.

Just as power plants emit greenhouse gases that cause global warming, global warming in turn affects the operation of power plants. As the global warming trend continues, significant changes in infrastructure may be required, and reliability of power plants may become a problem. A Rise in average temperature has led to increased demands for air conditioning. Meeting the peak demand in summers could be challenging in terms of not only production but also delivery. Also, a warmer climate would reduce the efficiency of power plants that use water for cooling. The warmer the water, the less efficient the cooling process, and more frequent droughts due to climate change could shrink available water supplies [10].

### *A. Thermal Power Plants*

Coal fired power plants have the highest GHG emission intensities on a lifecycle basis. Although natural gas, and to some degree oil, had noticeably lower GHG emissions, biomass, nuclear, hydroelectric, wind, and solar photovoltaic all had lifecycle GHG emission intensities that are significantly lower than fossil fuel based generation [8]. With over 179 GW of installed capacity in 2010, India remains the 5th largest consumer of electricity in the world. Thermal power plants account for more than half of the installed capacity and caters to 83% of the electricity generated [11]. The present capacity for electricity generation from coal and lignite based thermal power plants in India is 93772 MW. According to the information from Central Electricity Authority, there are 86 coal and lignite-based power plants with a total capacity of 77682MW. All these plants have different installed capacities with varying numbers of generation units of different capacities. Most of these plants use E and F grade coal. $CO_2$ emissions are estimated based on the carbon content as obtained from the elemental analysis of the coal and the excess air used at the power plants. The main reason behind the $SO_2$ emission can mostly be attributed to the sulfur content of coal fed into the respective units, firing temperature in the furnace, excess air supplied as well as particle used for fluidization. Annual $CO_2$ emissions from all the 86 coal and lignite based power plants for the years 2001-02 to 2009-10 are given in Table I for each region and for all India. $CO_2$ emissions have increased at an average annual rate of 5.6% on the all India basis in these power plants during the period 2001-02 to 2009-10 [12].

TABLE I
ANNUAL $CO_2$ EMISSIONS FROM COAL AND LIGNITE BASED POWER PLANTS IN INDIA

| S. No. | Thermal Power Plant | $CO_2$ (Thousand ton) | $SO_2$ (kg) | NO (kg) |
|---|---|---|---|---|
| 1 | Dadri | 6413.07 | 49.32 | 33.08 |
| 2 | Rihand | 13049.07 | 83.58 | 64.49 |
| 3 | Singrauli | 18185.23 | 84.07 | 81.71 |
| 4 | Sipat | 6142.32 | 49.57 | 31.62 |
| 5 | Kutch lignite | 807.08 | 39.73 | 4.16 |
| 6 | Chandrapur | 14938.09 | 196.53 | 41.68 |
| 7 | Dahanu | 3812.31 | 22.37 | 11.75 |
| 8 | Kahalgaon | 7319.83 | 30.77 | 24.11 |
| 9 | Simhadri | 5979.83 | 31.95 | 29.29 |
| 10 | Neyveli lignite | 12443.43 | 443.44 | 58.02 |

Even if the efficiency of coal fired power plant is improved drastically, $CO_2$ will still be emitted. In view of this, a technology for capturing the $CO_2$ itself has been developed known as Carbon Capture and Sequestration (CCS) is often cited as a technology that could dramatically reduce carbon emissions from coal fired power plants. CCS offers the means to achieve deep reductions in $CO_2$ emissions from coal-fired power plants and other large energy intensive fossil fuel sectors. The CCS process comprises three integrated stages, namely: 1. capture and subsequent compression of the $CO_2$ 2. transport of $CO_2$ usually as a supercritical fluid and 3. its subsequent utilisation or injection into the selected geological formation [13]. Although, this technology appears quite promising, it is currently in early developmental stages and does not have widespread commercial application.

### *B. Hydro Power Plants*

The electricity produced by hydroelectric reservoirs is generally considered as a carbon free and climate neutral energy. But recent researches show that this is not true.

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Global warming emissions are produced during the operation of hydroelectric power plants. This is because large amounts of carbon tied up in trees and other plants are released when the reservoir is initially flooded and the plants die. They are not able to assimilate $CO_2$ anymore. The leaves and litter of the flooded plants sinks down to the ground of the reservoir. Bacteria decompose the organic matter and produce $CO_2$ and under anaerobic conditions also $CH_4$ [14]. These gases are released into the atmosphere when water passes through the dam's turbines and increase the amount of anthropogenic greenhouse gases and thus contribute to global warming. $CO_2$ and $CH_4$ are two of the most important anthropogenic greenhouse gases.

The global warming potential of $CH_4$ is 21 times higher than the one of $CO_2$ in a period of 100 years, this means that the same amount of $CH_4$ is much more harmful than $CO_2$ (IPCC, 2007). Such emissions vary greatly depending on the size of the reservoir and the nature of the land that was flooded by the reservoir. Small plants emit between 0.01 and 0.03 pounds of carbon dioxide equivalent per kilowatt-hour. Life cycle emissions from large scale hydroelectric plants built in semi-arid regions are approximately 0.06 pounds of carbon dioxide equivalent per kilowatt-hour. However, estimates for life-cycle global warming emissions from hydroelectric plants built in tropical areas or temperate peat lands are much higher. After the area is flooded, the vegetation and soil in these areas decomposes and releases both $CO_2$ and $CH_4$. The exact amount of emissions depends greatly on site-specific characteristics. However, current estimates suggest that life-cycle emissions can be over 0.5 pounds of carbon dioxide equivalent per kilowatt-hour [15].

*C. Natural Gas Power Plants*

Natural gas is an extremely important source of energy for reducing pollution and maintaining a clean and healthy environment. Natural gas has some benefits over other fossil fuel energy sources. It has cleaner burning and has a lower carbon footprint. However, it is not possible to rely heavily on natural gas for several reasons. Natural gas-fired power plants also emit sulfur dioxide and nitrogen oxides, but of lower levels in comparison to coal-fired plants. These emissions contribute to acid rain and ground-level ozone, both of which can damage forests and agricultural crops. Ground-level ozone has also been linked to a range of respiratory illnesses. More recently, ground-level ozone has been linked to the development of a very common disease, childhood asthma. Possibly more troubling are the emissions of fine particulates from gas-fired power plants. These fine particulates have the greatest impact on human health because they by-pass our bodies natural respiratory filters and end up deep in the lungs. In fact, many studies have found no safe limit for exposure to these substances [16].

Natural gas thus have a considerable effect on climate change. No doubt, burning natural gas produces fewer greenhouse gas emissions as compared to coal or oil, but there will be no real climate change benefit until gas-fired power plants actually displace coal-fired generation. It seems that natural gas is not a solution to climate change.

*D. Nuclear Power Plants*

Nuclear power has the potential to continue to play a significant role in the effort to limit future GHG emissions while meeting global energy needs. Nuclear power plants produce virtually no GHG emissions during their operation and only very small amounts on a life cycle basis.

Many studies in recent years have estimated the life cycle GHG emissions from different power generation technologies. Fig. 5 shows that, on a life cycle basis, nuclear power, together with hydropower and wind based electricity, is one of the lowest emitters of GHGs in terms of $gCO_2$ eq. per unit of electricity generated. Coal based generation, even if equipped with CCS technology, is estimated to emit about one order of magnitude more GHGs per unit of electricity [17]-[20]. GHG emissions from nuclear energy technologies may be even lower in the future due to the following important trends: (i) a shift from electricity intensive gaseous diffusion uranium enrichment technology to centrifuge or laser technologies that require much less electricity; (ii) the increased share of electricity (also for enrichment) that is based on low or non-carbon fuels; (iii) extended nuclear power plant lifetimes (which mean reduced emissions per kWh associated with construction); and (iv) increased burn up (which means reduced emissions per kWh associated with uranium mining and manufacturing fuel).

Because nuclear power results in few global warming emissions, an increased share of nuclear power in energy could help to reduce global warming but nuclear technology poses serious threats to our security. The accident at the Fukushima Diaichi plant in Japan illustrates to our health and the environment as well. The serious issues associated with nuclear power are: 1. safety 2. proliferation 3. waste disposal and 4. cost barriers of nuclear power. Major researches agree that using nuclear power to have any remarkable effect on global warming would need building at least 1,000 new reactors worldwide. This would exacerbate all of the problems of the technology like, more terrorist targets, more cost, less safety, need for a new Yucca Mountain sized waste site every four or five years, more proliferation of nuclear materials and technologies, dozens of new uranium enrichment plants and then there may be a severe shortage of uranium even within this century, while displacing the resources needed to ensure a real solution to the global warming issue. It takes at least 15 years to build a nuclear power reactor. Nuclear waste is dangerously radioactive now and for hundreds of thousands of years. There is no safe way to store it and it poses a security threat. Nuclear power generation is seven times more expensive than energy reductions. Nuclear energy can only exist in a society that runs on cheap fossil fuels.

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Planning and building new nuclear power plants will not contribute to combating global warming over the next decade.

## IV. REDUCING FOSSIL FUEL USE: A PROMISING SOLUTION TO GLOBAL WARMING

The climate change issue is essentially a fossil fuel energy issue. But all the power plants do not emit copious amounts of greenhouse gases. There are some that rely on renewable resources or cleaner burning fuels. Among these are hydroelectric, wind, solar and geothermal power plants, some power plants use even solid waste and landfill gas. If we increase renewable energy and improve energy efficiency, we can completely eliminate the need for new coal fired power plants and shut down the old plants without any adverse effect to our electricity supply. Electric power generation is the most important application of alternative/renewable energy resources.

The process of carbon capture and storage, still in early phases of development, may enable coal-burning plants to continue operating while significantly reducing their greenhouse gas emissions. In this process, $CO_2$ from smokestacks is contained, liquefied and pumped back underground. Regardless, even if the entire world were to convert entirely to green-energy sources tomorrow, it would take hundreds if not thousands of years for the carbon dioxide already in the atmosphere to clear, according to NASA [21]-[23]. Thus, global warming would continue until the planet could restore its natural balance.

While agriculture, land use changes, cement production and the use of chemicals all contribute to greenhouse gas emissions, more than 70% of the problem is due to the unsustainable use of fossil fuels. The climate change challenge means shifting away from fossil fuels in the home, industry, at work and the way we travel. Furthermore, global energy demand is predicted to rise as countries industrialize and the population continues to grow.

The natural flow of energy on planet earth provide a huge potential for harnessing carbon-neutral energy for society. Powered by the sun, the flows of wind power, hydro power, biomass, wave, tidal and solar heat and power - which can be captured by modern technology - are more than enough to provide for all our needs. The sun powers planet earth and allows us to survive. With smart technology it can also provide heat and electricity. It is also the driver for wind power. Wind in turn creates waves, a huge potential power. Renewable energy technologies do have an impact on the environment, as do all energy technologies. However, the relative impacts of renewable sources are far less than those of fossil fuels and nuclear power. The sun also powers the evapotranspiration cycle, which allows water to generate power in hydro schemes - currently the biggest source of renewable electricity in use today. Plants photosynthesise in sunlight and create a wide range of so-called biomass crops ranging from wood fuel to rapeseed, which can be used for heat, liquid fuels and electricity. Interactions with the moon produce tidal flows which can be intercepted and produce electricity. Though humans have been tapping into renewable energy such as wood, solar and water power for thousands of years, so far we have managed to capture only a fraction of the technical and economic potential of renewables. The recent development of smarter and more efficient technology has been impressive. In the past 20 years these technologies have improved and costs have fallen dramatically. For solar photovoltaic cells, stimulated initially by the space programme, unit costs have fallen by a factor of 10 in the past 15 years.

India does not lack in renewable energy resources. It is the only nation in the world to have a dedicated ministry for renewable energy, the Ministry of New and Renewable Energy Resources (MNRE) which has set a target of achieving renewable energy installed capacity of 41,400 MW by 2017. As on March 31, 2014, the installed capacity of renewable energy is 32,269.6 MW, which is 12.95% of the total potential available in the country. As per the Renewable Energy Status Report 2014, the market potential for overall renewable energy in India is 2,16,918.38 MW which shows a huge growth of renewable energy. Power generation from renewable sources is therefore on the rise in India and by 2015, the National Mission on Enhanced Energy Efficiency (NMEEE) is expected to result in savings of nearly 23 million tons oil-equivalent of fuel in coal, gas and petroleum products.

## V. CONCLUSION

This study carried out the effect of different sources of energy on the increasing levels of greenhouse gases in the environment. The major anthropogenic greenhouse gases considered in the study were $CO_2$, $SO_2$, $NO_2$ and $CH_4$. We have discussed the impact of various sources of power generations on the environment and it has been concluded that the increased use of renewable energy sources could be a key towards the path of minimizing the emission of GHG gases which have become a cause of global concern.

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