

# Renewable Energy Growth Pattern and Correlation with CO2 Emissions in BRICS Nations

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Fossil fuel emissions have become a major concern for many countries worldwide. The adoption of renewable sources of energy is vibrant with sophistication in the field of renewable automobile engine technology innovations. Many countries have been investing large amounts of money in improving their economy and as result of this, CO2 emissions is increasing exponentially. So, the fossil fuels are being used at a faster rate and we are definitely going to run out of them faster than expected. Investing in other greener forms of energy becomes very important in such a situation. Many countries have come together in this regard and have stated making policies and holding meetings regularly to check the damage. But the reforms that have been taken have not been very effective as they have not lead to the required results. The aim of this paper is to sketch out the growth pattern of renewable energy in recent past and to find its correlation with CO2 emissions in BRICS nations. Data from the past 15 years for all the BRICS nations is taken and regression analysis is done with CO2 emissions to determine the impact of one on another. Results show that shifting to greener forms of energy is not the only way to reduce CO2 emissions. Recommendations are also suggested for renewable energy adoption and usage for each of the BRICS nation.

*Index Terms*—Renewable energy, CO2 emission, BRICS, energy emission correlation

## I. INTRODUCTION

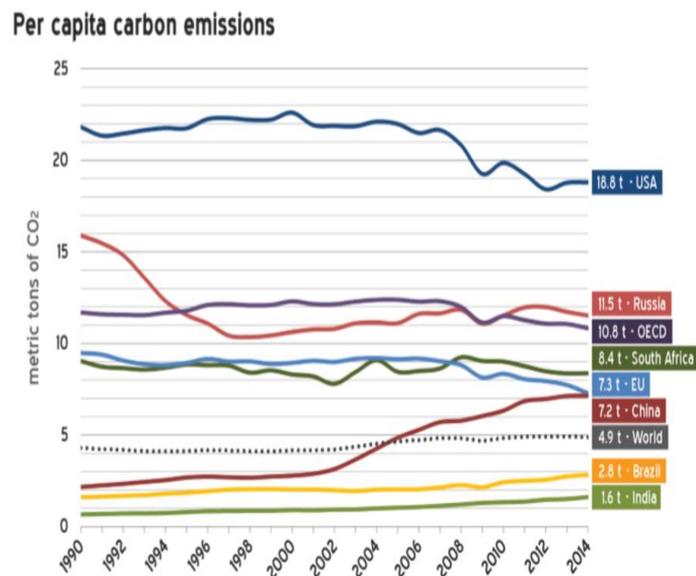
Throughout history, we have had a purely extractive attitude towards natural resources. Due to the problems generated by this over dependence, the United Nations (UN) created the World Commission on Environment and Development (UNCED). This commission criticizes risk of overusing natural resources without considering the capability of the ecosystems to meet these demands, pointing out the disparity between sustainable development and the existing production and consumption patterns.

Renewable energy is the need of the hour; every nation is trying hard to shift to this form of energy consumption from the traditional forms of energy. The world has reached to a point where consumption of fossil fuels has increased more than expected which is leading to exhaustion at faster rate which will make them unavailable for future generations and also are becoming a major cause of pollution. Many policies, conventions, conferences are being held worldwide every year but the outcome of these meetings are not very promising. BRICS Leaders' Summit was held in Goa in October, 2016 and the main agenda is financing clean energy infrastructure but it is found that these countries are facing a \$51 billion yearly funding shortfall to meet the requirement. BRICS nations are trying to introduce various policies to counter the pollution caused by the usage of non renewable energy but these have

not been executed properly. BRICS have a renewable energy objective of approximately 1250GW between 2020 and 2030, which is estimated to cost about \$975 billion. Many attempts have been made to shift to greener form of energy and the main idea behind shifting to renewable sources is that it reduces pollution and other forms of energy are soon becoming extinct.

Over the past few years, every country has been focusing on the economic condition and the ways that can be employed to improve their condition in world economy and this has lead to increase in demand for energy and this has lead to increase in the concentration of Greenhouse Gases, especially carbon dioxide leading to intensifying the natural greenhouse effect and global warming. The current standards of production and energy consumption in the world are mainly based on fossil fuels, which generate emissions of local pollutants, greenhouse gases and put at jeopardy the long-term supply of natural resources in the planet, which are non-renewable. It has been identified that economic growth is directly related to energy consumption. It is important that the planning of efficient energy conservation policies consider the direct affect of energy utilization on economic growth and the penalty of economic growth on energy consumption.

The main idea of this study is to understand whether the shift from traditional forms of energy has caused any reduction in carbon emissions over the past 10 years in each of the countries. Each of these countries has taken up some measures to reduce the dependence on pollution causing forms of energy. The relationship between type of renewable energy used and the corresponding reduction in carbon emissions is noted and the type of energy which will reduce the emissions maximum will be determined. The electricity generation mix for each country is taken and the dependence on each type of energy is analyzed and its relation to reduction in carbon emissions is determined.



## II. LITERATURE REVIEW

Many papers have been published suggesting the importance and the credibility of renewable energy and in one of those papers, data of economic growth, renewable energy and trade for 72 countries has been taken and the outcome suggested that there is a linkage between income and renewable energy consumption, between trade and income and between trade and renewable energy consumption. This paper shows that these variables are interdependent [1] and shows that working on one has an impact on the other and improve the overall well being. 85% of primal energy demand is met by conventional fossil fuels which in turn is

responsible for 56.6% of greenhouse gases emissions. Renewable energy plays an important role in providing sustainable and clean energy leading to reduction in climate change [2]. South Africa has gone from strength to strength in making all policies to improve their condition with regards to shifting to a cleaner form of energy of which Renewable Energy Independent Power Producers Programme is a part in which they are planning to install 17.8GW of electricity generation capacity over the period of 2012-2030 [3]. Renewable energy is said to be a very important factor in reducing carbon emissions and the impact has on the surrounding communities is very important to understand and this paper suggest that it has a positive impact [4]. A survey was conducted taken into consideration factors energy, environment and growth at the individual and regional scale studies covering the period from 1978 to 2014. These surveys show which type of energy can boost economic growth and which can boost the environmental damages through the augmentation of pollutant emissions [5]. ARDL approach have been used to investigate relationship between economic growth and renewable energy consumption in BRICS countries which shows that renewable energy helps in stimulating economic growth [6]. Rapid development in BRIC nations has lead to consumption of large amount of natural resources which has lead to lot of serious environmental issues and as a result this paper [7] calculates the resource footprints of biomass, fossil fuels, minerals and water for the years 1995-2008. The results shows that about 1/3 of global resources were extracted to satisfy the consumption of BRIC countries but the overall per capita footprint was still below the world average which finally try to suggest that the policies employed in BRIC countries should have more rational urban plans which will help in shifting renewable energy and developing a circular economy. Russian government has taken many initiatives to shift from traditional forms of energy to greener and pollution free forms but there is an implementation gap and this paper tries to address the gap and steps that can be used to overcome it [8]. India is a developing country and a lot of energy is required to meet the demand of a growing nation of which major chunk is provided from the traditional forms. This paper focuses on showing the steps taken to improve renewable energy in India [9]. The Indian academic literature on renewable energy form 1998-2014 is taken and review has been done. After doing the research, the authors concluded that Indian energy market is not yet researched well academically and there is a slow growth from form 1988[10]. Another paper shows that higher energy demand and shortage of energy has become a big problem and as a result, energy modeling has become a very important area of research. The author is trying to say that proper and efficient execution is very important and helps in easy implementation of new innovations. The author concludes that there are various stakeholders and variables which will decide the acceptance of renewable energy in India [11].

After doing the literature review, a gap was identified in determining the amount of installed capacity of all forms of energy generation over the past few years and its link with carbon emissions and also the usage of renewable energy usage. A study of the electricity generation mix over the period of 2000-2015 in BRICS nations.

### III. COUNTRY DATA AND ANALYSIS

#### 1. *Brazil*

Over the past 25 years, carbon emissions which have been released from the usage of energy in Brazil have become twice, which made it one of top 10 greenhouse gas emitters from all the other countries worldwide and 1out of 7 in the world.

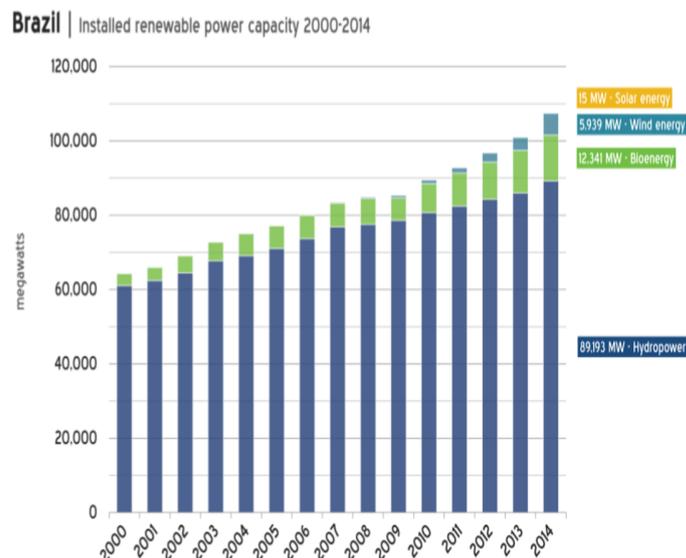
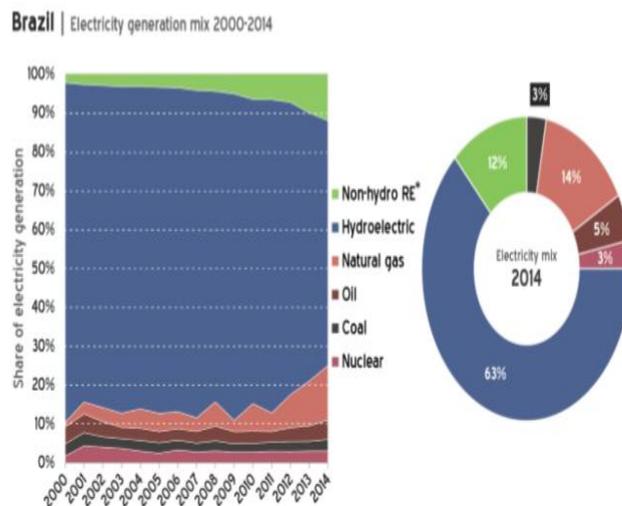
When it comes to generating power, the motive for low per capita emissions is hydropower. Brazil is constructing large hydropower plants and the generation capacity has risen by 50

percent as a result. In 2014, 3 gigawatts were recently built, which made the sum to 84 gigawatts and Brazil and Paraguay share the Itaipu dam, which is the second largest hydroelectric plant in the world. Lot of plants that have been constructed are affecting the people and neighboring communities as they are constructed in the center of the forest. Changes in rain patterns can be traced back to climate change which might create risks to hydropower.

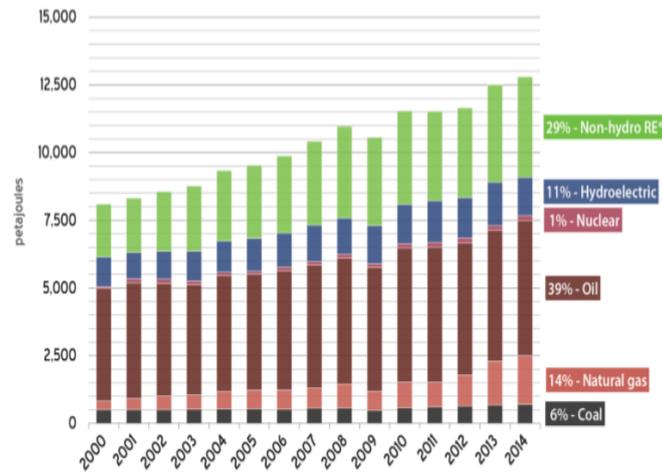
Brazil has constructed farms in several sites in the world as a result; the percentage of non-hydro renewable has developed by 10%. Entire installed wind capacity is still at a mere 6GW at the conclusion of 2014. The sector identified that 4GW could be constructed this year, and installed capacity will reach 16.5 gigawatts by the end of 2019.

10 year map published in September 2015 for the energy sector by Brazilian Ministry of Mines and Energy will raise Photovoltaic production 7GW by 2024. It will be a great improvement for Brazil as the country has 15MW constructed. Greenpeace Brazil anticipated in 2013 that Brazil could put in 100GW of Photovoltaic by 2050 and 23.6GW by 2030.

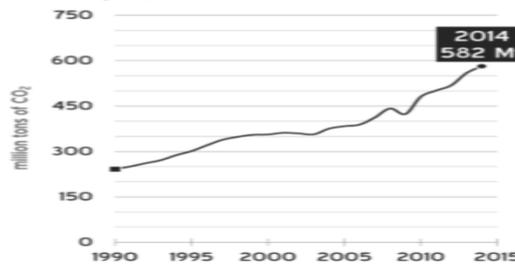
Natural gas utilization in the power sector has increased which is replacing other renewable forms of energy with fossils. The data shows that by increasing the renewable energy dependence, CO2 emissions is coming down. Only 17.6% decrease in CO2 emissions can be attributed to increase in renewable energy usage.



**Brazil** | Primary energy consumption 2000-2014



**Brazil** | CO<sub>2</sub> emissions since 1990



R Square	Beta Coefficient
.176	-.42

Table 1: Regression Analysis for Brazil

## 2. Russia

Russia is the country which has large amount of land area when compared to other nations in the world and also with respect to natural resources, it's a leader. But it has used only its traditional ones, not the greener energy.

Russia is completely dependent on conventional energy and only a little share comes from hydropower. Russia is one the major exporters of oil, natural gas, and coals in the world and Germany gets a large portion of its energy from Russia making Russia Germany's major single supplier.

Carbon emissions in Russia have come down mainly as a consequence of 2 events. Russian economy shrunk in the 1990s but subsequent to that; emissions have been on ascend again. CO<sub>2</sub> emissions have come down again second time due to the financial crisis of 2008. Also, Russia has not made any policies which will help in decreasing dependence on oil, gas and coal.

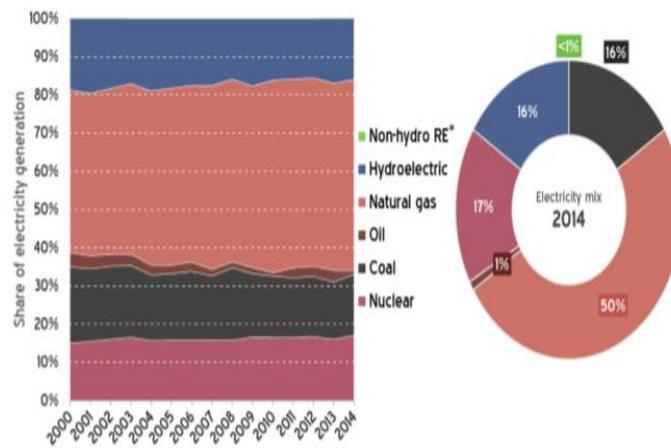
Russia has a big impact on the global climate as it exports a lot and this is larger what domestic emissions indicate. Renewables usage is very good as they can protect the fossil resources for other purposes and hence it will help in improving the condition of climate change and for the Russian economy. Also, they can use their skills to get new sources of fossil extraction; they could make a domestic market for clean energy by contributing and benefitting from greening energy markets.

Russia would gain from this change in a lot of ways. First, the country should create added values locally and should not depend on variable fuel prices, which have taken them to a

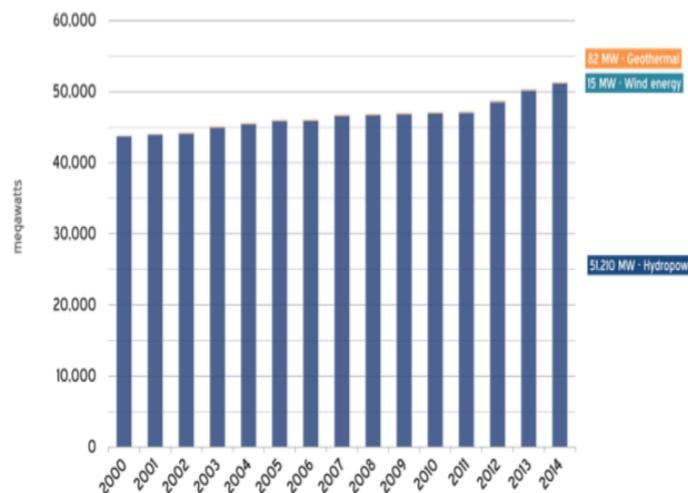
terrible state. Second, there are various smaller benefits. Some of them are: saving large amount of national finances spent for the Northern Supply to give petrol, heavy oil and coal. Over last 15 years, people have shifted towards natural gas, which now provides half of power supply. Coal utilization has come down but only slightly because of this and all through this whole time frame, fossil fuels and nuclear were the most utilized and constituted 80 and 85 percent of power supply.

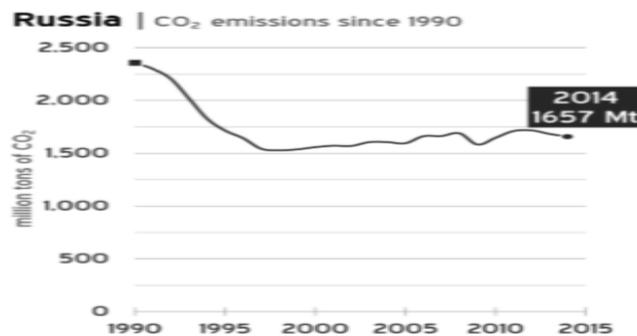
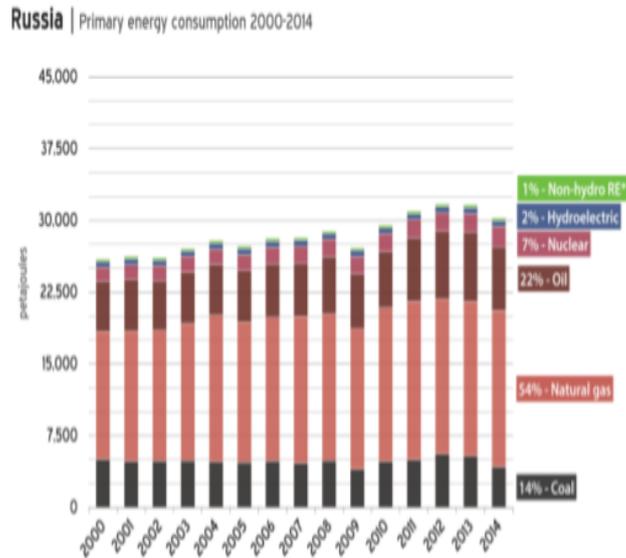
When it comes to primary energy consumption, the supremacy of traditional energy becomes clearer. The data shows that by increasing the renewable energy dependence, CO2 emissions is not coming down. Only 50.9% increase in CO2 emissions can be attributed to increase in renewable energy usage.

**Russia** | Electricity generation mix 2000-2014



**Russia** | Installed renewable power capacity 2000-2014





R Square	Beta Coefficient
.509	.713

Table 2: Regression Analysis for Russia

### 3. India

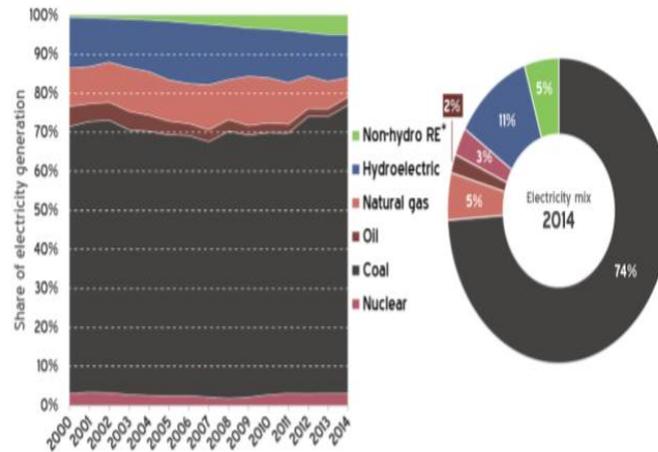
India's CO<sub>2</sub> emissions have become thrice since 1990 but they are less than 1/3 of the EU's per capita emissions. Majority of this raise can be contributed to the remarkable growth over the past 25 years. India had 22.5GW of wind power capacity and 3GW of solar capacity by the end of 2014. Solar market is becoming large as the Indian government is planning to install 100 gigawatts of solar energy by 2022. 40 gigawatts are for distributed rooftop solar power.

The renewable goal for 2022 is 175GW (60 GW- wind power, biomass- 10 GW). India has 306 GigaWatts of generation capability as on 2015, and the GOI is trying to add 250 GigaWatts by 2025.

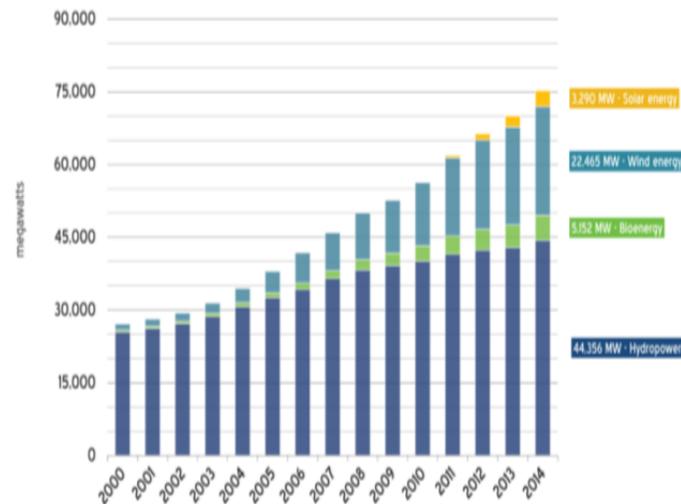
India has targets for nuclear also which is 63 GW by 2032, 3 times the value in 2014, however not much progress happened in this area and target is 14.5GW by 2024. 4.3 GW plant is under construction, but it is unsure whether the plants which have been started will finish on time. Nuclear goals have never been met in India and worldwide and it contributes 3% of electricity generation and 1% of energy consumption. Consumption of coal is increasing faster than domestic creation. India's coal utilization grew by 11.1 percent in 2014 which is highest in any country. India is growing rapidly and at the rate that any country is not able to match up to as a result they are becoming too reliant on coal might be leaders in coal usage in the near future. The data shows that by increasing the renewable energy

dependence, CO2 emissions is not coming down. Only 55.1% increase in CO2 emissions can be attributed to increase in renewable energy usage.

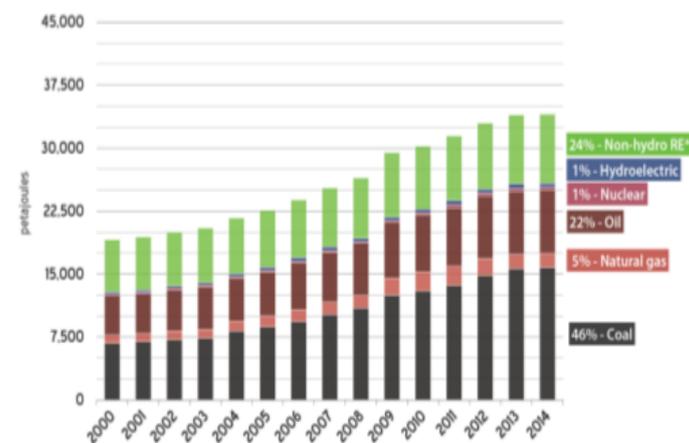
India | Electricity generation mix 2000-2014

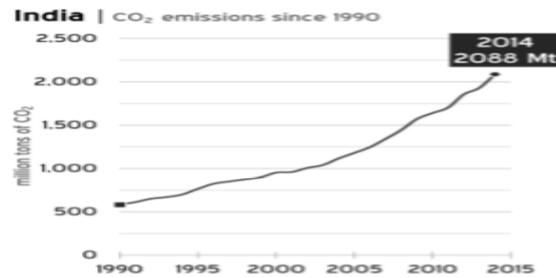


India | Installed renewable power capacity 2000-2014



India | Primary energy consumption 2000-2014





R Square	Beta Coefficient
.551	.662

Table 3: Regression Analysis for India

#### 4. China

China's affect on climate change has become very substantial and China has become the largest emitter of CO2.

Chinese have reported coal utilization in a wrong way in the past as they of defied government orders to close old coal mines. These records have been corrected later in 2013.

This is excellent news as it has given a clear indication of China's coal usage and CO2 emissions. It has made China's emission related goals more determined.

Coal use has been in double digits for almost a decade and it has come down to 4% for the first time because of the economic rebalancing. A large amount of increase in global CO2 emissions is due to coal from China.

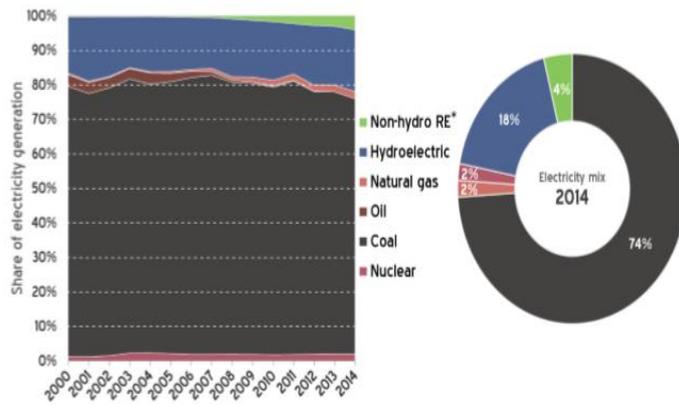
From 2011 to 2015, China's power generation has not increased although they added 190 Giga Watts of thermal producing capacity, and 20% rise in demand for power during this time was met by conventional energy.

China had 28GW of Photovoltaic capacity, only behind Germany and while Germany slows down, China continues to construct more plants up to 7.7 gigawatts. Reports have shown that China may go all-out for a huge 150 to 200GW of Photovoltaic but planned goal is 100 GW.

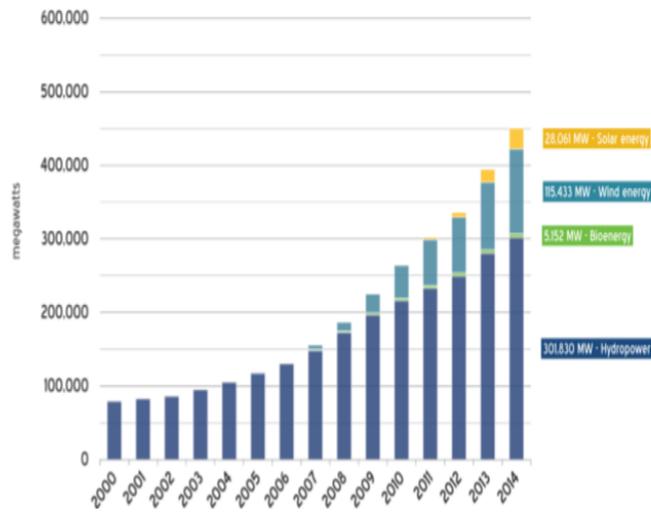
Wind power growth is equally impressive in China and they have competed with US for leadership in the wind and they have set new records by installing more than 23 gigawatts in one year which is the highest ever by a single country to be done and now the total is up to 114GW.

Consumption of coal has stabilized starting in 2012 although china has been growing and their demand for energy is also high and reports suggest that coal utilization is now declining faster than planned. As China is using less amount of coal, global coal prices have come down drastically and China seems committed to stay away from coal, so what other countries have to do is to keep away from taking benefit of these lower prices to boost their own utilization. China is increasingly becoming a country to follow and not criticize. The data shows that by increasing the renewable energy dependence, CO2 emissions is coming down. Only 35.1% decrease in CO2 emissions can be attributed to increase in renewable energy usage.

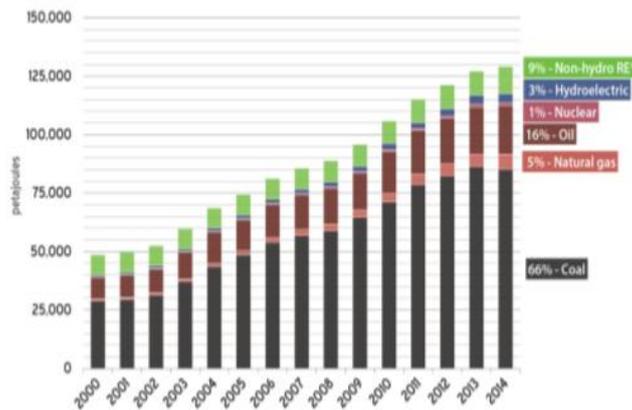
**China** | Electricity generation mix 2000-2014

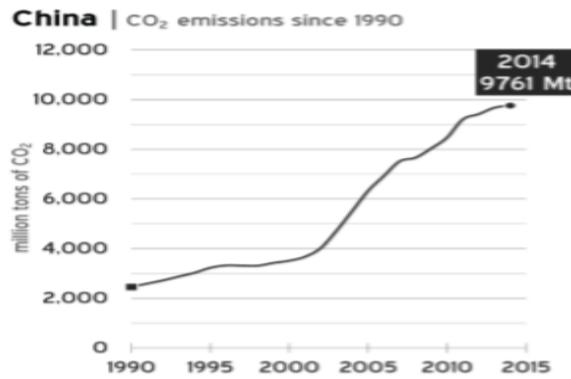


**China** | Installed renewable power capacity 2000-2014



**China** | Primary energy consumption 2000-2014





R Square	Beta Coefficient
.351	-.592

Table 4: Regression Analysis for China

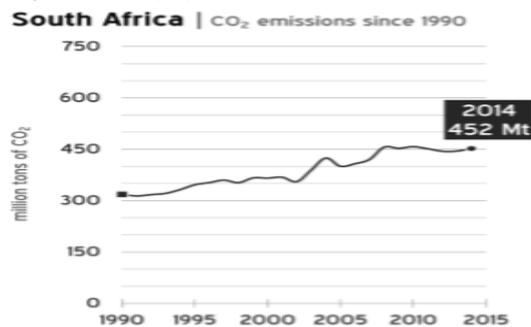
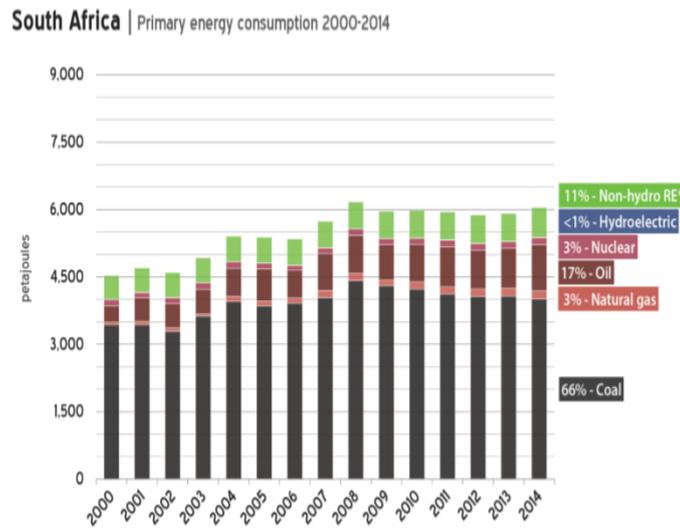
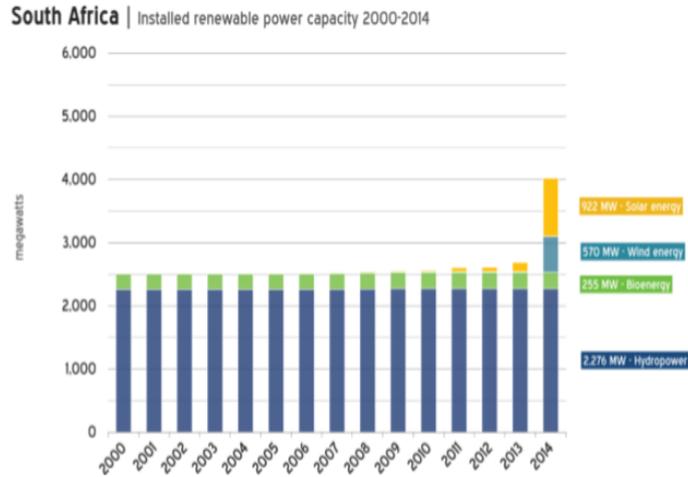
### 5. South Africa

South Africa's carbon emissions have been rising steadily since 1990's but it was more noteworthy in the 2000s. Change in South Africa related to renewable energy started in 2014. Biomass constituted the main part of renewable energy till then although very small amount of solar and wind was installed. Onshore wind installations increased from 10MW in 2013 to 570MW last year.

An additional of 6.3 gigawatts of capacity is planned to be added to the existing 5.24 gigawatts already in mind. The overall target of 17.8 Gigawatts is very low and there is scope for so much more. In South Africa, only 1 in 10 households have 24 hours electricity supply facility. Micro grids which are based on renewable energy are cheapest alternative for these communities.

South Africa, among all the BRICS nations is the most dependent on coal and it constitutes about 92% of power supply, a level which has never changed in the past 15 years. The dependence is increasing as very huge coal stations are being built at Medupi and Kusile.

The Government is planning to invest in nuclear to build plants up to 9600MW, but independent analysis shows this will be more costly than either coal or renewables. South Africa's per capita carbon emissions have been very high and it has reached to a level higher than the one mentioned by European Union even though per capita gross domestic product is a lot greater in the European Union. South Africa has great renewable energy potential which is proved by a study which says they could get 75% of power generation from renewables. Also, another report for the UNEP suggested that South Africa could get more than 1/2 of its electricity from renewables by 2030. The data shows that by increasing the renewable energy dependence, CO2 emissions is not coming down. Only 8.1% increase in CO2 emissions can be attributed to increase in renewable energy usage.



R Square	Beta Coefficient
.081	.285

Table 5: Regression Analysis for South Africa

#### IV. RECOMMENDATIONS AND CONCLUSION

##### 1. Brazil

Brazil should use the resources properly with regards to renewable energy as they have a lot of potential which will allow shifting to wind and solar power to reduce carbon emissions from power. Brazil should target 42.7 GW of wind and 23.6 GW of Photovoltaic, and 44.9

GW of other renewable by 2030. Adding to greener projects will strengthen urban and rural populations, which will provide them with better idea about the energy sector. In this way, people become energy makers themselves and gain economically which will in turn increase the energy efficiency. More fossil fuel extraction by the Brazilian government would lead to many problems and one of that being financial losses which will happen because of climate change. Brazil should try to be below the global per capita average for carbon emissions in 2020 and CO<sub>2</sub> emissions should be limited to 1Gigatonne by 2030. Deforestation should be reduced in Amazon forest and Cerrado regions. Higher funds should be put in public transport which is needed to limit fossils use in infrastructure.

## *2. Russia*

Russia should try to reconsider options and set ambitious goals in renewable energy production and get rid of all the legal barriers which will help in implementing energy efficiency technologies. They should try to orient state subsidies from new oil and gas withdrawal and also from nuclear in different way which will favor renewable energy and energy efficiency. Russia should try to increase the speed of development of the domestic system which is responsible for greenhouse gas emissions, and find a method which will regulate greenhouse gases. Also, start new international renewable energy plans with neighbouring countries like China, Mongolia, and Kazakhstan etc.

## *3. India*

India should focus on creating effective financing layouts for easy energy access by trying to varying the climate negotiations. Sustainable energy is not accessible to 1.2 billion people around the world but India has promised to deliver 24 hours power supply to everyone by 2019 and the best way to do this is to use distributed renewable energy. Coal mining should not be done from forests and these activities should be prohibited. Government must try to impose restrictions on mining in forest areas to extract coal otherwise the climate would be badly impacted. The government must make plans which include the fact that we will run out of fossils and nuclear energy, and how to change to renewable energy.

## *4. China*

China should try to set a ruthless coal consumption threshold for the years 2016 – 2020, and make sure that every province has its own target and this target should be prepared taking into account coal consumption in 2014. China should make all the changes required to take the national CO<sub>2</sub> emissions to the peak level much earlier than 2030, maybe even as early as 2025. They should change structure of its power generation system so that growth of renewable energy should not be stopped, and solar power production is increased.

## *5. South Africa*

South Africa should change their electricity plan (made in 2011) as it is out of date, mainly because renewable energy has become so cost competitive. The plan which is being employed by South Africa overlooks the enormous advantage that it has in renewables, and the openings that can be used to shape the future of the country capacity as a of renewable energy producer. Small projects should be employed as they can enhance electrification and rural. Barriers to rooftop solar occur due to the lack of a regulatory framework, financing methods, go-getting targets for the renewables and also a reliable grid. South Africa should

prefer greener investments instead of water and pollution causing ones which will mean that the country's target of 17,800MW of renewables will be met by 2030. No more coal stations have to be constructed after Medupi and Kusile, and rest of the coal stations must be shut down after they complete their life span of working.

## REFERENCES

- [1] Fethi Amri (2017)“Intercourse across economic growth, trade and renewable energy consumption in developing and developed countries”, *Renewable and Sustainable Energy Reviews*, Volume 69, Pp 527-534
- [2] Souvik Sen and Sourav Ganguly (2017) “Opportunities, barriers and issues with renewable energy development – A discussion”, *Renewable and Sustainable Energy Reviews* , Volume 69, Pp 1170-1181
- [3] David Richard Walwyn (2015) “Renewable energy gathers steam in South Africa”, *Renewable and Sustainable Energy Reviews*, Volume 41, Pp 390-401
- [4] Mario Orestes Gonzalez, Joeberson S Goncalves, Rafael M. Vasconelos (2017) “Sustainable Development: Case Study in The Implementation of renewable energy Brazil”, *Journal of Cleaner Production*, Volume 142, Issue 1, Pp461-475
- [5] Sofien Tiba and Anis Omri (2017) “Literature survey on the relationships between energy, environment and economic growth”, *Renewable and Sustainable Energy Reviews*, Volume 69, Pp 1129-1146
- [6] Maamar Sebri and Ousama Ben-Salha (2014) “On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries”, *Renewable and Sustainable Energy Reviews*, Volume 39, Pp14-23
- [7] Rui Wu, Yong Geng and Wenjing Liu (2017) “Trends of Natural Resource Footprints in the BRIC Countries”, *Journal of Cleaner Production*, Volume 142, Issue 2, Pp 775-782
- [8] Niels Smeets (2017) “Similar goals, divergent motives. The enabling and constraining factors of Russia's capacity-based renewable energy support scheme”, *Energy Policy*, Volume 101, Pp 138-149
- [9] Arpit Gupta, Balkrishan Sahu, Archana Soni (2016) “Growth of Renewable Energy in India”, *International Journal of Innovative Science, Engineering and Technology*, Volume 3, Issue 6, Pp 614-617
- [10] G.S.Sisodia, P.Singh (2016)“The Status of Renewable Energy Research in India”, *Energy Procedia*, Volume 95, Pp 416-423
- [11] G.S.Sisodia, M. Sahay, P. Singh (2016)“System Dynamics Methodology for the Energy Demand Fulfillment in India: A Preliminary Study”, *Energy Procedia*, Volume 95, Pp 429-434