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Modeling and Forecasting Carbon Dioxide Emissions from Fossil Fuel Combustion in Pakistan Using ARIMA Model: Implications for Climate Change

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ABSTRACT

Greenhouse gases emissions, notably CO_2, into atmosphere has driven profound climate change and amplified global warming. This phenomenon not only compromises environmental integrity but also poses a threat to sustainable development, giving rise to a multitude of environmental challenges. Despite the pressing need to mitigate climate change, there is a lack of comprehensive forecasting models specifically tailored to predict CO_2 emissions from fossil fuel combustion in Pakistan. Therefore, emissions data of 1990-2020 was obtained from IEA (International Energy Agency) to forecast future increase in CO_2 using Autoregressive Integrated Moving Average (ARIMA) model for forecasting CO_2 and assessing the implications of forecasted CO_2 emissions on climate change. ARIMA model emphasizes on autocorrelations in time series and higher accuracy compared to other models. Exact order for "p" and "q" was determined using autocorrelation function (ACF) and partial autocorrelation function (PACF) to specify the MA (q) and AR (p) order in ARIMA forecasting. ARIMA (2,1,2), ARIMA (6,1,2) and ARIMA (10,1,10) were finalized to analyze the data. Among these ARIMA (6,1,2) was found suitable to forecast CO_2 emissions. Analysis of the data from 2021-2030 confirmed 220.117 Mt CO_2 rise by 2030. This represents a 9.188% increase in CO_2 emissions over the forecast period, highlighting a significant growth rate compared to the initial increase observed in 2021. This increase will not only disturb the environment, but it will also put serious implications on social and economic development of Pakistan. This study will help the policy makers and other stakeholders to take proactive actions and sustainable practices to balance economic development and environmental ministration.

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INTRODUCTION

The greenhouse gases emissions, notably CO_2, into the atmosphere has driven profound climate change and amplified global warming. (Rehman et al., 2021; Garba et al., 2021; Abd et al., 2020). This phenomenon not only compromises environmental integrity but also poses a threat to sustainable development, giving rise to a multitude of environmental challenges (Khan et al., 2021; Wang et al., 2021). To stop climate change and global warming, emissions from human activities must be reduced to net zero (Schweizer et al., 2020). Global warming will reach 1.5 °C by 2052 if it continues to increase at this rate (PC Change, 2018). Failure to recognize the factors responsible for continuous CO_2 emissions could limit the world's ability to remain consistent with a 1.5°C or 2°C increase in global warming (Peters et al., 2019). Currently, the amount of CO_2 in the atmosphere is 414 ppm, and the biggest contributor to this is the combustion of fossil fuels used for energy production, resulting in the phenomenon of

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global warming (Talapaneni et al., 2019; Shearer et al., 2017; Chang et al., 2020).

Pakistan, being a developing country striving for economic growth and relying on fossil fuels for its energy needs, imports 89% of its fossil fuel requirements from the Gulf. This accounts for approximately 0.6% of the world's total energy needs (Raza et al., 2021). The major sectors consuming energy are power, industry, transport, residential, agriculture, and other government sectors. With the increasing population and economic projects like the China-Pakistan Economic Corridor (CPEC), energy demands have increased. This has given rise to many ecological issues, among which CO_2 emissions are prominent. In Pakistan CO_2 emissions have been increased substantially from 57.8 Mt in 1990 to 200 million Mt in 2023 (Raza et al., 2025).

Despite a developing nation having persistent electricity crisis and high energy demands Pakistan endorsed the Paris Agreement in 2016 which aims to restrict global rise in temperature to 1.5 °C during 21st century (Rezaei et al., 2022, Qudrat-Ullah, 2022). The country faces the challenge of balancing energy needs for population and economic growth with its commitment to reduce emissions by 5% by 2030. Energy sector alone contributes 46% of Pakistan's overall CO_2 emissions, with the electricity sector alone projected to emit around 64 $MtCO_2$ by 2030. Addressing this, Pakistan's power sector holds potential for significant emission reductions through alternative measures (Qudrat-Ullah, 2022).

It is of immense importance to forecast CO_2 emissions specially for Pakistan because it is one of those countries vulnerable to climate change due to its geographic location (Malik *et al*, 2020, Hussain *et al,* 2020). Melting of Himalayan glaciers at faster rate due to climate change that results unpredictable flooding, hurricanes, abrupt rainfall, saturation of lakes, lack of water resources, varying temperature, storms, pest diseases, seasonal changes, alterations in lifestyles and healthcare issues (Hussain *et al,* 2020). Effective sustainable policies formulation and their timely implementation is not possible without forecasting CO_2 emissions (Kour, 2023).

For prediction of CO_2 emissions forecasting models can be divided into three groups i.e. Univariate model, multivariate model and nonlinear model. Fuzzy regression, least square support vector machine (LSSVM), artificial neural network (ANN) and a few other hybrid models are included in nonlinear intelligent model. Forecasting efficacy of these models is significant, but their accuracy is dependent on the availability of large input of data. On the other hand, the efficacy of multivariate models depends on data availability and their reliability on independent variables, for this additional data collection is required. Univariate models such as ARIMA require large data, but its flexibility and accuracy make it significant as compared to other models (Malik *et al*, 2020). Friedman ranking values also revealed that AR model is most suitable to forecast CO_2 emissions (Parakash *et al.,* 2023). As compared to multivariate model, reliability, soothing techniques and accuracy ARIMA model is considered better. The ARIMA model was also found to be more suitable in forecasting short time series and when past observation correlations is strong (Kour et al, 2023). To forecast time series data, machine learning methods require extensive preprocessing unlike ARIMA model. Machine learning models treat data points as independent which make them less effective in CO_2 predictions (Rehman *et al*, 2024).

Irrespective of the need to mitigate climate change in Pakistan there is lack of data acquired through models to forecast CO_2 emissions resulting from fossil fuel burning. This research gap impedes the formulation of strategies specific to address greenhouse gas emissions and their impact both on economy and climate. So, the objectives of study are i. To develop an ARIMA model to forecast CO_2 emissions resulting from the burning of fossil fuel in Pakistan by analyzing historical emission data and identifying key variables which influence CO_2 emissions trends. ii. Assessment of implications of CO_2 emissions on economy and climate change of Pakistan. This includes assessment of potential scenarios of CO_2 emissions trajectories and their impact on, economic growth, climate-related risks, sustainable development and energy security in Pakistan. After achieving these objectives aim of the study is to provide a valuable insight to policymakers and other stake holders to design strategies vital for mitigating climate change in Pakistan along with understanding of the drivers of CO_2 emissions.

MATERIALS AND METHODS

Current study was conducted to predict CO_2 emissions from power plants of Pakistan specifically working on fossil fuels for energy production. Among South Asian countries Pakistan is most vulnerable country effected by climate change (Fahad *et al.,* 2020). Pakistan's climate is shaped by its diverse topography such as Hindu-Kush and Kirthar ranges by influencing the winter westerlies and South Asian Monsoon. During monsoon in June-September these factors results varying rainfall patterns which is crucial for livelihood and economy of the country (Optiz-Stapleton *et al,* 2021). Climate change severely affected economy and environmental and social development of Pakistan. Moreover, melting of glaciers, heat waves, abrupt rainfall, water scarcity, pests diseases, healthcare issues, flooding, droughts and varying temperature are core issues related to changing climate (Hussain *et al.,* 2020). Extreme weather and climate change badly affected the Pakistan's economy and resulted in loss of US$9.6 billion since 2010 (Lin *et al*, 2019). Food insecurity and urbanization are other major concerns related with climate change in Pakistan and need proactive and timely measures to adopt with changing climate (Hussain *et al.,* 2020). Meeting the target of decreasing emissions by 5%–2012 levels by 2030, energy needs for growing population and economic stability Pakistan is facing enormous challenges as specified in Pakistan's Intended Nationally Determined Contributions (INDC) submitted in 2016 (Qudrat-Ullah, 2022).

Therefore forecasting CO_2 emissions is significant for both economic and environmental development. Dataset of CO_2 emissions (in Mt) from 1990-2021 of fossil fuels in Pakistan (coal, oil and natural gas) was provided by Internal Energy Agency (IEA). ARIMA model was employed to forecast emissions as this model is considered as benchmark in empirical evaluation and due to its accuracy and robustness it is widely used in environment and health sector. It is widely recognized for its superior and accurate forecasting as compared to other multivariate and econometric models particularly in short term-time series analysis. ARIMA model emphasis on autocorrelations in time series higher accuracy compared to other methods (Rehman *et al.,* 2017, Nyoni and Bonga, 2019, Kour, 2023). It also outperforms multivariate models and explains time series using their lagged values and stochastic error terms (Kour, 2023). It was developed by Box and Jenkins in the 1970s and its firm statistical nature depend exclusively on historical data, making it a robust and reliable forecasting tool (Nyoni and Bonga, 2019).

Eviews 12 lite was used for statistical analysis to develop ARIMA model. ARIMA is a combination of Autoregressive (AR) and Moving Average (MA). The steps of ARIMA model are model selection, parameters calculation and forecast. In this model AR(p) refers Auto Regressive model of order 'p' whereas MA(q) refers Moving Average model or order 'q'. Therefore, ARIMA model is the difference between AR(p) and MA(q). The equation of ARIMA model is:

$$Yt = b + \phi 1 yt - 1 + \cdots + \phi p yt - p + bt$$

Where:

Yt	Variable y at time t
$\phi_1 \ldots \phi_p$	Model parameters
Yt_{-1}	First order of difference of variable y

b	Constant
b_t	Noise

The moving average (q) model means moving average model of order q.
The equation is:

$$yt = c + vt + \theta 1vt - 1 + \cdots + \theta qvt - q \qquad (2)$$

where:

$\theta_1 \ldots \theta_q$	Model parameters.
c	Expectation of yt (typically taken zero)
v_t, v_{t-1}, …, and v_{t-q}	Noise and lagged noise/error

$$yt = c + \phi 1yt - 1 + \phi 2yt - 2 + \cdots + \phi pyt - p + \theta 1vt - 1 + \theta 2vt - 2 + \cdots + \theta qvt - q + vt \qquad (3)$$

The ARMA (p, q) is the combination of both AR (p) and MA(q) models (Malik *et al.,* 2020). Stationarity of the data will be confirmed visually through plot, ADF Unit Root Test and PP Unit Root Test (Kour, 2023). The ARIMA model is based on Box Jenkins approach which forecasts the future trends to make data stationary and remove seasonality (Dimri, and Sharif, 2020). Order of stationarity (d), the autoregressive order (p), and the moving average order (q) will be determined through autocorrelation (ACF) and partial autocorrelation (PACF) graphs, these graphs will also help with ARIMA model selection. To select the optimal ARIMA model, several statistics techniques such as the number of significant coefficients, SIGMASQ, Adjusted R-Squared and Akaike Information Criterion (AIC) will be used. Dataset consists of annual CO_2 emissions in metric tons (MT) from 1980-2021 as depicted in table 1.

Key indicators which influence the CO_2 emission trends will be identified from the literature and will be compared with ARIMA results. Similarly, two scenarios, viz Business as Usual (BAU) and Green Growth (GG) will developed and compared to assess the potential impacts of CO_2 emissions. The BAU scenario assumes the continued dependence on fossil fuels and weak policies will lead to a rise in CO_2 emissions which will be forecasted through ARIMA model. On the other hand, GG scenario will consider shifting towards renewable energy, environmental regulations and efficiency improvements. By comparing these scenarios study will evaluate their implications for environmental future and energy of Pakistan which will provide an insight into possible measures to mitigate emissions for policy maker and stakeholders.

RESULTS AND DISCUSSION

The stationarity test was conducted by plotting a graph of data, acquired from IEA shown in fig 1. The graph clearly shows the non-stationary data of CO_2 emissions from 1990-2021. A continuous and strong upward trend is a clear indication of non-stationarity in the data.

Table 1. CO2 emissions data from IEA

CO_2 emissions data					
No.	Data source	Database	Unit of CO_2 emissions	Data type	Time
i.	IEA	IEA	Mt	Yearly	1990-2021

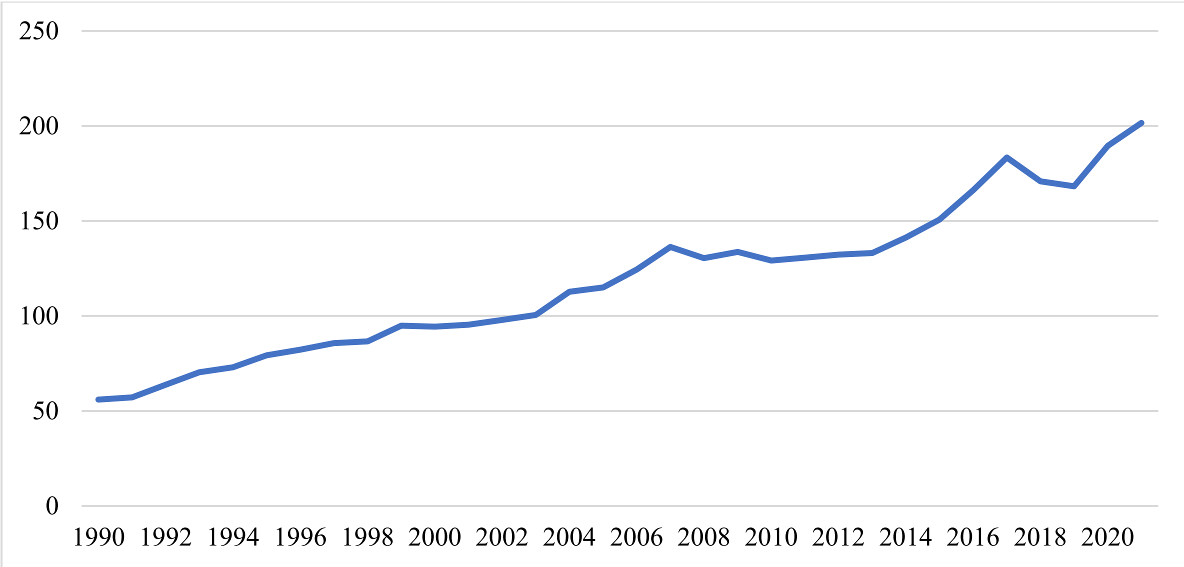


Fig. 1. CO2 emissions from fossil fuels (1990-2021)

Table 2. ADF test sequence level

Null Hypothesis: TOTAL_CO2_IN_MT has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.573892	0.9866
Test critical values:	1% level	-3.661661	
	5% level	-2.960411	
	10% level	-2.619160	

*MacKinnon (1996) one-sided p-values.

Persistent directional movement indicates that mean value is not constant which violates the principle of stationarity. Augmented Dickey-Fuller (ADF) and Philip-Perron (PP) Unit Root Tests were also conducted to confirm the stationarity of the data.

Initially, the ADF statistics of 0.573892 exceeded the critical values at 1%, 5%, and 10% significance levels, indicating non-stationarity in the data shown in table 2. After applying a first-order differencing to mitigate fluctuations, the revised ADF statistic of – 4.915199 fell below the critical values, confirming stationarity, table 3.

Similarly, PP statistic 1.453893 exceeded the critical values at 1%, 5%, and 10% significance levels, indicating non-stationarity in the data. After applying a first order differencing the revised PP statistic of – 4.929956 fell below the critical values, confirming stationarity. So, the PP test corroborated these findings, affirming that the CO_2 data became stationary post first-order differencing, thereby rendering it appropriate for ARIMA model estimation, shown in table 4 and 5.

To determine the order of stationarity (d), the autoregressive order (p), and the moving average order (q) for ARIMA model selection, autocorrelation (ACF) and partial autocorrelation (PACF) graphs are utilized shown in figure 2. Exponential decay pattern in ACF at level confirms that model is autoregressive and exponential decay pattern in PACF confirms moving average. After

Table 3. ADF test first difference

Null Hypothesis: D(TOTAL CO2 IN MT) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.915199	0.0004
Test critical values:	1% level	-3.670170	
	5% level	-2.963972	
	10% level	-2.621007	

*MacKinnon (1996) one-sided p-values.

Table 4. Phillip-Perron test sequence level

Null Hypothesis: TOTAL_CO2_IN_MT has a unit root
Exogenous: Constant
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		1.453893	0.9988
Test critical values:	1% level	-3.661661	
	5% level	-2.960411	
	10% level	-2.619160	

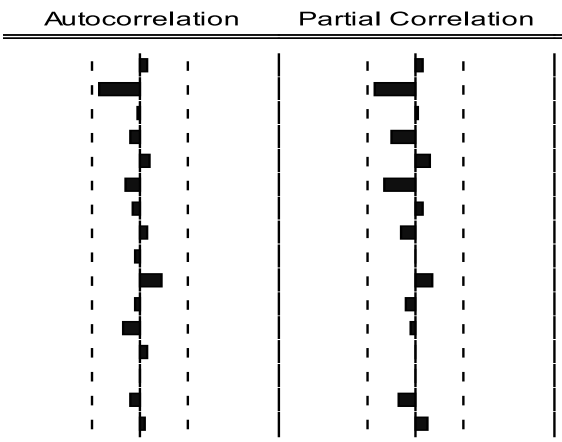
*MacKinnon (1996) one-sided p-values.

Date: 05/21/24 Time: 23:54
Sample (adjusted): 1990 2021
Included observations: 32 after adjustments

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.868	0.868	26.429	0.000
		2	0.743	-0.042	46.428	0.000
		3	0.660	0.103	62.782	0.000
		4	0.571	-0.071	75.473	0.000
		5	0.454	-0.149	83.789	0.000
		6	0.361	0.012	89.248	0.000
		7	0.292	0.005	92.966	0.000
		8	0.237	0.031	95.514	0.000
		9	0.188	0.005	97.179	0.000
		10	0.143	-0.025	98.196	0.000
		11	0.088	-0.094	98.597	0.000
		12	0.029	-0.071	98.644	0.000
		13	-0.039	-0.107	98.731	0.000
		14	-0.109	-0.070	99.444	0.000
		15	-0.181	-0.081	101.55	0.000
		16	-0.236	-0.006	105.35	0.000

Fig. 2. Correlogram (level)

Date: 04/27/24 Time: 15:03
Sample: 1990 2021
Included observations: 31



	AC	PAC	Q-Stat	Prob
1	0.056	0.056	0.1076	0.743
2	-0.299	-0.303	3.2667	0.195
3	-0.022	0.018	3.2852	0.350
4	-0.066	-0.173	3.4501	0.486
5	0.082	0.112	3.7130	0.591
6	-0.110	-0.232	4.2061	0.649
7	-0.061	0.048	4.3660	0.737
8	0.044	-0.109	4.4501	0.814
9	-0.029	0.006	4.4900	0.876
10	0.171	0.129	5.9126	0.823
11	-0.026	-0.072	5.9478	0.877
12	-0.133	-0.026	6.8938	0.865
13	0.053	0.006	7.0521	0.899
14	0.002	-0.002	7.0524	0.933
15	-0.077	-0.126	7.4283	0.945
16	0.026	0.097	7.4728	0.963

Fig. 3. Correlogram (first difference)

Table 5. Phillip-Perron test first difference

Null Hypothesis: D(TOTAL_CO2_IN_MT) has a unit root
Exogenous: Constant
Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-4.929956	0.0004
Test critical values:	1% level	-3.670170	
	5% level	-2.963972	
	10% level	-2.621007	

*MacKinnon (1996) one-sided p-values.

confirmation of AR and MA from ACF and PACF respectively we move to first difference of correlogram to confirm the exact order of AR and MA.

After taking first difference correlogram for ACF and PACF exact order for “p” and “q” can be determined. Autocorrelation is used to specify the MA (q) order and PACF is used to identify the AR (p) order in ARIMA forecasting. The AR order can be observed from PACF plot in figure 3 which indicate that order, 2, 6 and 10 can be chosen for AR. Similarly from ACF plot order for MA can be selected and it is 2 and 10. Thus, the models selected for further analysis to finalize the ARIMA model specification are ARIMA (2,1,2), ARIMA (6,1,2) and ARIMA (10,1,10).

To select the optimal ARIMA model, several statistics are considered: the number of significant coefficients, SIGMASQ, Adjusted R-Squared and Akaike Information Criterion (AIC). An ideal model will have a low SIGMASQ, a high Adjusted R-Squared, a low AIC, and a greater number of significant coefficients. Table 6 presents these statistics for the three ARIMA models evaluated. As shown in Table 6, ARIMA (6,1,2) has the lowest SIGMASQ, the highest Adjusted R-Squared, the smallest AIC. The significant coefficients of ARIMA (2,1,2) and ARIMA (6,1,2) are same and lowest is for 10,1,10 but this significant coefficients only cannot make model superior as other criteria are fulfilled by ARIMA (6,1,2). Therefore, ARIMA (6,1,2) is the best model to explain CO_2 emissions in Pakistan.

Table 6. Comparison of different models evaluated.

	ARIMA (2,1, 2)	ARIMA (6,1,2)	ARIMA (10,1,10)
Significant Coefficients	3	3	1
Sigma Value	38.767	35.924	39.143
Adjusted R-Square	0.094	0.160	0.085
Akaike Criteria (AIC)	6.775	6.721	6.877

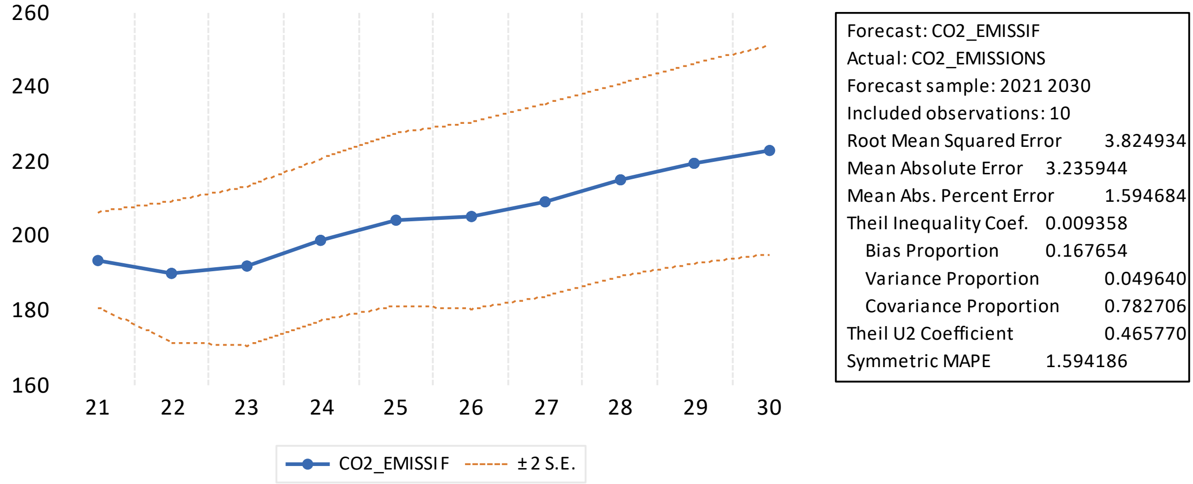


Fig. 4. CO2 emissions forecast form 2022-2030

Table 7. Percentage rise of CO_2 emissions from fossil fuels till 2030

Year	CO_2 emissions in Mt	% of CO_2 emissions
2021	201.594	20 %
2030	220.117	9.188 %

Using the ARIMA (6,1,2) model, future CO_2 emissions in power plants of Pakistan were projected for the years 2021 to 2030. These forecasts are illustrated graphically in Figure 4. The Root Mean Squared Error (RMSE) for this forecasting model is 3.824934, suggesting that the projected CO_2 emissions are highly accurate estimates.

Table 7 displaying CO_2 emissions 201.594 Mt CO_2 in 2021 which indicates a 20% increase compared to previous levels. Forecasting CO_2 emissions from 2021 to 2030, the calculations found a total emissions value of 220.117 Mt CO_2 rise by 2030. This represents a 9.188% increase in CO_2 emissions over the forecast period, highlighting a significant growth rate compared to the initial increase observed in 2021. The forecasted values are calculated using the equation Total = C (1) + C (2) × Year, where Total is the dependent variable, which is to be forecasted, Year is the independent variable used to forecast dependent variable, C1 is the intercept term and represents the estimated value of the Total and C2 is the slope term representing the change in Total. A similar study also confirmed the rise of CO_2 emissions by the use of fossil fuels in Pakistan (Ali *et al.,* 2021).

The key indicators having significant impacts on CO_2 emissions are economic development, population growth and technological progress (Wu *et al*, 2021). Current study revealed that CO_2 emissions from power sector of Pakistan will continue to rise till 2030 if emissions continue

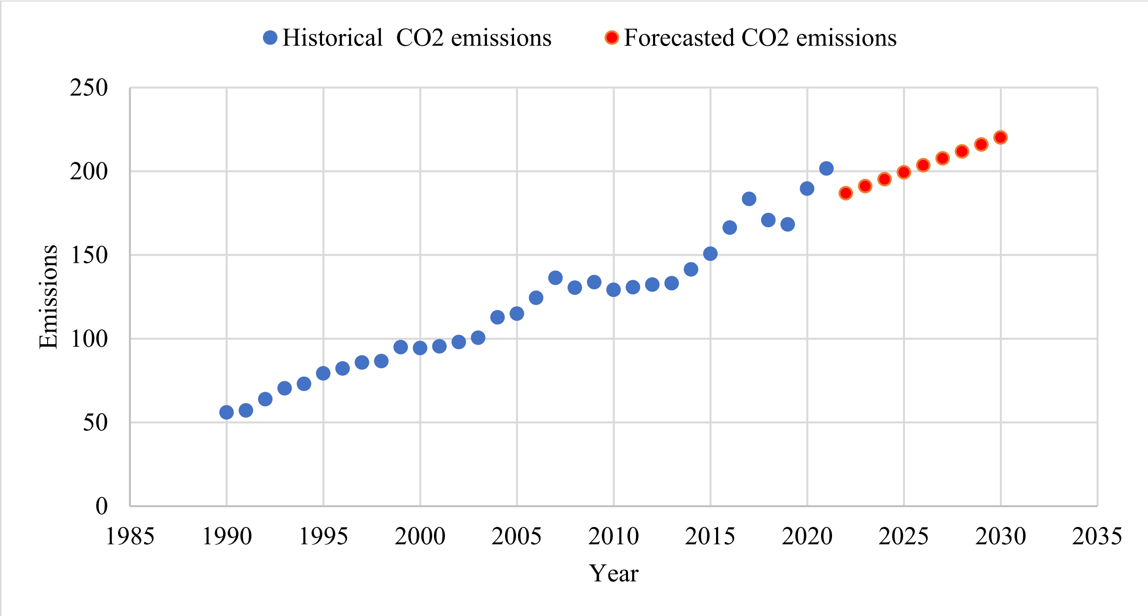


Fig. 5. Historical (1990-2021) and forecasted (2022-2030) CO2 emissions from fossil fuels

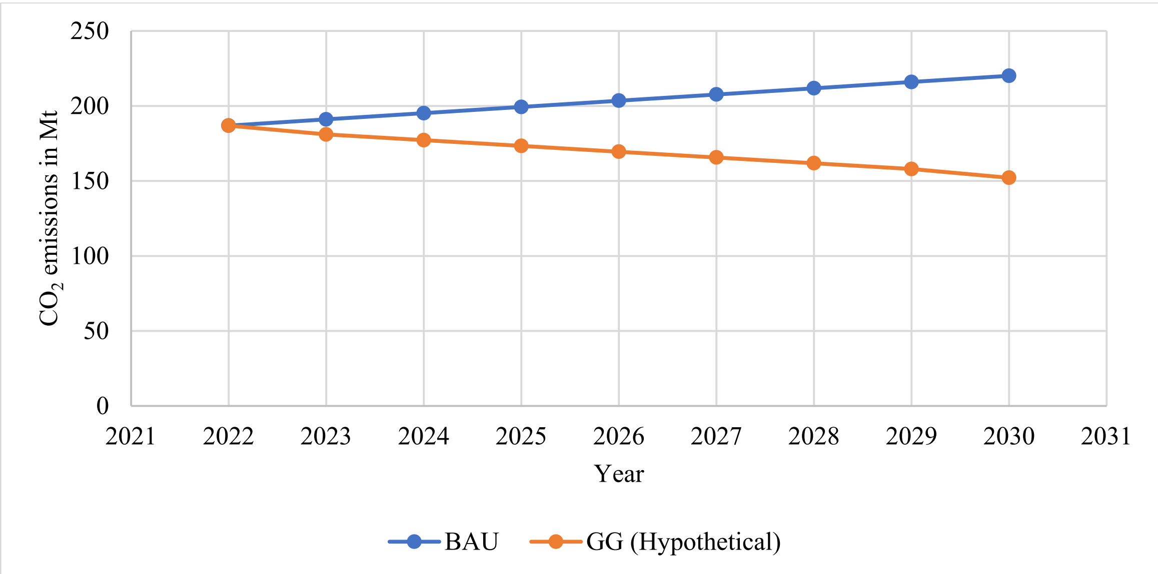


Fig. 6. Comparison of BAU and GG (hypothetical) scenarios

to release at current pace. The increase in CO_2 emissions is linked with stunted economic growth in both the short and long run, a 1% increase in carbon dioxide results 0.61% reduction in economic growth. Food production and livestock output is also directly linked with CO_2 emissions (Abbasi *et al*, 2021, Hussain *et al.,* 2022, Rehman *et al.,* 2021). A study found the wheat, sugarcane, maize, bajra, cotton, sesamum, gram, and land use have productive association with CO_2 emission having positive coefficients, while temperature, rainfall, jowar, rice, and barley uncovered an adversative linkage to CO_2 emission in Pakistan (Rehman *et al.,* 2022). Another study confirmed that energy consumption increase CO_2 emissions which results in environmental degradation and create negative impact on economy (Abbas *et al*, 2021, Uzair *et al.,* 2022). Another study also found that Pakistan instead of shifting to renewable energy still

Table 8. Comparative analysis of scenarios

Markers	BAU Scenario	GG Scenario
CO_2 emissions	CO_2 emissions continue to rise with the use of fossil fuels as forecasted ARIMA (220.117 Mt) till 2030	Clean energy will help in lowering CO_2 emissions, enhance environmental protection, and reduction in fossil fuels (Rehman *et al*, 2022).
Economic growth	The increase in CO_2 emissions is linked with stunted economic growth in both the short and long run, a 1% increase in carbon dioxide results 0.61% reduction in economic growth (Abbasi *et al*, 2021, Hussain *et al.,* 2022, Rehman *et al.,* 2021).	Wind energy will help to reduce the use of fossil fuels (Zhao *et al*, 2022). Similarly, deployment of renewable energy, and research and development could result in a 3.2% increase in growth of sustainable performance (Mohsin *et al,* 2022).
Climate-related risks	Air pollution, health issues, extreme weather conditions will be higher	Improvement in air quality will increase health and reduce extreme weather events.
Sustainable development	Sustainable development goals (SDG's) cannot be achieved with existing reliance on fossil fuels.	With the deployment of clean energy measure SDG's can be achieved.
Energy security	Socioeconomic conditions and environment is damaging due to energy insecurity (Qudrat-Ullah, 2022). Reliance on imports of fossil fuels	Renewable and alternate energy will help to reduce reliance on imports of fossil fuels.

Table 9. CO_2 emissions in BAU and GG scenarios

Year	BAU CO_2 emissions Mt	GG (Hypothetical) emissions Mt	Increasing decreasing percentage of both scenarios	Measures for CO_2 reduction
2022	186.88	186.88	N/A	Implementation of environmental policies, reduction in fossil fuels and shifting to alternate energy sources
2023	191.03	182.73	2.22	
2024	195.19	178.57	2.17	
2025	199.34	174.42	2.12	
2026	203.50	170.26	2.08	
2027	207.65	166.11	2.04	
2028	211.80	161.96	2.00	
2029	215.96	157.80	1.96	
2030	220.11	153.65	1.92	

favors the fossils fuels for energy consumption which will lead to economic, ecological and environmental loss (Butt *et al.,* 2021). The CO_2 emissions from 2021-2030 are shown in figure 6, it is evident that carbon dioxide is continuously increasing from 2021 onwards at a rate of 9.188% per year.

ARIMA model predicted a significant rise in CO_2 emissions from the power plants of Pakistan. This indicate that emissions if not intervened could reach 220.117 metric tons by 2030. This future projection demands a swift evaluation of future trajectories of Pakistan's energy sector. Two contrasting scenarios (BAU and GG) were applied to assess the potential implications of policy and energy pathways. By providing a framework these scenarios will help to examine how different policy options could shape economic growth, tackle climate-related risks, provide sustainable development, and ensure energy security of Pakistan in coming years. The BAU scenario assumes the continued dependence on fossil fuels and weak policies will lead to a rise in CO_2 emissions which are confirmed through ARIMA model forecast. On the other hand, GG scenario will consider shifting towards renewable energy, environmental regulations and efficiency improvements. Comparison of both the scenarios is depicted in table 8, which shows that by adopting the green policies, deployment of alternate energy sources and lesser reliance on fossil fuels, CO_2 emissions can be decreased.

Study further compared the forecasted values of CO_2 emissions of BAU scenario (forecasted) and hypothetical values of GG scenario to present valuable suggestions to policy makers and other stakeholders. Considerable reduction in CO_2 emissions can be achieved by implementing environmental policies, reduction in fossil fuels and shifting to alternate energy sources. Emissions in the BAU scenario are increasing in a continuous pattern from 186.8838 Mt to 220.1177 Mt, on the other hand GG scenario have same values but we decreased them at same pattern as BAU is increasing, assuming that by taking accurate measures CO_2 emissions can be reduced gradually or stop steady increase. The difference between BAU emissions is calculated by simple arithmetic formula (New value - Old value/ old value x 100) and for GG scenario by using formula (Old value – New value / Old value x 100). Similarly, emissions in the GG scenario have the same difference and percentage as BAU scenario. Furthermore the increase and decrease percentage of both the scenarios is almost same ± 2.

The results again showed that if Pakistan is able to adopt green policies emissions can be controlled in considerable amount as depicted in figure 6. Emissions can be decreased if environmental policies are strictly followed, more Billion Tree Tsunami (BTS) projects, lesser use of fossil fuels and shift towards environment friendly energy sources.

CONCLUSION

The analysis and forecasting of CO_2 emissions from fossil fuel combustion in Pakistan reveal a concerning trend of increasing emissions, which have grown significantly from 56 Mt in 1990 to over 160 Mt in 2021. The ARIMA (6,1,2) model, identified as the most suitable for this dataset with an RMSE of 3.8, projects a continued rise in emissions, estimating a 9.18% increase by 2030 from the current level of 20%. This future increase will not only disturb the environment, but it will also put serious implications on social and economic development of Pakistan. Rising emissions cause global climate change, leading towards extreme weather conditions, threatening agriculture productivity and strong impact on public health. Economically, national resources may be strained by the expenses of mitigating and adapting to climate change. This upward trajectory underscores the critical need for Pakistan to implement robust and effective climate policies. Therefore, it is essential that corporations, civil society organizations, and politicians work together to develop and implement sustainable practices that tackle these issues. Strategies to promote renewable energy, reduction in fossil fuel consumption and improving energy efficiency are vital in controlling the anticipated CO_2 emissions growth. Every year 2% increase in carbon tax will significantly reduce carbon emissions and increase the economic growth. Emissions can be decreased if environmental policies are strictly followed, more Billion Tree Tsunami (BTS) projects, lesser use of fossil fuels and shift towards environment friendly energy sources. Pakistan can work toward a more sustainable future by being proactive today and striking a balance between environmental stewardship and economic prosperity.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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DATA AVAILABILITY STATEMENT

The data sets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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