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Forecasting CO_2 Emissions Level in Saudi-Arabia (2014-2018) using Zeytun Time Series Statistical Software

Ahmed A.H
Department of Earth Science, King Fahd University of Petroleum and Minerals-31261 Dhahran, Saudi Arabia

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Abstract

Our results on this research paper propose that the forecasted path of Saudi Arabia's carbon dioxide (CO_2) emissions has considerably been increased over the last years. The scale of the predicted increase in emissions out to 2018 is much higher than last years. Our estimate is based on the World Bank CO_2 emission data. This records set contain significantly more information related to the trend of likely Saudi Arabia carbon dioxide (CO_2) gas emissions which can be used by the government and all other stakeholders.

Keywords: Carbon dioxide (CO_2), Emissions, Saudi Arabia, World Bank, Data, Zeytun Time Series.

Introduction

Saudi Arabia is among the gulf countries situated in South West Asia, is the largest country of Arabian peninsula, bordering the famous Red Sea and the Persian Gulf and to the North of Yemen[1]. It approximately covers about 2,217,949 square kilometers, as per Saudi Arabia government and also among the world largest oil-producing countries with over 63% of the world's oil production. According to the reports in 2012 November, Saudi-Arabia produced 9.9 million barrels, while Russia which is one of the main oil producers accounted for 10.9 million barrels of crude per day[2].

Climate change, global warming, Biodiversity, acid rain, desertification and deforestation have called considerable worldwide attention specially environmentalists and its believed to be related to the fossil fuel. Many researchers have determined on the relationships between growth and gaseous emissions for the last decades. It has been watched that higher economic development causes natural problems and undermines the manageability of the earth in general because of the way that energy utilization and economic development are firmly interconnected[3]. Higher economic development needs higher amount of energy use and is in charge of larger amounts of CO_2 emissions. This notion attracted the world's attention in the 1990s because of the potential threats to the ecosystem. It became the general consensus that higher economic growth should not be pursued at the expense of the environment and this issue raised the question of how economic growth can be made more sustainable. Brundtland defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs[4]. Many International agencies and organizations in different parts of the world attempted continuously to decrease the major impacts of global warming. One such attempt is the Kyoto Protocol agreement, titled the United Nations Framework Convention on Climate Change (UFCCC), made in 1997 as an attempt to reduce the adverse impacts of global warming. Among the variety of polluting substances, CO_2 is a major one and represents 58.8 percent of greenhouse gas emissions [5].

Generally, carbon emissions, particularly carbon dioxide (CO_2), are among the group of difficult gases that impact negatively on the quality and the standard of our clean air and rises our global temperature and contributes to the greenhouse effect.

In this way, greenhouse gasses have immediate consequences for the indigenous habitat starting a great climate changes, a worldwide temperature build, and the loss of environments, corrosive downpours and possibly dangerous wellbeing impacts for individuals and animal planet. Many regulations and policies have been laid to regulate carbon emissions through government and inter-governmental mandates. In regards, government mandates on emissions can be summarized in two schools of thoughts where the first school is taxing companies directly based on their emissions magnitude, with the aim of reducing total emissions by convincing businesses and industrial entities to minimize emissions to save the environment.

The other school of thought is called cap-and-trade legislation and its governmental control approach which is still under study for the last couple of years. In this system, the government will give a limit or a range or a "cap" on the maximum quantity of emissions it will allow. Therefore, it then sales off emissions allowances and limits to industries and companies until it reaches that cap or range and if company exceed the limit is forced to either reduce their total emissions or buy quotas from other companies. This is noted to be imposing strict emission standards without directly taxing companies. The policy has possible problems although, as the carbon cap grows more rigid and tough over time the companies will be forced to buy special

permits at higher prices and in return the cost would likely be passed to the consumers who are the end users. In addition, the regulation will have drawdown on the general economy[6] because as the policy tightens all the commodities that use energy for production or transportation will increase price hence causing end user the consumers in particular to dig deep into their pockets to make ends meet[7].

In all the conditions and efforts tried by the countries and the international world after even Rio declaration of 1992 the effects of carbon dioxide is anonymously felt in Saudi Arabia and the other parts of the world. Carbon dioxide is available in the natural atmosphere in the form of earth's carbon cycle and its natural circulation is found in atmosphere, hydrosphere, geosphere and biosphere. Human activities are disturbing the equilibrium of the natural carbon cycle by adding CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere through deforestation. However, CO_2 emissions come from a variety of natural sources; human-related emissions and industrialization have contributed to the highest CO_2 emissions to the atmosphere[8].

The major modern and human action that delivers CO_2 is the blazing of hydrocarbons particularly the fossil fuels (coal, common gas, and oil) for transportation and vitality, despite the fact that land-use changes certainly and predominantly mechanical procedures and autos additionally emanate CO_2 yet the most infamous one is the car and modern outflows. Carbon dioxide is delivered if adequate oxygen is given to the procedure of ignition and if there is little oxygen, carbon monoxide CO, is formed. Besides, Carbon Monoxide in the environment can respond with oxygen under certain wavelength to shape carbon dioxide and Ozone, Carbon dioxide is additionally the by item or creature breath forms on the grounds that creatures take in oxygen and breathe out carbon dioxide after oxidation of sustenance stuffs to deliver vitality to support life. Additionally, carbon dioxide is created amid aging process anaerobically where glucose is separated in the vicinity of Oxygen. In any case, nature settles the issue of access carbon dioxide in photosynthesis process where the impetus (chlorophyll) the green shades in plants and the energy from daylight produce nourishment in this procedure, photosynthesis, which happens in every single green plant, changes over CO_2 and water to starches, discharging oxygen as a waste item and the cycle of life proceeds. On the off chance that carbon dioxide (CO_2) is available in the best fixation in the troposphere it contributes most to the acidity of water. Carbon dioxide responds with water to form carbonic acid which is corrosive. Carbonic acid then separates to give the hydrogen ion (H^+) and the hydrogen carbonate ion (HCO_3^-). The capacity of H_2CO_3 to convey H^+ is the thing that groups this atom as a corrosive, subsequently bringing down the pH of an answer[9].

The choice of predicting Saudi Arabia emissions is inspired by the fact that the kingdom is the largest oil producer and exporter of total petroleum liquids in the world and being a faster developing country that utilizes energy more than the other developing countries in Asia or other continents. Saudi Arabia ranks 14th among nations based on 2008 fossil-fuel CO_2 emissions with 118 million metric tons of carbon, and ranked world 73rd in SO_x emission by producing 560 thousand metric tons/squ. Growth theory predicts that in the initial stages of development, the pressure on the environment is high because the use of energy is crucial to economic growth and development hence, increasing the emissions. Saudi Arabia has no public transport like train within the big cities hence use more private vehicles increasing fuel consumption and emissions. In addition Saudi Arabia is among the fastest developing countries and has well established industrial system that consumes more fossil fuel increasing emissions.

In this study, we present a logical framework and statistical tool to accurately forecast the resulting carbon dioxide emissions in the coming five years (2014-2018). The main objective behind the forecasting study is to help environmentalist and entire scientist's to reduce the relatively high-cost of infrared radiation adsorption and electrochemical instruments, highly priced real-time measuring devices and active monitoring time. Furthermore, the forecasting will help the government institutions design prior the right measures to minimize the effects like government departments working together as they develop a national low carbon development plan, help government to facilitate the approval of renewable energy and energy efficiency and also investigate generation options for the coming 5-year time horizon.

Howsoever, the forecasting is coherent and reliable the characteristic of technological forecasting is still uncertain about the rate of change of technological capabilities and other key factors contributing to the decrease in carbon dioxide emissions included an economy in recession with a decrease in gross domestic product, a decrease in the energy intensity of the economy, and a decrease in the carbon intensity of energy supply and in addition taking population expansion into account.

The affiliation and the co-association between the measure of carbon dioxide (CO_2) and the world's surface rising temperature has been without a doubt comprehended, regardless of the way that the tremendous and the honest to goodness outline is now and again discernible. The past Soviet specialist M. I. Budyko is credited with first outlining the movements in valid rising temperature against changes in CO_2 obsessions where he diagrammed direct, relationship between the typical temperature and the measure of CO_2 in the atmosphere that is, temperature raises as CO_2 centers increases. The temperature moreover climbs as methane additions. Then again, increases in the measure of dust in the atmosphere are associated with colder atmosphere[9].

Current verifiable information relate with the start of cutting

edge climate anticipating, which began with weight estimations taking after the development of the (atmospheric pressure) in 1644. Temperature, weight, wind rate and bearing, and (rain, snow, and so on.) estimations have heaped up from an expanding number of spots/areas. The chronicled temperature record demonstrates an increment in overall normal temperature by around 0.5^0C in the course of recent years. Groupings of CO_2 measured and recorded at the Siple Station in Antarctica over the same period demonstrate an increment from 285 sections for every million by volume (ppmv) in 1850 to 312 ppmv in 1853. Estimations made at Mauna Loa (an extensive well of lava related mountain in Hawaii) demonstrate that groupings of CO_2 have expanded from 315 ppmv in 1958 to 360 ppmv in 1993 and most recent is 391.01ppmv and 393.66ppmv for 2012 and 2013, the most elevated CO_2 esteem so far recorded[9]. The evaluated Mauna Loa once-a-year mean development rate is 0.11 ppm/yr. This estimation depends on the standard moving without end of the contrasts between month to month mean qualities measured freely by the Scripps Institution and by NOAA/ESRL. The once-a-year development rate measured at Mauna is not the same as the overall development rate, but rather it is very nearly the same and can be utilized as reference for this study.

Methodology

This study attempted to use 3 software to explore the relationships with data prediction in terms of software dependency and found that the best predicting of the three is Zeytun time scale model which is been used for analysis in this forecast study and the result graphed using Microsoft Excel and tabled using Microsoft Word. Energy forecasting framework and emissions consensus tool (EFFECT) and SAS/AF are the other software that was tried but the study selected Zeytun because it had the most minimal error.

Zeytun time series software: A Time series is a period construct grouping in light of specific variables. The objective of building a period arrangement model is the same as the objective for different sorts of models which is to make a model such that the blunder between the estimation of the objective variable and the real estimate is as little as would be prudent. The primary distinction between time arrangement models and different sorts of models is those slacks estimations of the objective variable are utilized as a part of time arrangement though conventional models use other variable as expectation, and the thought of a slack worth doesn't have any significant bearing the perceptions don't speak to a sequential grouping.

Zeytun Time Series is intended for simplicity, of utilization, for examination, arrangement demonstrating and gauging of time arrangement information. It gives insights and neural system models, and graphical instruments that will make chip away at time arrangement investigation simpler.

Statistics and Neural Networks Analysis such as Trend Analysis, Decomposition, Moving Average, Exponential Smoothing, Linear Regression, Correlogram and Neural Networks. Graphical Tools such as Time Series Plot, Actual and Predicted Plot, Actual and Forecasted Plot, Actual vs Predicted Plot, Residual Plot, Residual vs Actual Plot, Residual vs Predicted Plot and Normal Probability Plot.

Zeytun Time Series was produced by the "Time Series" group of understudy in Indonesia and the model is as yet being taken a shot at now. The product is free and simple to introduce as it needs just 10MB hard drive space.

Trend Analysis Overview: Linear Trend is a straightforward capacity depicted as a straight line along a few purposes of time arrangement esteem in time arrangement diagram. The linear trend pattern has a typical example:

$$Tt = a + b.Yt$$

Where: Tt = Trend value of period t, a = Constant of trend value at base period, b = Coefficient of trend line direction, Yt = an independent variable, represents time variable, Normally assumed to have Integer value 1, 2, 3....as in the sequence of time series data.

There are systems that can be utilized to locate the direct pattern mathematical statement of a period arrangement. Most usually utilized is minimum squares strategy. This strategy finds the coefficient estimations of the pattern mathematical statement (a and b) by minimizing mean of squared mistake (MSE). The equation is:

$$b = n\sum Y_t T_t - \sum Y_t \sum T_t$$

$$\frac{n\sum Y_t^2 - \sum (Y_t)^2}{a = \underline{Y}_t - b\underline{T}_t}$$

Nonlinear Trend: In cases, straight is bad for time arrangement information, these cases happen when a period arrangement has an alternate slope between the starting period of the information and the following stage. For these cases, it is ideal to utilize non-direct pattern than straight pattern.

There are various nonlinear trends, they are:

Exponential: $T_t = ab^y$

Quadratic: $T_t = a + bY_t + cY_t^2$

Cubic: $T_t = a + bY_t + cY_t^2 + dY_t^3$

The most suitable trend is a one with the smallest error that is the smallest difference between actual data and the predicted data from trend value. The common rule used to find the best trend is by choosing a trend with the smallest standard error value and having the biggest R-square value[10].

Table-1
Actual Data 1980-1996 from World Bank

Year	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Amount of Emissions (Metric Tons per Capita)	17.2	16.7	14.1	13.6	12.4	13.0	14.7	13.1	13.4	16.0	13.4	16.0	16.5	17.1	17.0	12.7	13.7

Table-2
Actual Data 1997-2010 from World Bank

Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Amount of Emissions (Metric Tons per Capita)	11.3	10.8	11.5	14.7	14.2	15.0	14.3	16.6	16.1	17.1	15.2	15.9	16.1	17.0

Table-3
Saudi-Arabia Emission Data forecasted in Metric Tons per Capita using the 4 models in the Software

Year	**Linear**	**Nonlinear Trend**		
		Quadratic	Cubic	Exponential
2011	15.35	17.14	17.24	15.23
2012	15.39	17.52	17.62	15.27
2013	15.43	17.91	18.02	15.31
2014	15.47	18.33	18.44	15.36
2015	15.51	18.76	18.88	15.40
2016	15.55	19.22	19.33	15.44
2017	15.59	19.70	19.80	15.48
2018	15.63	20.19	20.29	15.52

Results and Discussion

The information is from World Bank and it is in metric tons per capita. CO_2 are these originating from the smoldering of (coal, characteristic gas, oil, and so forth.) and the assembling of bond. They incorporate carbon dioxide delivered amid utilization of strong, fluids and gas energizes and gas flaring and the information Carbon Dioxide Information Analysis Center Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, and United States and Catalog Sources of World Development Indicators.

First the study has compared all the existing models in the software and found that cubic was the most suitable for this study because it has less error and consistent data prediction. However, this does not prevent the use of other model comparison methods. The combination of the models was not possible after performing a generalization criterion comparison. The cubic was found to be having advantage of giving better parameter estimates. The combination and generalization of models was proposed by Busemeyer and his counterpart[11].

Comparing Figure-2 and Figure-1: The CO_2 emission decreased by 9.18% according to the World Bank data due to the strict policies nationally and internationally that were implemented. However slight deviation was noticed in 1986 and 1989.

Table-4
Actual Data 1997-2010 from World Bank

Years	Amount of Emissions (Metric Tons per Capita)
2011	17.24
2012	17.6
2013	18.0
2014	18.4
2015	18.9
2016	19.3
2017	19.8
2018	20.3

Comparing Figure-2 and Figure-3: The emission increased rapidly by 19% between 1990-1994 compared to 1985-1989 that is an average yearly increment of 3.8% due to the gulf war and other uncontrolled parameters contributing to the emissions.

Figure-4: Contrary to all earlier years, the years between 1995 and 1999 witnessed a continuous decline in Saudi Arabia's emission by 25% that is approximately 5% average annual reduction and probably reduced consumption of primary energy, mostly driven by the significant reduced use of fossil fuels in the country. The result is in agreement with work done by Javid and his group in recently in 2015 in Saudi Arabia who found that increase in oil consumption has directly correlation with carbon dioxide emission[12].

As can be seen in Figure-5 continuously rapid growth of energy consumption is noticed as indicated by high emissions of 24.7% increase, total emissions of Saudi Arabia grew steadily in the years 2000-2004, with an annual average emission rate of 4.94%. The finding is in line with work done by Khalid and his team in Saudi Arabia in 2012 who found that increase in energy consumption increases carbon dioxide emission[13].

Figure-6 illustrates slight increase by 7.5% in the emissions compared to the previous years (2000-2004, in Figure-7 and Table-4 it can be seen that Saudi's CO_2 emissions will probably increase to about 18.4,18.9, 19.3,19.8 and 20.3 in 2014, 2015, 2016, 2017 and 2018 respectively if none effective control measures were adopted.

Further, Saudi's CO_2 in the future will still remain unevenly allocation among different fuels and economic sectors. By 2018, fossil fuel will still be the largest fuel source, accounting for more than 80% of the totals. The predicted results is in line with work done by many studies done on carbon emissions in the world and in Saudi Arabia in particular[12-16].

The Figure-8 illustrates an average annual emission increment of 1.8% for the last 5 years (2009-2013) and forecasted average annual increment of 2.2% in the coming 5 years (2014-2018)

Recommendations: The study recommends the use of Zeytun software for the forecasting of all carbon dioxide and other related emissions whether linear or non-linear in nature because the software has very minimal error in forecasting data and has many models programmed to choose the appropriate and the most relevant. The study recommends the government and stakeholders to provide reliable and up to date data for the study in the near future. More information and variables like weather condition, topography and the terrain of the areas, seasons, temperature, pressure to be incorporated in all emission forecasting. To reduce the forecasted high level of CO_2 emission the study recommends the following measures and methods to minimize the concentration in the atmosphere: Strong government policies to be implemented and punishment of defaulters to be imposed, Employing energy efficiency and conservation practices, Importing fuel effective machine and vehicles, Strict adherence to the global natural traditions like Kyoto convention and Rio Declaration, Using without carbon or diminished carbon vitality assets, Capturing and putting away carbon either from fossil fills or from the environment.

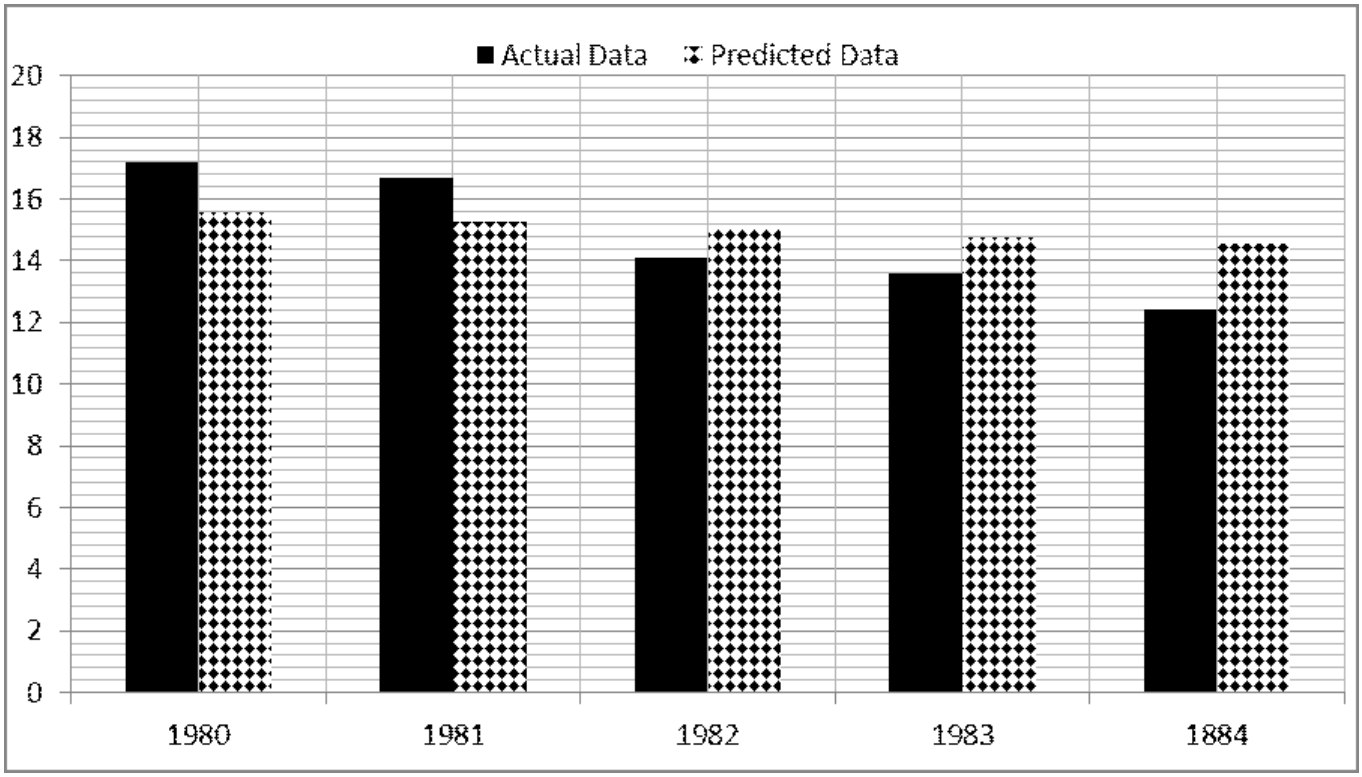

Figure-1
Actual and Predicted Data of 1980-1984

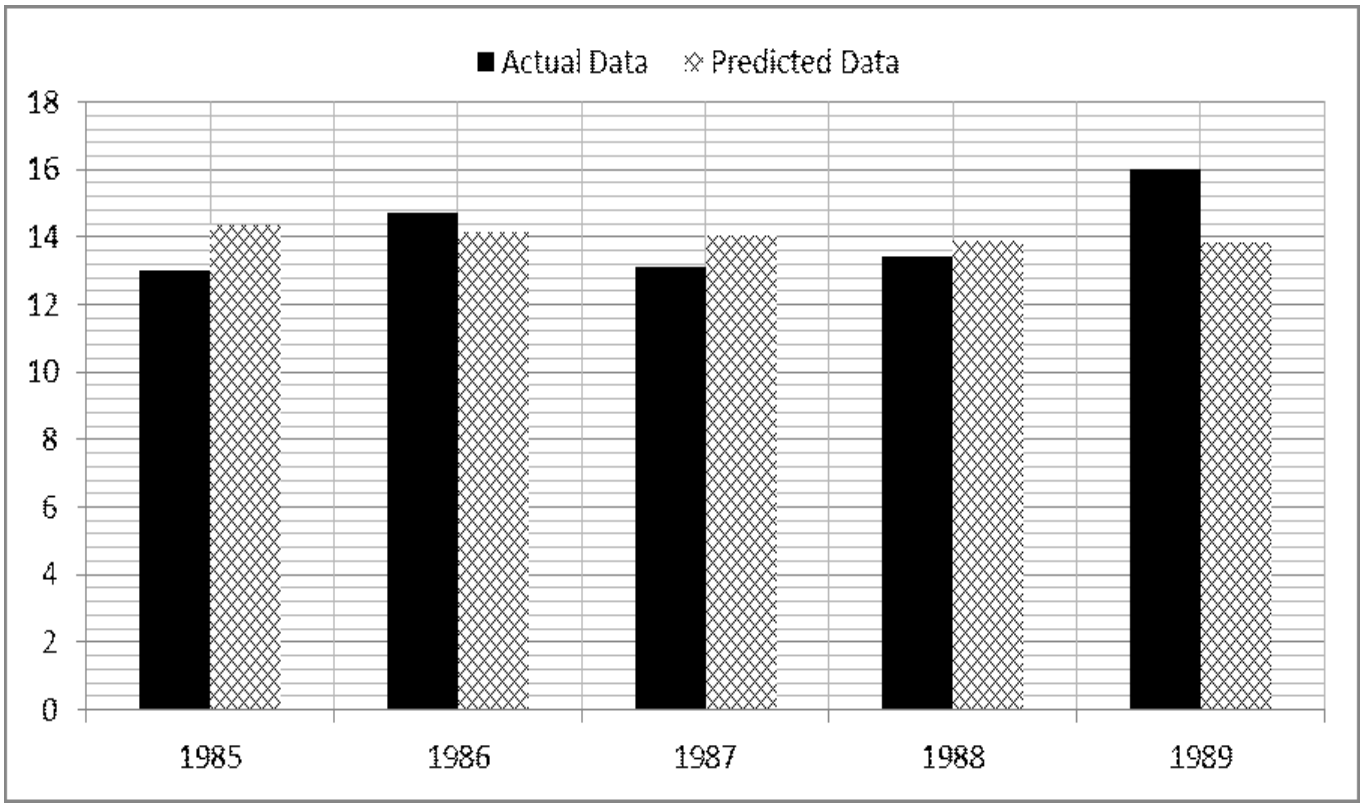

Figure-2
Actual and Predicted Data of 1985-1989

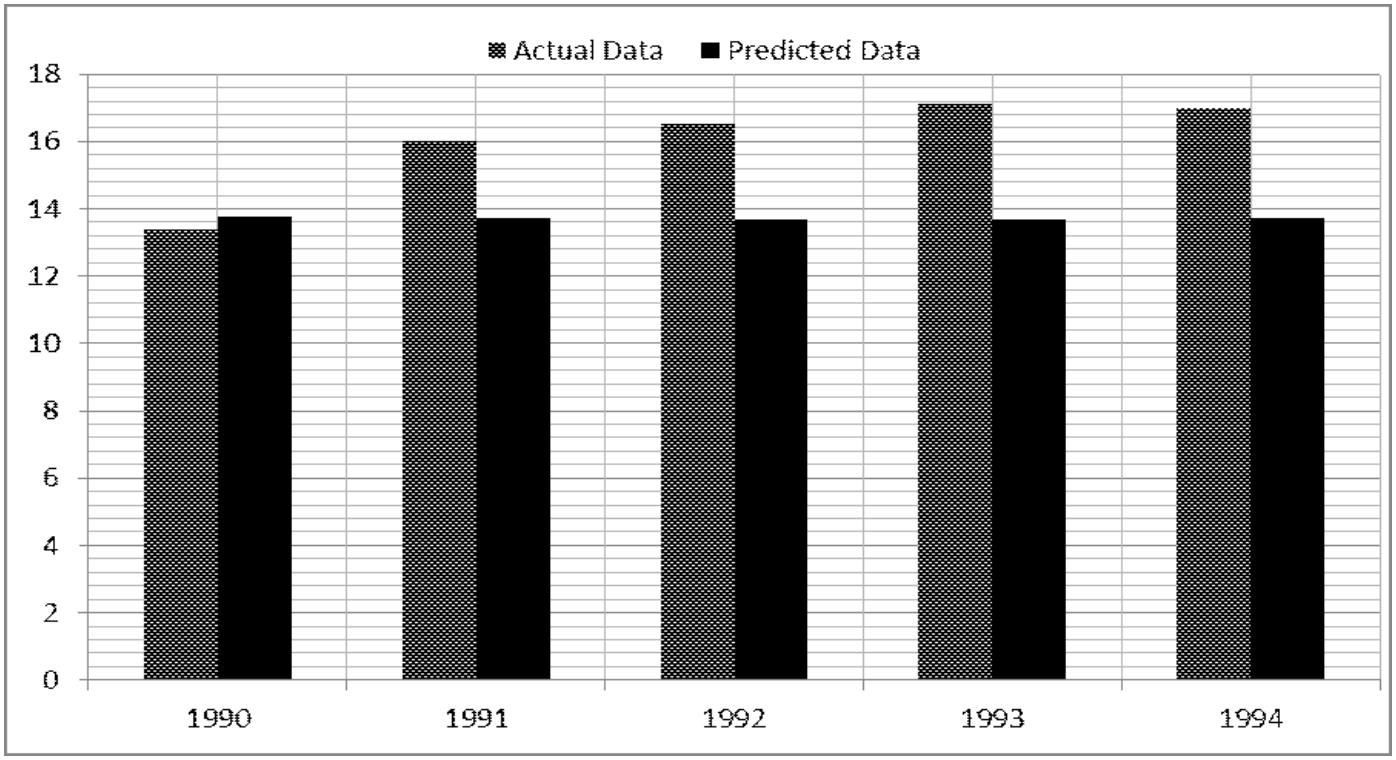

Figure-3
Actual and Predicted Data of 1990-1994

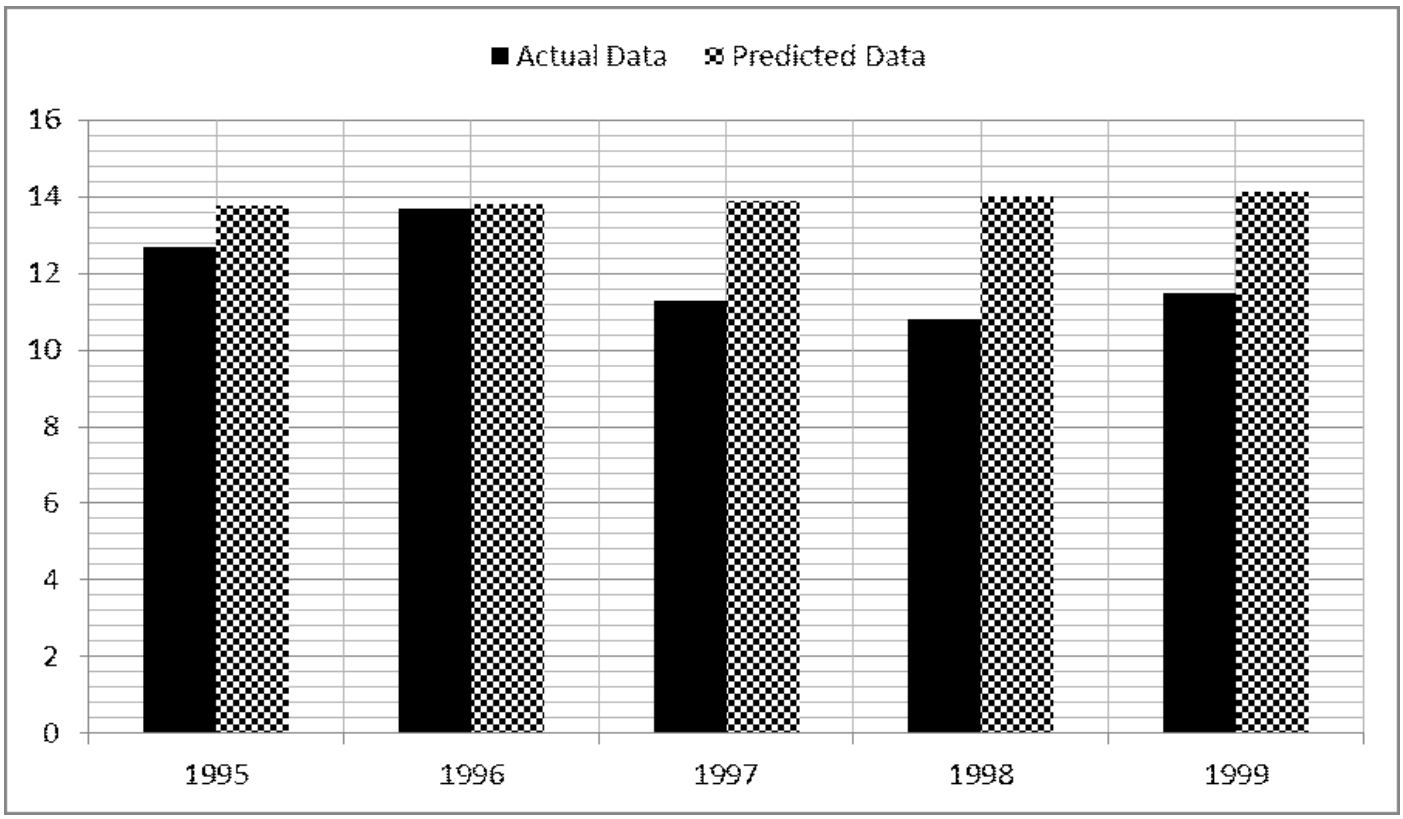

Figure-4
Actual and Predicted Data of 1995-1999

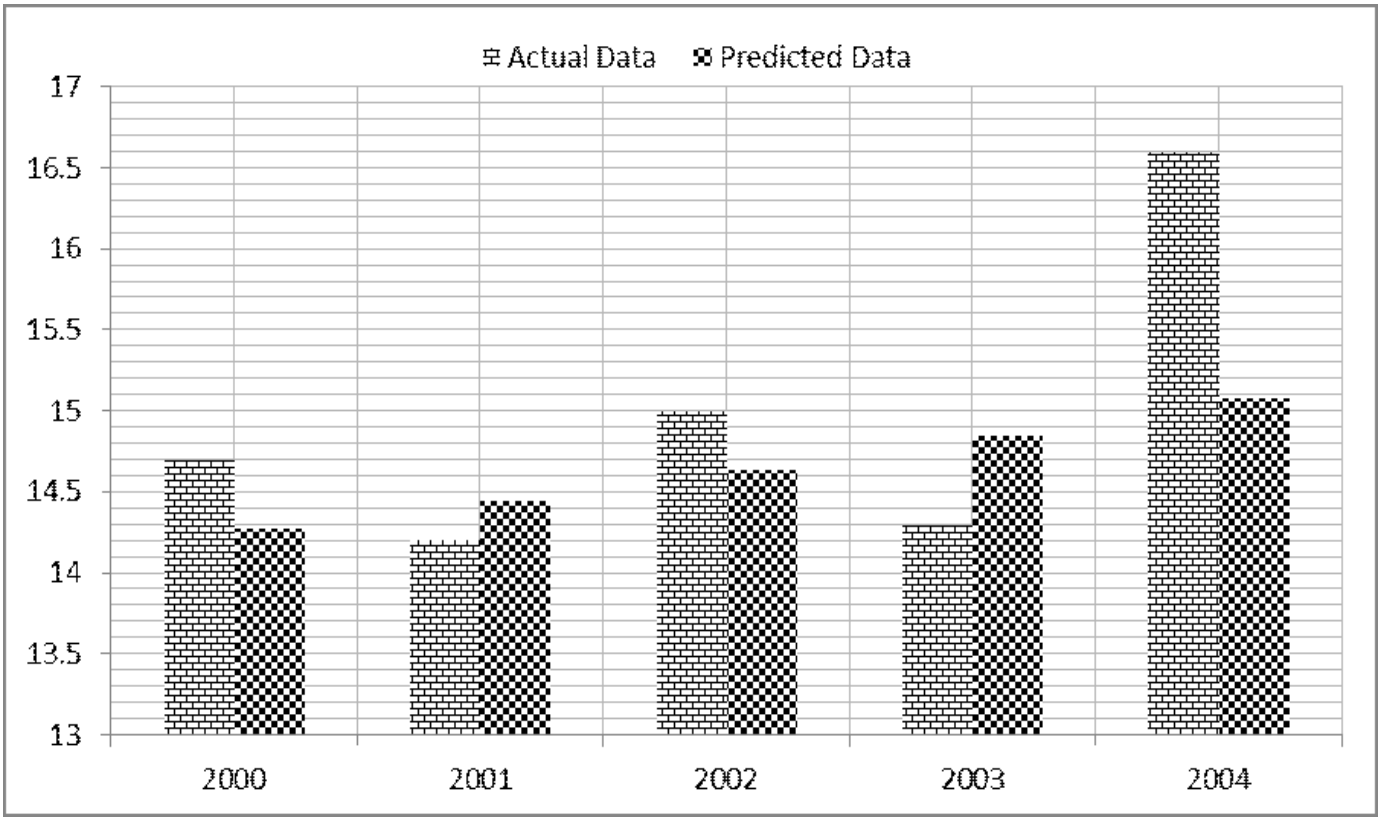

Figure-5
Actual and Predicted Data of 2000-2004

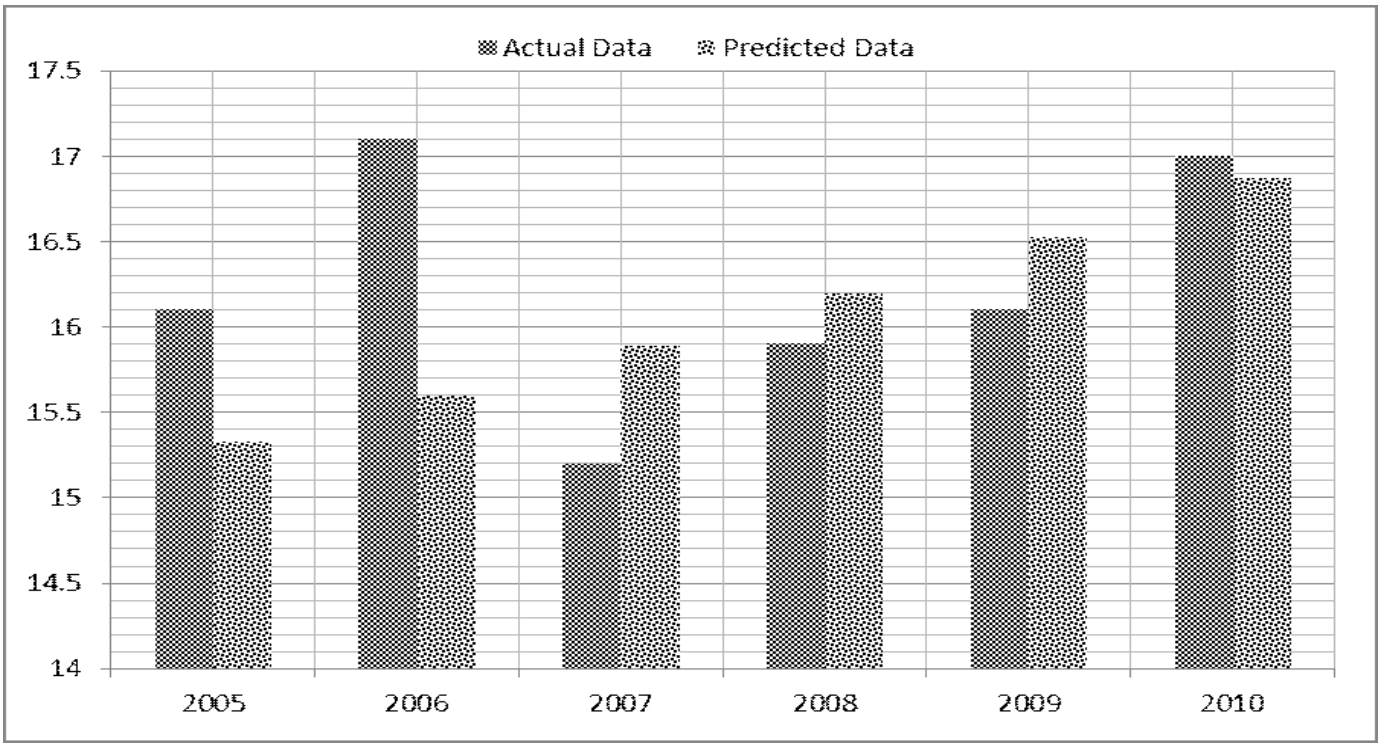

Figure-6
Actual and Predicted Data of 2005-2010

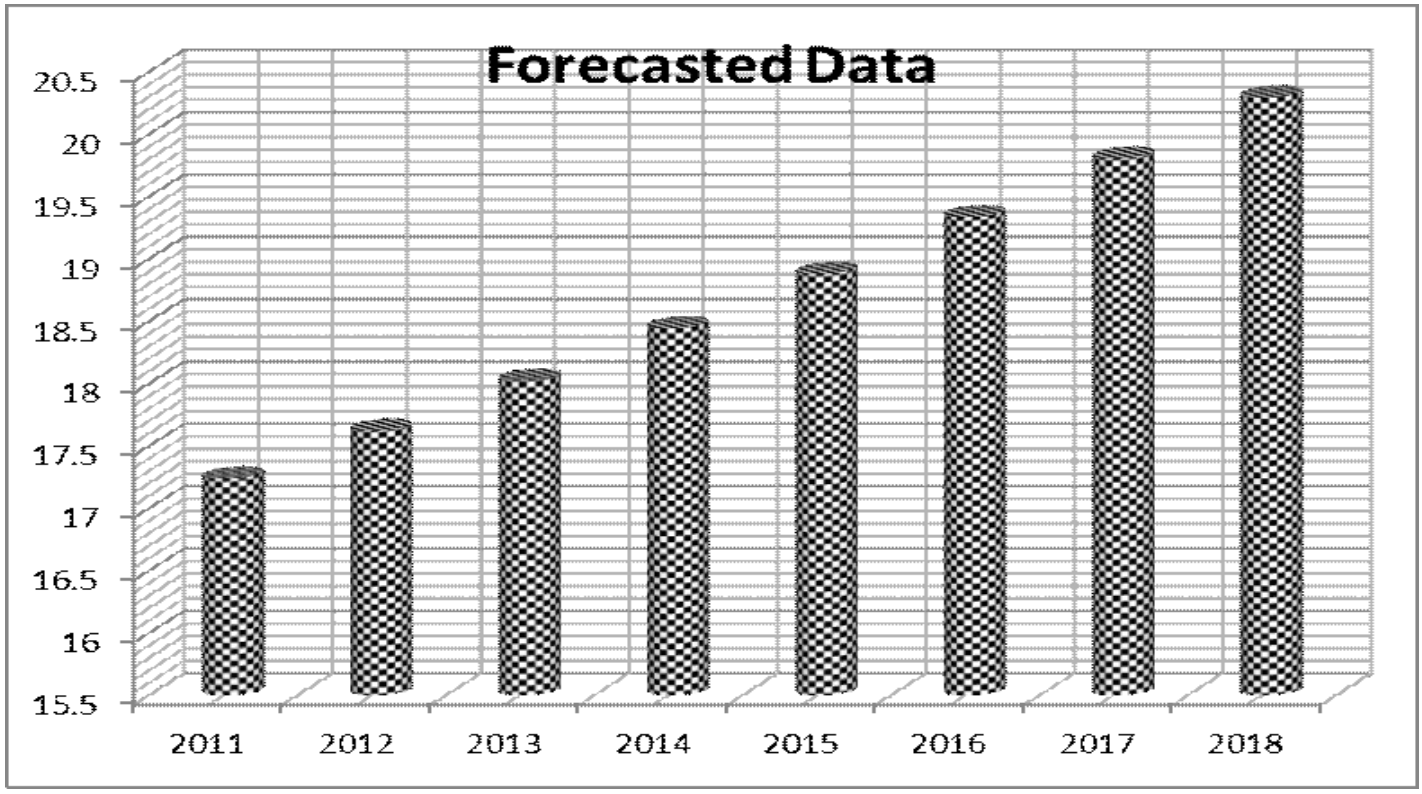

Figure-7
Forecasted Data of 2011-2018

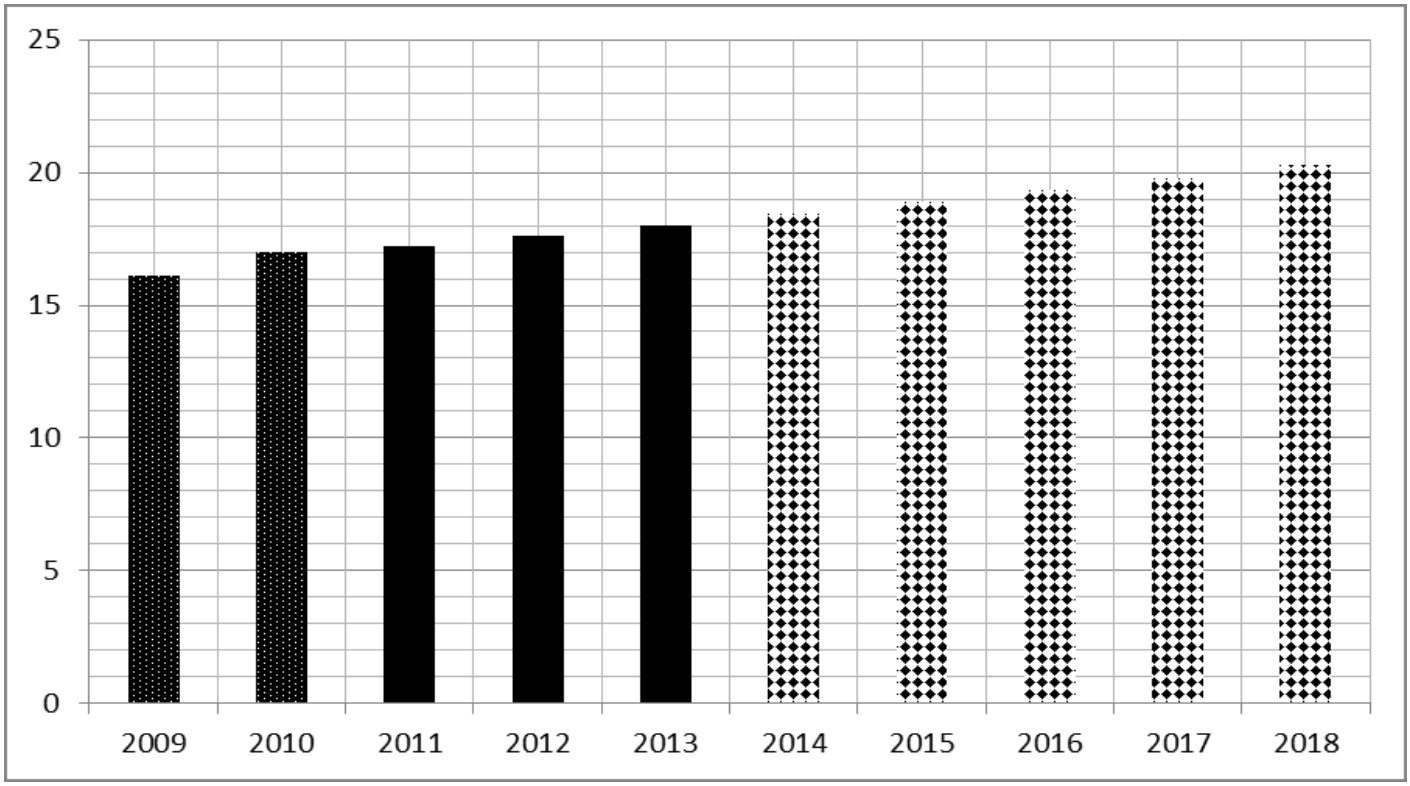

Figure-8
Comparing Last five years (2009-2013) and Coming five years (2014-2018) emissions

Conclusion

The study utilized benchmark information from World Bank in metric tons per capita. CO_2 discharges are these originating from the copying of fossil energizes and the assembling of concrete. They incorporate carbon dioxide delivered amid utilization of strong, fluids and gas powers and gas flaring.

Using the above database the software forecasted the expected emission of carbon dioxide in Saudi Arabia in the next five years (2014-2018). Carbon dioxide emission forecasting is an inherently uncertain process. This uncertainty is currently dealt with in an ad-hoc and a subjective way. Advances in emission science have led to systematic and objective ways to deal with uncertainty, and it is hoped that these advances will be incorporated in operational emission forecasting in the future. The best way to communicate this uncertainty still needs to be discussed with emission response managers, and wide consultation is important to communicate effectively with users of the carbon dioxide emission warning service.

The study used Cubic non-linear option of the software for the forecasting and found that it's most convenient, reliable and appropriate software compared to the other tried software.

Cubic

$T_t = a + bY_t + cYt^2 + dY_t^3$

Yt = 15.887 -0.32976*t +0.012869*t**2 -3.8912E-05*t**3

The study found that in the next five years the carbon dioxide emission will increase an annual average of 2.2% compared to the last 5 years with an average emission of 1.8%.

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