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ORIGINAL RESEARCH PAPER

Forecasting CO_2 emissions in the Persian Gulf States

F.A. Olabemiwo [1], G.I. Danmaliki[1,2], T.A. Oyehan [1], B.S. Tawabini [1]*

[1]*Department of Environmental Science, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*

[2]*Department of Biochemistry, Faculty of Medicine and Dentistry, University of Alberta, Alberta, Canada*

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ABSTRACT: The Persian Gulf States (Bahrain. Iran, Iraq, Qatar, Saudi Arabia, Kuwait and UAE) have dominated the oil and gas sector since the discovery of oil in the region. They are the world largest producers of crude oil, producing about 35 and 25 percent of the world natural gas and crude oil respectively. The use of fossil fuels is directly linked to the release of CO_2 into the environment. CO_2 accounts for 58.8 percent of all greenhouse gases released via human activities, consequently, presenting a malign impact on the environment through climate change, global warming, biodiversity, acid rain and desertification among others. Due to its importance, the data on CO_2 emission obtained from US EIA from 1980 – 2008 was regressed using least square techniques and projections were made to the year 2050. Results indicated that each country's p-value was less than 0.05 which implies that the models can be used for predicting CO_2 emissions into the future. The data shows the emission of CO_2 by country from the highest to the lowest in 2016 as: Iran (590.72 Mtonnes; 7.58 tonnes of CO_2/person) > Saudi Arabia (471.82 Mtonnes; 18 tonnes of CO_2/person) > UAE (218.58 Mtonnes; 41.31 tonnes of CO_2/person) > Iraq (114.01 Mtonees; 3.71 tonnes of CO_2/person) > Kuwait (92.58 Mtonnes; 36.31 tonnes of CO_2/person) > Qatar (68.26 Mtonnes; 37 tonnes of CO_2/person) > Bahrain (33.16 Mtonnes; 27.5 tonnes of CO_2/person)". The sequence from the country with highest emission (Iran) to the country with lowest emission (Bahrain) will remain the same until 2050. A projection depicting a 7.7 percent yearly increase in CO_2 emission in the Persian Gulf States.

KEYWORDS: *CO_2 emission; Least square technique; Persian Gulf countries; Prediction; Regression*

INTRODUCTION

The Persian Gulf is located between 24° to 30° 30' N latitude and 48° to 56° 25' E longitude. It lies between the Arabian Peninsula to the Southwest and Iran to the Northeast. It is part of the Indian Ocean, an area of enormous economic and strategic importance, where the main interests consist of the control of huge oil reserves and shipping routes used to transport them. The water body is mostly shallow having very low currents and limited tidal range with a pleasant temperature and a high level of salinity. Its coasts are home to mangrove plants and the natural environment is rich in coral reefs. It has many islands, of which Bahrain is the largest. The Persian Gulf comprises of eight nations bordered by Oman and the United Arab Emirates (UAE) to the south, to the west by Qatar and Saudi Arabia, to the north by Kuwait, and Iraq, and along the entire east coast by Iran (Briant, 2002).

The Persian Gulf nations have dominant industries with the world largest single source of crude oil. In 2002, the Persian Gulf States had about 2/3 of the world's crude oil reserve, produced about 35 % of the world natural gas and 25 % world oil. This region has

*Corresponding Author Email: *danmalik@ualberta.ca*
Tel.: +780 729 2605 Fax: +780 492 0886
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broad-range of coral reefs, ample of treasured oysters and several fishing grounds but its ecosystem has been dented by oil spills and industrialization (Rashtchi *et al.,* 2013; Persian Gulf Online, 2011). The level of carbon dioxide (CO_2) in the atmosphere has been amplified by about 25 % due to human activities. The influence of human activities on the environment has developed intensely because of steep elevation in world population, urbanization, industrial activities and energy consumption. The use of energy in different forms plays a perilous role in upsetting local and global climate (Köne and Büke, 2010). In the last two decades, emission of CO_2 has been responsible for 55 % of greenhouse effect in which CO_2 released from combustion of fossil fuel accounts for about 60 % of the global total, making it the single most important greenhouse gas (Dunn and Flavin, 2002; Liu, 2007). Since the industrial revolution, the prompt extermination of forests and the increasing use of fossil fuel has led to a substantial increase in greenhouse gases. Thus, the growing threat of global warming and climate change has been the chief worldwide unending concern especially in the last two decades. This has a negating effect on the world economy and it has been gauged intensively by researchers since the 1990s (Köne and Büke, 2010). The emission of CO_2 from energy differs extremely by country due to dissimilar domestic energy configurations. For the last decades, investigators have been able to connect thoroughly economic growth to energy consumption (Ozturk *et al.,* 2005). It was observed that rise in economic growth terrorizes environmental sustainability as well as led to degradation of this environment at both home-grown, nationwide and global level (Köne and Büke, 2010). This fascinated the worries of Policy makers and energy analysts in the direction of the side effect of energy use and related social welfare to the environment. In order to certify preferred level of environmental distinction side by side with economic growth and social welfare, guidelines for decreasing use of energy may not be sufficient. The qualitative aspect of energy use is becoming progressively more essential for ecological improvement and sustainable development. As define by (Brundtland, 1987), Sustainable development is the progress that meets the necessities of the present-day without conceding the ability of the future generations to meet their own needs. The United Nations has made countless efforts to deal with the adverse impact of the greenhouse effect by tying with the intergovernmental treaties called Kyoto protocol agreement from UNFCC (United Nations Framework Convention on Climate Change). According to the accord, the total emissions of greenhouse gases (GHG) in developed countries during the first binder period (2008-2012) must be reduced by at least 5% below 1990 level (Mirasgedis *et al.,* 2002; Muneer, 2007; Erdogdu, 2014).

Forecasting emissions in the Persian Gulf region was driven by the fact that they are the world largest producers of crude oil and combustion of fossil fuels (coal, oil and natural gas) is the major human activity that leads to the emission of CO_2 into the environment (Quadrelli and Peterson, 2007). Carbon dioxide is the principal greenhouse gas released via human activities. It has negative influence on the environment triggering elevation in global temperature, climate change, ecosystem loss and possibly precarious health effects to people and animals on earth. Additionally, the Persian Gulf countries have witnessed an expansion of petrochemical industries over the past decade.

Carbon emission have doubled in the Persian Gulf states in the last decades due to high reliance on power sources such as certain factors which sustain an assured quality of life in mostly desert environment; examples include air conditioning systems and seawater desalination plants, electricity from coal burning power plants. In terms of carbon emitted per capita in Persian Gulf States in 2011 as shown in Table 1, Qatar and UAE were the highest producers of greenhouse gases with 44 metric tons of carbon dioxide per person which is 10X the global average in 2010. The value was closely followed by Kuwait, Bahrain, and Saudi Arabia which are liable for high rate of per capital carbon dioxide emissions with 39, 25, 21 tons respectively. Iran and Iraq were accountable for minimal emission of carbon dioxide per person only 7.6 and 3.9 tons respectively (World Bank, 2010). In view of that, the energy intensity performance showing purchasing power parities and the market exchange rates for each of the seven countries is given in Figs. 1 (a and b). Energy intensity measures the energy efficiency of a nation's economy. Higher energy intensities indicate a high price or cost of converting

Table 1. Per capita CO_2 emissions from the consumption of energy (Metric tons of CO_2/person)

Year	Bahrain	Iran	Iraq	Kuwait	Qatar	Saudi Arabia	United Arab Emirates
2010	26	7.4	3.9	33	45	20	44
2011	25	7.6	3.9	39	44	21	44

energy into GDP and vice versa.

Carbon dioxide emissions of quite a lot of regions and nations of the world have been studied. Ramanathan, 2005 analyzed energy consumption and emission of CO_2 in Middle East and North Africa by using data envelopment analysis estimates. Mohammed was able to link CO_2 emissions contribution of Persian Gulf cooperation countries (GCC) to their electricity consumption using data from per capital electricity consumption in the region (Qader, 2009). In Greece, emission of CO_2 was analyzed through the decomposition investigation and assessment of outcomes using the Logarithmic Mean Divisia Index (LMDI) and Arithmetic Mean Divisia Index (AMDI) techniques for the period of 1990-2002 (Hatzigeorgiou *et al.,* 2008). International energy outlook 2009 also projected CO_2 emissions of nations for five diverse cases viz. reference case, high economic growth case, high oil price case, low economic growth case and low oil price case. Emissions projected for each case strongly hinge on macroeconomic growth cases. Thus, CO_2 emissions projected for respective case were estimated diversely from each other (U.S. Energy Information Administration (U.S. EIA, 2009). Innumerable methods can be employed for projections, these consist of trend analysis, macroeconomics forecasting models, sector-specific econometric multiple correlation forecasts and surveys (Sharma, 2002; Pokharel, 2007; Erdogdu, 2007; Ozturk *et al.,* 2005; Sozen *et al.,* 2007; Yumurtaci and Asmaz, 2004).

A review on the energy models for demand forecasting has been elucidated by (Suganthia and Samuel 2012), since energy management is crucial for the future economic prosperity, environmental security and for proper allocation of available resources, several techniques are being used for energy demand management to accurately predict the future energy needs. These energy demand forecasting models include

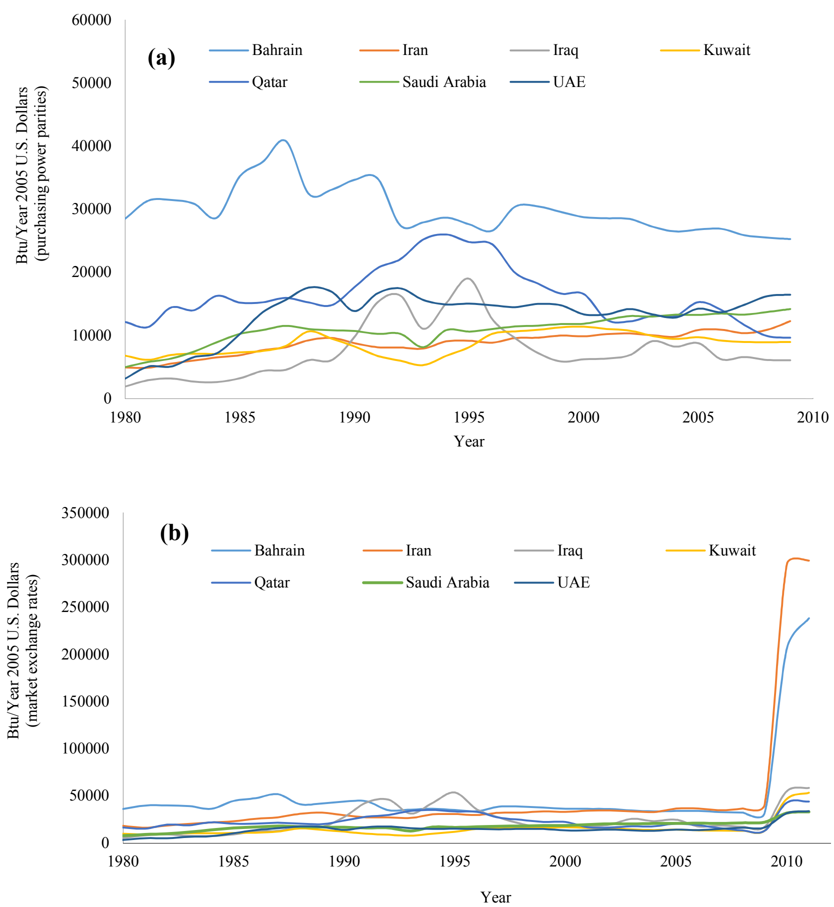

Fig. 1: Energy Intensity–Total primary energy consumption/Dollar of GDP for the Persian Gulf States
(a) Purchasing power parities (b) Market exchange rates

traditional methods such as time series, regression, econometric, ARIMA as well as soft computing techniques such as fuzzy logic, genetic algorithm, and neural networks are being extensively used for demand side management. A structural time series technique has been used by (Alkhathlan and Javid, 2015) to monitor the total carbon emissions in Saudi Arabia. The result indicated that the trend was nonlinear and stochastic. The forecast of CO_2 emission in Saudi Arabia has also been conducted by (Ahmed, 2016) using Energy Forecasting Framework and Emissions Consensus Tool (EFFECT), SAS/AF, and Zeytun time series. Zeytun time series was selected because it gave minimal error. Both linear and non-linear models were applied and the study concluded that cubic model was the most appropriate because it gave minimal error and an acceptable R-sq. A study by (Pao and Tsai, 2011) examined the dynamic relationships between CO_2 emission, energy consumption, and output for Brazil during 1980 – 2007 using Grey prediction model and autoregressive integrated moving average (ARIMA) model. The study concluded that both models had strong forecasting performance. Köne and Büke, (2010) also carried out analysis on emission of CO_2 from fossil fuel combustion of 25 countries of the world using trend analysis approach. Among the various methods trend analysis has always been employed because of it straightforwardness and to the fact that projections are based on availability of data, unlike other techniques which are more complicated and require numerous parameters (Tutmez, 2006; Gutierrez *et al*., 2008).

Here, the data available at the U.S. EIA website from 1980 – 2008 was taken and forecasts were made on the emission of CO_2 by country to the year 2050 using a least square approach. A linear trend analysis was used because the deviations were minimal and it was fairly straightforward depicting a straight line with reasonable and acceptable R-sq values. Studies like this are extremely important in order to meet the expectations set by the Kyoto Protocol. Moreover, the results can be used by government agencies, environmentalist, and other stakeholders to aid in policy and decision making.

This study was carried out in Saudi Arabia during the year 2014.

MATERIALS AND METHODS

Data for total CO_2 emissions from the consumption of energy was gathered for 1980-2008 from the International energy Statistics of United State Energy Information Administration (US EIA). Trend analysis was used for modeling in order to forecast energy-related CO_2 emissions. This was at first employed to identify trends in the CO_2 emissions of each countries of the Persian Gulf States. These data were regressed against the years using least square techniques. During the regression analysis, the independent variables (Y) for all the countries were significant in the model because their respective p-value are less than 0.05 (i.e. 5% level of significance), thus significance trends were indicated for the countries. The analysis of the result indicated that each country's model can be used for the projected emission of CO_2 into the future forecasting. Results calculated for 2013-2014 was compared with the actual data gotten from the US EIA website to compare the variability of the model. The regression analysis was carried out in an 'R' environment in conjunction with Microsoft Excel for applicable statistical analyses.

Statistical analysis of CO_2 emission

Trend analysis predicts the future based on past data. It deals mostly with the capacity and recognition of trends presented by surfaces or lines. When the factors to be analyzed are quantitative, then trend analysis can be used anytime (Maxwell and Delenay, 2004). Thus, the aim of the trend analyzed here is to determine an equation which will be useful in projecting past data into the future as stated in the Eq. 1.

$$y = \sum_{i=0}^{n} a_n x^n \tag{1}$$

Where y is the emission of CO_2 in year x, coefficient is a_n and n is the power which increase means the actual data behavior could be more thoroughly denoted. Linear regression analysis was made from eqn. (1) to denote these data into the form of Eq. 2.

$$y = a_0 + a_1 x \tag{2}$$

Hence, the data for CO_2 emissions was analyzed by carrying out Eq. 2, which is an analysis that predicts the future activities established on previous data.

Regression study for future predictions

Trend analysis has almost been efficiently employed for forecasting energy related emissions of CO_2. There is a sharp change in the levels of CO_2 emissions for each country in the Persian Gulf States as shown in Fig. 2. The CO_2 emissions for these countries were correlated against the year (Y) which was acquired from modeling with R values and fit coefficients (Table 2). The validation for the regression models was carried out using CO_2 emissions data released from 2013-2014 for each country in the Persian Gulf States on the US EIA website. The data was compared with the predicted data for this respective years and plots comparing regression study of CO_2 emissions of each country were analyzed. In addition, P-values of respective countries as determined during the regression study were less than 0.05. That is 5% level of significance, these were used to estimate the goodness of the regression analysis fit. Confidence interval of a 100(1-α) % on new fitted values was obtained for CO_2 emissions for the predicted years as stated in Eq. 3.

$$y_{new} \pm t_{\alpha/2n-2}\sqrt{\hat{\sigma}^2\left(1+\frac{1}{n}+\frac{x_{new}-\bar{x}}{\sum_{i=1}^{N}(x_i-\vec{x})^2}\right)} \quad (3)$$

Where $\hat{\sigma}$ represent the estimated standard deviation, $t_{\alpha/2n-2}$ represent the degrees of freedom and N represent number of observations. Values were predicted for years (2011-2020 and 2050), also confidence interval was estimated for each regression study.

RESULTS AND DISCUSSION

The data forecasted was extracted from the United State Energy Information Administration (US EIA) website. The data used was total CO_2 emissions from consumption of energy measured in million metric tonnes for 1980 to 2008. The CO_2 emissions are those

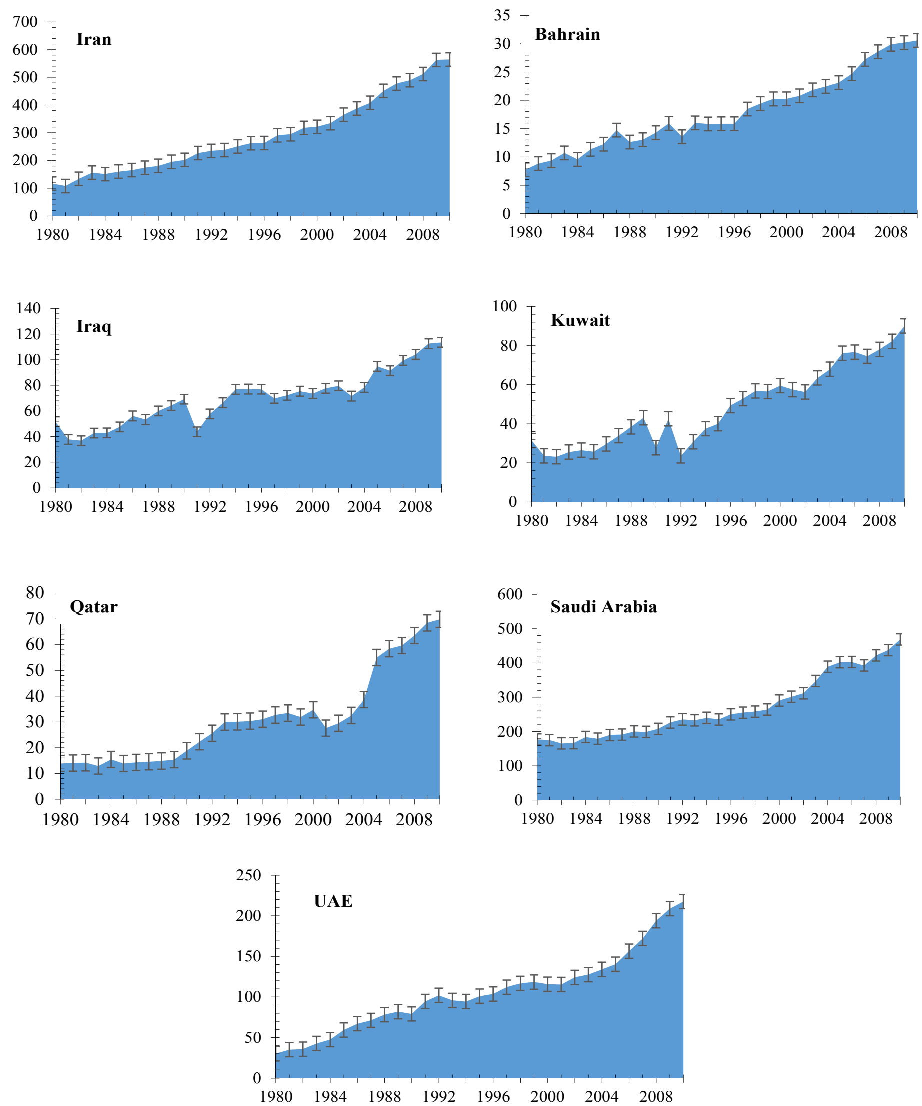

Fig. 2: Stacked area chart for Persian Gulf Countries CO_2 emissions during 1980-2008
(The vertical axis unit is CO_2 emissions in Mtonnes and the horizontal axis is in year)

of fossil fuel combustion, natural gas flaring, coal, electricity, manufacture of cement and so on which the International energy statistics depict as indicators. The results in Fig. 3 show actual and correlated emissions of CO_2 by the Persian Gulf States, which shows linear trends between the actual and correlated data supporting the desirability of the model chosen. All the Persian Gulf countries have witnessed a constant rise in CO_2 emission over the years and the results in this study confirmed that CO_2 emissions will continue increasing over the course of the projected years. The model indicated no sign of decline despite the mitigation policies in place. This result is in accordance with the finding of (Gregg *et al.,* 2008) which indicates the emission of CO_2 in China has more than doubled between 2001 and 2005.

The results calculated for CO_2 emissions from curves fitted for each country, their confidence intervals, and predictions are presented in Tables 2, 3 and 4 respectively. As shown in Fig. 4, the predicted level of CO_2 emissions are expected to elevate in 2011-2050 for all the Persian Gulf States based on trend

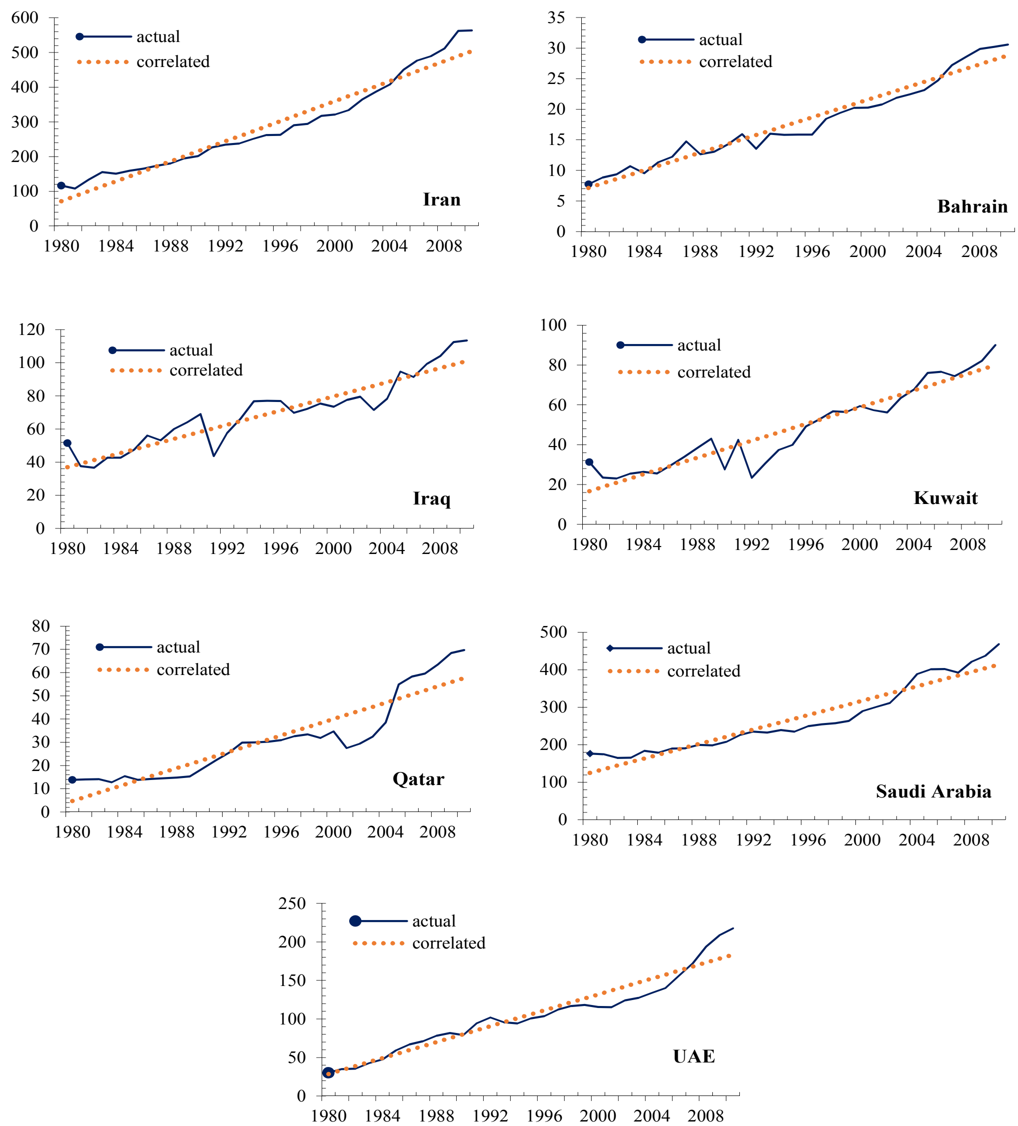

Fig. 3: Persian Gulf Countries actual and correlated CO_2 emissions during 1980-2008
(The vertical axis unit is CO_2 emissions in Mtonnes and the horizontal axis is in year)

analysis. These predicted increases pose a certain trial to regressed countries because of the Kyoto protocol agreement. For each county in the Persian Gulf States, there will be an average of 7.7% increase yearly from 2011-2050, if measures are not taken to reduce the emission. The comparison between actual and predicted data for 2013 and 2014 shown in Fig. 5 was taken in order to validate the model used, from this it was observed that both predicted and actual values are closely related evident from the miniscule standard error.

The results in this study are in agreement with the results obtained by (Ahmed, 2016) which showed Saudi Arabia's forecasted CO_2 emissions increasing dramatically between the years 2014 to 2018. The study concluded a 2.2 % yearly increase in CO_2 emission in Saudi Arabia within 2014-2018. The result obtained in this study also reiterates the result of (Auffhammera and Carson, 2008) which indicates the dramatic increase of China's carbon dioxide emissions over the last five years. The magnitude of the projected increase in Chinese emissions out to 2010 was several times larger than reductions embodied in the Kyoto Protocol. The results obtained in this study are comparable to those published by (Galeotti and Lanta, 1999) where a panel of data model for 110 world countries was used to estimate the relationship between CO_2 emissions and GDP and to produce emission forecast. The forecasts showed that future global emissions will rise. The study also showed that the average world growth of CO_2 emissions between 2000 and 2020 is about 2.2%/y.

RECOMMENDATION AND CONCLUSION

In many developed countries, there is need to include economic, social and environmental aspects within developmental policies in the concept of sustainability. To analyze whether the present situation in the world can be called sustainability, it is germane to consider the adverse impact of the existing energy production

Table 2: Regression study by country in the Persian Gulf State from 1980 - 2008

Country	$CO_2 = A + BY$ (Mtonnes)	R^2	P-value
Bahrain	-1423.00 + 0.7223Y	0.9536	< 2.2 e-16
Iran	-28480.00 + 14.40Y	0.9474	< 2.2 e-16
Iraq	-4196.8022 + 21383Y	0.8617	5.51 e-14
Kuwait	-4152.7167 +2.1058Y	0.8883	2.43 e-15
Qatar	-3486.3536 +1.7632Y	0.834	7.88 e-13
Saudi Arabia	-18,910.000 +9.614Y	0.908	< 2.2 e-16
United Arab Emirate	-10,190.000 +5.161Y	0.9248	< 2.2 e-16

Table 3: The projected data of CO_2 emission from 2011 to 2050

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2050
Bahrain	29.55	30.27	30.99	31.71	32.44	33.16	33.88	34.6	35.32	36.05	57.72
Iran	518.62	533.04	547.46	561.88	576.3	590.72	605.14	619.56	633.98	648.4	1081
Iraq	103.32	105.46	107.6	109.73	111.87	114.01	116.15	118.29	120.43	122.56	186.71
Kuwait	82.05	84.15	86.26	88.37	90.47	92.58	94.68	96.79	98.89	101	164.17
Qatar	59.44	61.21	62.97	64.73	66.49	68.26	70.02	71.78	73.55	75.31	128.21
Saudi	423.75	433.37	442.98	450.6	462.21	471.82	481.44	491.05	500.67	510.28	798.7
UAE	188.77	193.93	199.09	204.25	209.42	214.58	219.74	224.9	230.06	235.22	390.05

Table 4: Confidence interval of projected data from 2011 to 2050

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2050
Bahrain	±3.21	±3.23	±3.25	±3.27	±3.29	±3.31	±3.34	±3.36	±3.39	±3.41	±4.52
Iran	±68.50	±68.90	±69.32	±69.76	±70.23	±70.71	±71.22	±71.74	±72.29	±72.85	±96.47
Iraq	±17.27	±17.37	±17.48	±17.59	±17.71	±17.83	±17.96	±18.09	±18.22	±18.37	±24.32
Kuwait	±15.03	±15.12	±15.21	±15.31	±15.41	±15.52	±15.63	±15.75	±15.87	±15.99	±21.18
Qatar	±15.86	±15.95	±16.05	±16.15	±16.26	±16.37	±16.48	±16.61	±16.73	±16.86	±22.33
Saudi Arabia	± 61.66	±62.02	±62.40	±62.79	±63.21	±63.65	±64.10	±64.57	±65.06	±65.57	±86.83
UAE	±29.66	±29.84	±30.02	±30.21	±30.41	±30.62	±30.84	±31.07	±31.30	±31.55	±41.77

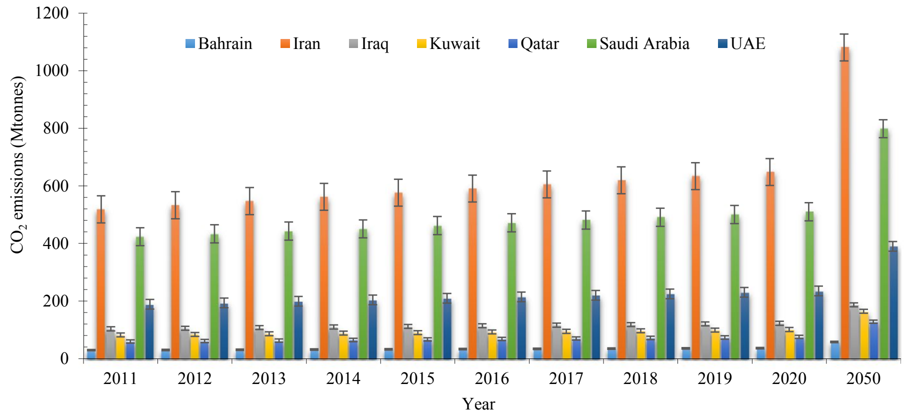

Fig. 4: Projected levels of CO_2 emission in Persian Gulf countries (2011 - 2050)

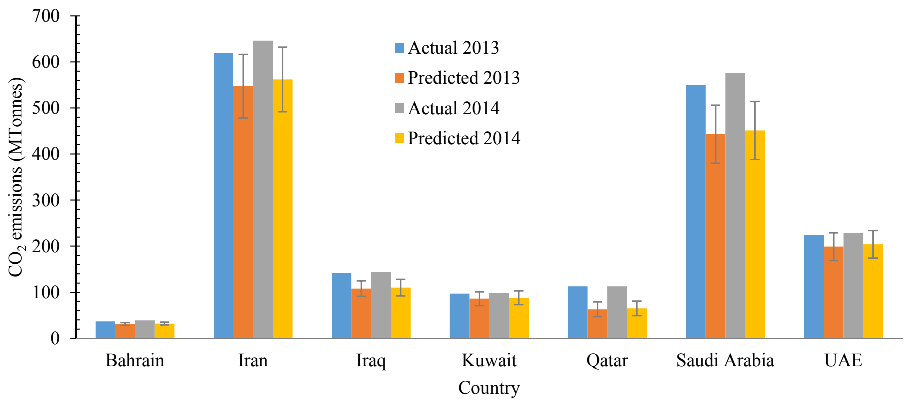

Fig. 5: Comparing actual and predicted CO_2 emissions data in the Persian Gulf Countries

and consumptions on the environment which at present the energy sector has malign impact on. Therefore, the following should be considered by the Persian Gulf States in cutting down the level of CO_2 emissions in the environment:

1. There should be replacement of consumable energy with renewable and nuclear sources of energy which can add to CO_2 emissions reductions. The study conducted by (Alkhathlan and Javid, 2015; Yüksel, 2008) has shown that increase in the total consumption of oil and an increase in total income forces CO_2 emission to grow. Measures to reduce the total oil consumption therefore will hold great promise in lowering the level of air pollution. The study conducted by (Pao and Tsai, 2010) examined the relationship between CO_2 emission, energy consumption and output in BRIC countries over the period of 1971–2005. The study confirmed the statistically significant effect of energy consumption to the emission of CO_2. However, in order to reduce emissions and not to adversely affect economic growth, energy supply investment and energy conservation policies need to be increased in order to reduce unnecessary wastage of energy.

2. There should also be proficient transfiguration of fossil fuel by switching to low carbon fossil fuel and suppressing emissions, CO_2 sequestration (capturing and storing carbon either from fossil fuels or from the atmosphere) and so on.

3. There should be Stern adherence to the international environmental conventions like Kyoto protocol and Rio Declaration.

4. The oil and gas policies employed by the Persian Gulf nations at present aim only at increasing the capacity of energy production (Karbassi *et al.,* 2007). Meaning, it is consumption oriented and unsustainable. All the analysis of energy consumption for the past years suggests ineffective and inefficient energy usage. Most of these countries do not consider energy prices as a reflection of economic costs. Price reform is a key policy that can be utilized in these countries to conserve energy

and provide alternative forms of renewable energy.

5.Energy efficient measures and the use of funds stipulated for clean production are beautiful policies that can be used to lower the amount of greenhouse gases emitted to the environment. A study conducted by (Karbassi *et al.,* 2010) has shown that a simple replacement of ball mills with vertical roller mills can reduce the electricity consumption from 44.6 to 28 kWh/ton and as a result of such substitution, 720 million kWh/y of electricity would be saved (almost a power plant of 125 MW capacities). This replacement translates into the reduction in emission of 4.3 million tons of CO_2 into the environment.

6. Government policy should be made on Importing fuel proficient machine and vehicles.

7. The government and stakeholders should be compelled to make available consistent, dependable and up to date data for the study in the nearest future.

8. There should be integration of more variable like topography and the terrain of the areas, weather conditions, temperature and pressure in future emission analysis.

9. The Persian Gulf States should intensify efforts to minimize carbon emissions by taxing companies based on the volume of carbon they release into the atmosphere.

10. As outlined by (Tehrani and Karbassi, 2005), measures such as e-commerce in local home shopping can be adopted by these countries in order to lower the level of both energy consumption and CO_2 emissions. Measures like these can reduce energy consumption by 88 percent and 20.12 tons/yr of CO_2 emissions in each country.

Conclusively, this study highlighted the trends in emissions of CO_2 for seven countries of the Persian Gulf States (Bahrain, Iran, Iraq, Qatar, Saudi Arabia and United Arab Emirate) from 1980-2008. Data of CO_2 emissions from consumption of energy was used for regression analysis. On developing the regression analysis, substantial trends were shown for all the countries. The p-value of these countries was less than 5% level of significance. The result of the regression model showed that the models can be used for predicting CO_2 emissions in those countries. These were validated by comparing the actual and predicted data for 2013-2014 to see whether there is variability in the model. Also, confidence interval was calculated for the projected years (2011-2050) for comparison with the original data as well. In reality, prediction of CO_2 emissions can be subjective to numerous factors like type of fuel consumed, economic growth rates, industrial advances and political inventiveness. In other to have a more convincing and effective results, the above mentioned factors must be considered.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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AUTHOR (S) BIOSKETCHES

Olabemiwo, F.A., M.Sc. student, Department of Environmental Science, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. Email: *g201405060@kfupm.edu.sa*

Danmaliki, G.I., Ph.D. Candidate, Department of Biochemistry, Faculty of Medicine and Dentistry, University of Alberta, Alberta, Canada as well as Department of Environmental Science, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. Email: *danmalik@ualberta.ca*

Oyehan, T.A., M.Sc. Research Assistant, Department of Environmental Science, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. Email: *tajudeenoyehan@kfupm.edu.sa*

Tawabini, B.S., Ph.D., Associate Professor, Department of Environmental Science, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. Email: *bassamst@kfupm.edu.sa*

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