Analyzing and Comparing CO_2 Emissions from Coal against Solar PV

Ankit Paithankar[1], Prasad Koppal[2]

[1]B.E, Department of Mechanical Engineering, K.K. Wagh Institute of Engineering Education and Research, Nashik, Maharashtra (India)

Abstract – Conventional power plants release excessive toxic gases in to the earth's atmosphere. Out of which carbon dioxide stands dominant and vicious among all the other pollutants. These gases replicate the main reason for ozone layer depletion and Global Warming. Under the light of this topic, this research paper is concerned about the carbon dioxide emissions from conventional (coal specifically) and non-conventional (Solar PV's) energy sources. The concept of carbon footprints is also employed here in order to compare the pollution rates from the major countries with their respective energy sources. Lastly, with detailed graphical analysis this research paper will encourage people to steer towards renewable energy applications.

Key Words: carbon footprints, CO_2 emissions, solar PV's, Coal, GHG's, Global Warming

1. Introduction

Electricity is the most basic and most essential part of life. As this electric energy is not readily available in the nature, it requires to pay some cost in order to produce it. The cost involved in generating electricity can be either with money or by pollution or both. As conventional sources became dominant in the first place, pollution started to increase globally. Especially coal powered thermal power plants emit tons of toxic gases as well as carbon dioxide. Forecast analysis is also carried out to estimate the amount of CO_2liberation up to 2028. Non-conventional or renewable energy sources became popular in late 20th and early 21st century. Various concepts like carbon footprints, carbon credits, CO_2emissions etc. were coined to help educate people about the unbounded pollution blow in the environment. In view of this, various countries are taken into consideration which generate huge amount of electricity (year wise) and which contribute to the environment in either way. Comparing the amount of carbon dioxide emissions from coal to that from the solar PV's will pave a clear way towards the renewable energy applications.

2. Global CO_2 Emissions (in Metric tonnes)

With help of data obtained following line graph was plotted which shows global CO_2 emissions for last 50 years (1960-2018).

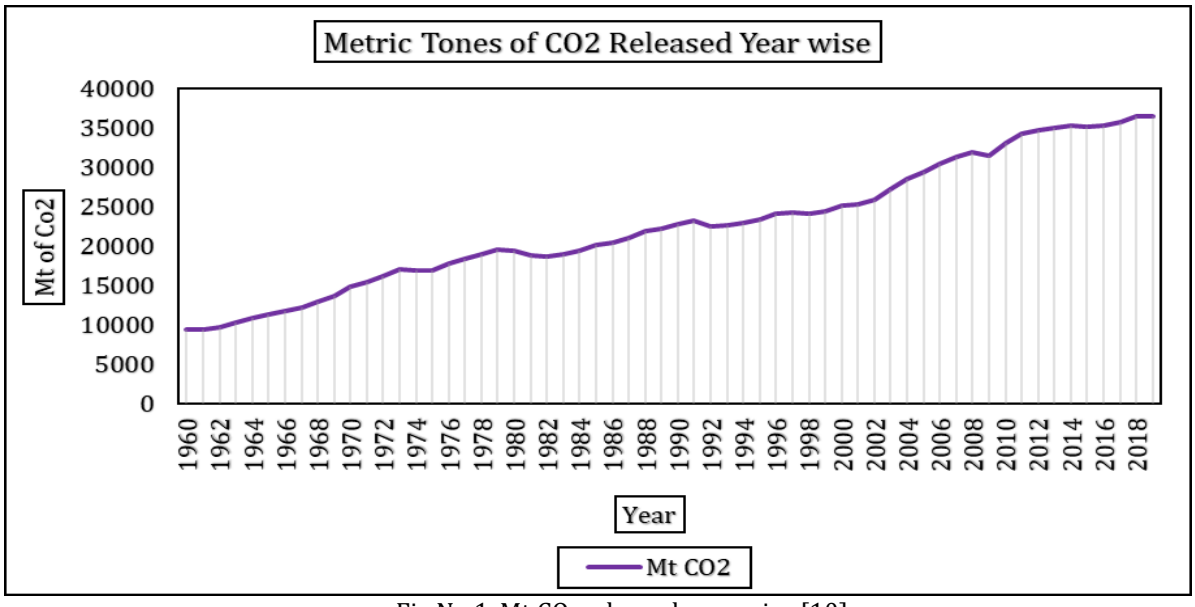

Fig No.1. Mt CO_2 released year wise [10]

From the above graph, it can be extracted that the global carbon dioxide emissions have increased up to 35x over the past 50 years. The graph just depicts the year wise CO_2emissions which does not account for the cumulative emission. If we consider the cumulative amount, certainly the current amount of CO_2present in the earth's atmosphere has travelled beyond the alarming situation and needs to be dealt with the single most important step

3. Forecast Analysis

The following line graph shows what will happen if the global emissions are not controlled.
The line graph is also known as forecast analysis for future.

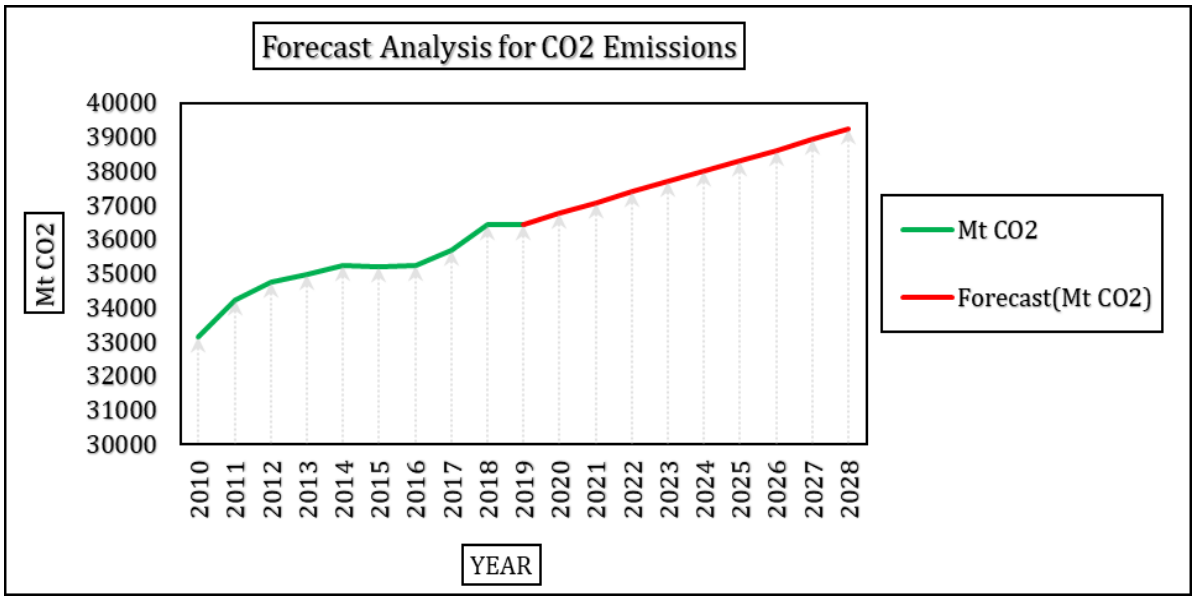

Fig No.2.Forecast Analysis for CO_2 Emissions

Based on the above line graph following table was obtained which shows forecast values for future emissions if they are not controlled. It is clear from the below values that if the emissions are not controlled it can cause problems in terms of air pollution.

Table No.1. Forecast values for CO_2 emissions obtained

Year	Mt of CO_2	Forecast (Mt of CO_2)
2010	33132	-
2011	34210	-
2012	34760	-
2013	34987	-
2014	35245	-
2015	35209	-
2016	35220	-
2017	35696	-
2018	36420	-
2019	36441	-
2020	-	36772

2021	-	37079
2022	-	37387
2023	-	37694
2024	-	38001
2025	-	38308
2026	-	38616
2027	-	38923
2028	-	39230

4. Carbon Footprints

a) What are carbon footprints?

A carbon footprint is the total greenhouse gas (GHG) emissions caused by an individual, event, organization, service, place or product, expressed as carbon dioxide equivalent.

b) Carbon Footprints emitted during burning of coal

Coal burning power generating systems have the largest carbon footprint of all the electricity generation systems. Conventional coal combustion systems result in emissions of the order of greater than 1,000 gCO_2eq/kWh. Lower emissions can be achieved using newer gasification plants (<800gCO_2eq/kWh), which is still an emerging technology so it is not widespread as proven combustion technologies.

c) Carbon Footprints emitted by Solar PV

Solar cells are manufactured from crystalline silicon which is semi- conducting material which converts sunlight into electricity. The pure silicon which is the base element for manufacturing solar cell is extracted from quartz at high temperatures. Life Cycle emissions for solar are currently 58gCO_2eq/kWh. Further reduction is possible as new technologies are emerging such are thin film technology which uses thinner layer of silicon as well as new semi-conducting materials are being introduced. Life cycle CO_2 emissions are even lower for PV systems operating in southern Europe (35gCO2eq/kWh).

5. Comparing carbon emissions for Solar PV against Coal

The power generation from both the conventional and non-conventional sources possess some kind of harmful gases, of which $CO_2$is the major environmental polluter. Coal power generation is the most dominant conventional source of energy and solar being the major non-conventional energy source. However, $CO_2$is released in both the cases but on very different and distinct scales. In the following study, one will get to know the vitality of using PV powered electricity or that of any renewable/non-conventional source of electricity.

Consider the following data in the table which shows top 10 countries in electricity generation for a specific year: -

Table No.2. Country wise electricity generation for a specific year

Sr No.	Country	Total Electricity Generated (GWh)	Percentage Share of Coal (%)	Percentage Share of Solar PV (%)
1	China	7503400	65	10.2
2	USA	4401300	20	2.3
3	India	2558700	71	3.6

4	Russia	1118100	15.7	~0.0
5	Japan	1036300	26	6
6	Canada	954400	8	0.6
7	South Korea	794300	30	6
8	Brazil	688000	2.4	1.1
9	Germany	648700	25	10.5
10	France	574200	2	2

All these top 10 electricity generating countries hold bizarre distribution of coal and solar as the source of energy. Geographical reason stands dominant among all these countries as every country desire to use their natural resources optimally and economically without depending up on any other country.
Considering that on an average 26.51% of electricity is generated from coal and 4.23% from solar PV, we can calculate the amount of CO_2being released just from these two sources.
We neglect the other 69.26% of electricity generated as this paper is concerned about the carbon dioxide emissions which is heavily experienced by coal powered thermal plants and solar cells manufacturing industries.

Calculations:

a) Electricity generation:

For China,
Total Electricity generated = 7503400 GWh
Electricity generated from coal = 26.51% of 7503400
= 1989151.34 GWh

Electricity generated from Solar PV = 4.23% of 7503400
= 317393.82 GWh

Similarly, we calculate for other countries.

b) CO_2 equivalent produced:

Now, we can find out CO_2 equivalent that is produced when electricity is generated.
We know that when coal is burned to produce 1kWh of electricity, 1000g or 1kg of CO_2 equivalent is generated. Similarly, when we use Solar PV 58g or 0.058kg of CO_2 equivalent is generated.

For China,
CO_2 equivalent produced from coal burning to generated electricity
= 1 * 1989151.34 * 10^6
= 1989151.34 kg of CO_2eq/GWh

CO_2 equivalent produced from Solar PV to generate electricity
= 0.058 *317393.82 * 10^6
= 18408.84156 kg of CO_2eq/GWh

Similarly, we calculate for other countries and finally the following table is obtained:

Table No.3. CO_2 equivalent produced corresponding to Coal and Solar PV

Sr No.	Country	Electricity generated from coal (GWh)	CO2 equivalent produced in kg from coal burning to generate electricity (CO2 eq/GWh)	Electricity generated form Solar PV (GWh)	CO2 equivalent produced in kg from Solar PV to generate electricity (CO2 eq/GWh)
1	China	1989151.34	1989151.34	317393.82	18408.84156
2	USA	1166784.63	1166784.63	186174.99	10798.14942
3	India	678311.37	678311.37	108233.01	6277.51458
4	Russia	296408.31	296408.31	47295.63	2743.14654
5	Japan	274723.13	274723.13	43835.49	2542.45842
6	Canada	253011.44	253011.44	40371.12	2341.52496
7	South Korea	210568.93	210568.93	33598.89	1948.73562
8	Brazil	182388.8	182388.8	29102.4	1687.9392
9	Germany	171970.37	171970.37	27440.01	1591.52058
10	France	152220.42	152220.42	24288.66	1408.74228

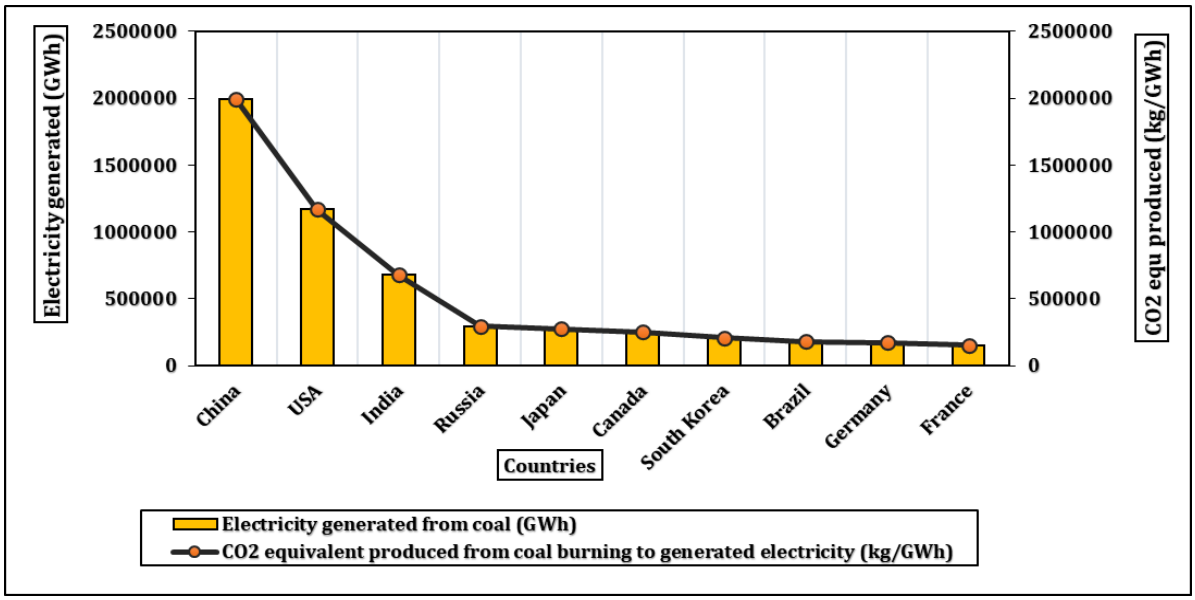

Fig No.3. Comparing Electricity generated from coal and corresponding CO_2 equivalent produced

Let us consider the above combination graph which shows comparison between electricity produced from coal and corresponding CO_2 equivalent produced. The combination graph consists of bar graph which represents electricity generated by coal in GWh and the line graph represents the equivalent CO_2 produced. It can be clearly seen in the graph that equal amount of CO_2 is produced when electricity is generated from coal which is extremely harmful for the environment. If we continue to use excess amount of coal to generate electricity it will certainly cause air pollution, the global temperature will rise and lead to global warming.

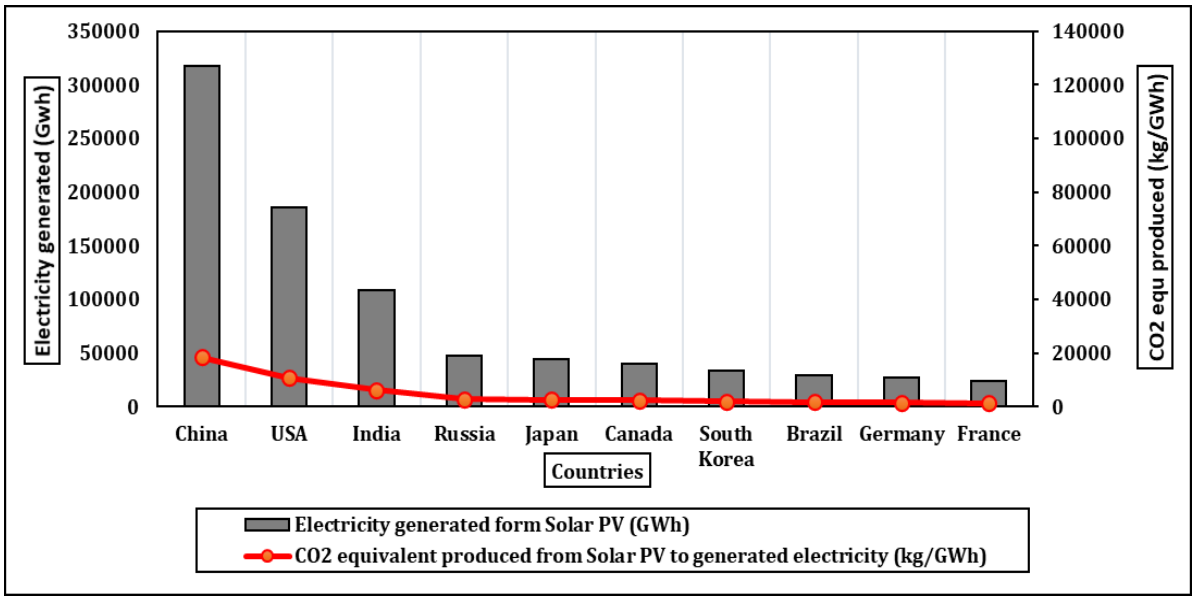

Fig No.4. Comparing Electricity generated from Solar PV and corresponding CO_2 equivalent produced

Similarly, considering above combination graph which shows electricity generated from Solar PV and corresponding CO_2 equivalent produced. In similar way the bar graph shows electricity generated from Solar PV in GWh and the line graph shows CO_2 equivalent produced. It is observed that extremely low amount of CO_2 equivalent is produced when Solar PV is used to generate electricity.

Comparing above two graph gives us a clear idea that it using Solar PV instead of coal to generated electricity will reduce your carbon footprints to considerably high amount.

6. Conclusion

Greenhouse gases or carbon emissions are the root cause for all the natural calamities experienced on this planet. Climate change, glacier melting, human health problems, sea life getting endangered etc. are some of the serious but hidden consequences from these pollutions. Getting shifted to renewable energies does not provide a fool proof solution but it can surely mitigate the current situation to a great extent and can ensure a better and sustained life.

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