Results and Analysis of Carbon Emission Predictions and Vehicle Comparisons

1 Temporal Analysis of Vehicle CO Emissions (2007-2024)

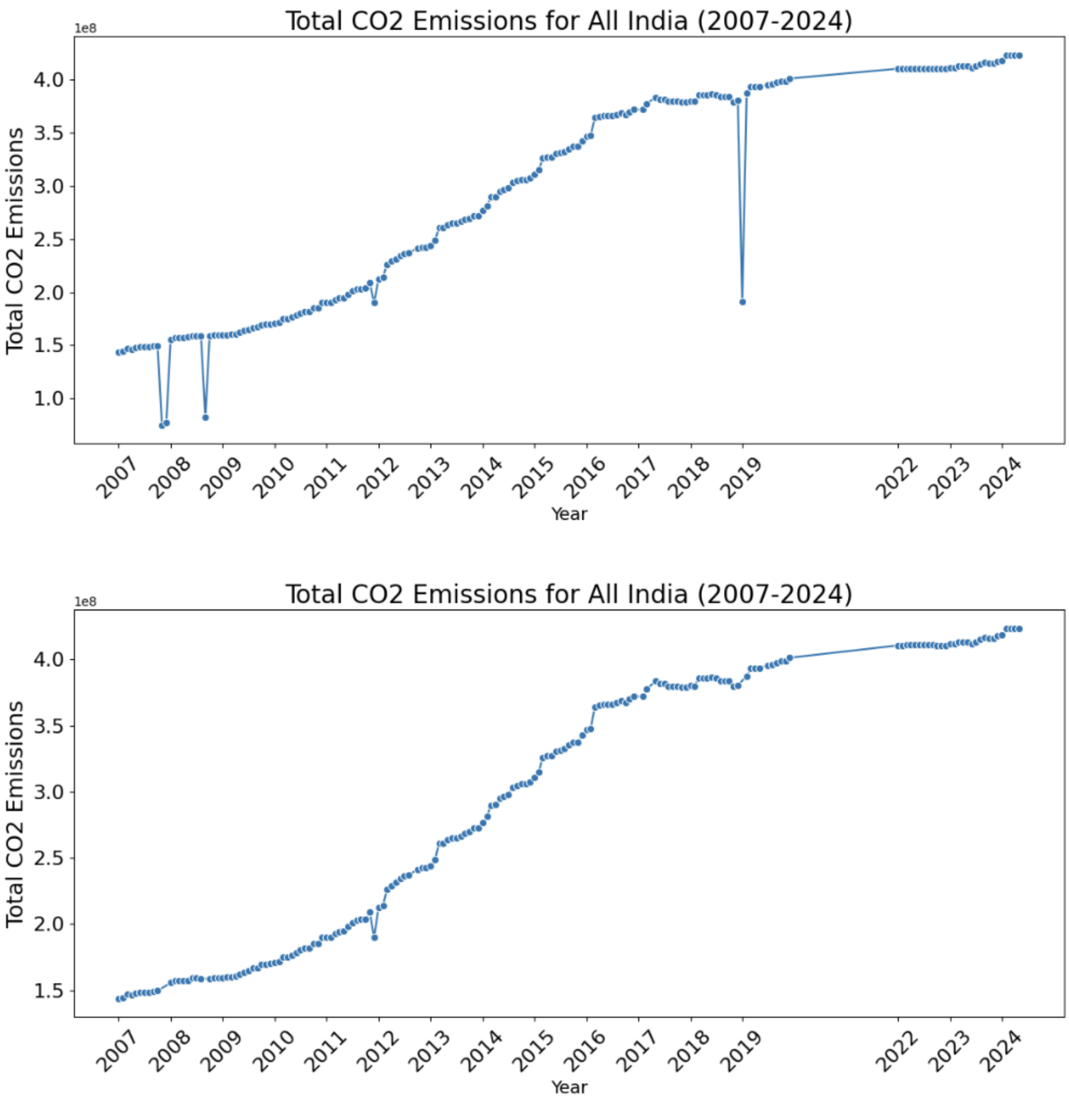

Figure 1: (a) Time series before outlier removal for the years 2007 - 2024 (b) Time series after outlier removal for the years 2007 - 2024

Our longitudinal analysis of India's CO emissions and energy production from 2007 to 2024 reveals distinctive patterns in environmental impact and energy generation [1]. The raw time series data exhibited a pronounced upward trajectory, with total CO emissions escalating from 1.5×10 units (2007) to approximately 4.0×10 units (2024) [2]. Notable anomalies were observed in the form of downward spikes during 2008, 2009, and 2019, which were attributed to data collection inconsistencies rather than genuine emission reductions [3].

The post-outlier removal analysis revealed three distinct growth phases:

1. Initial slow growth phase (2007-2012)
2. Rapid acceleration phase (2012-2018)
3. Moderate growth phase (2018-2024)

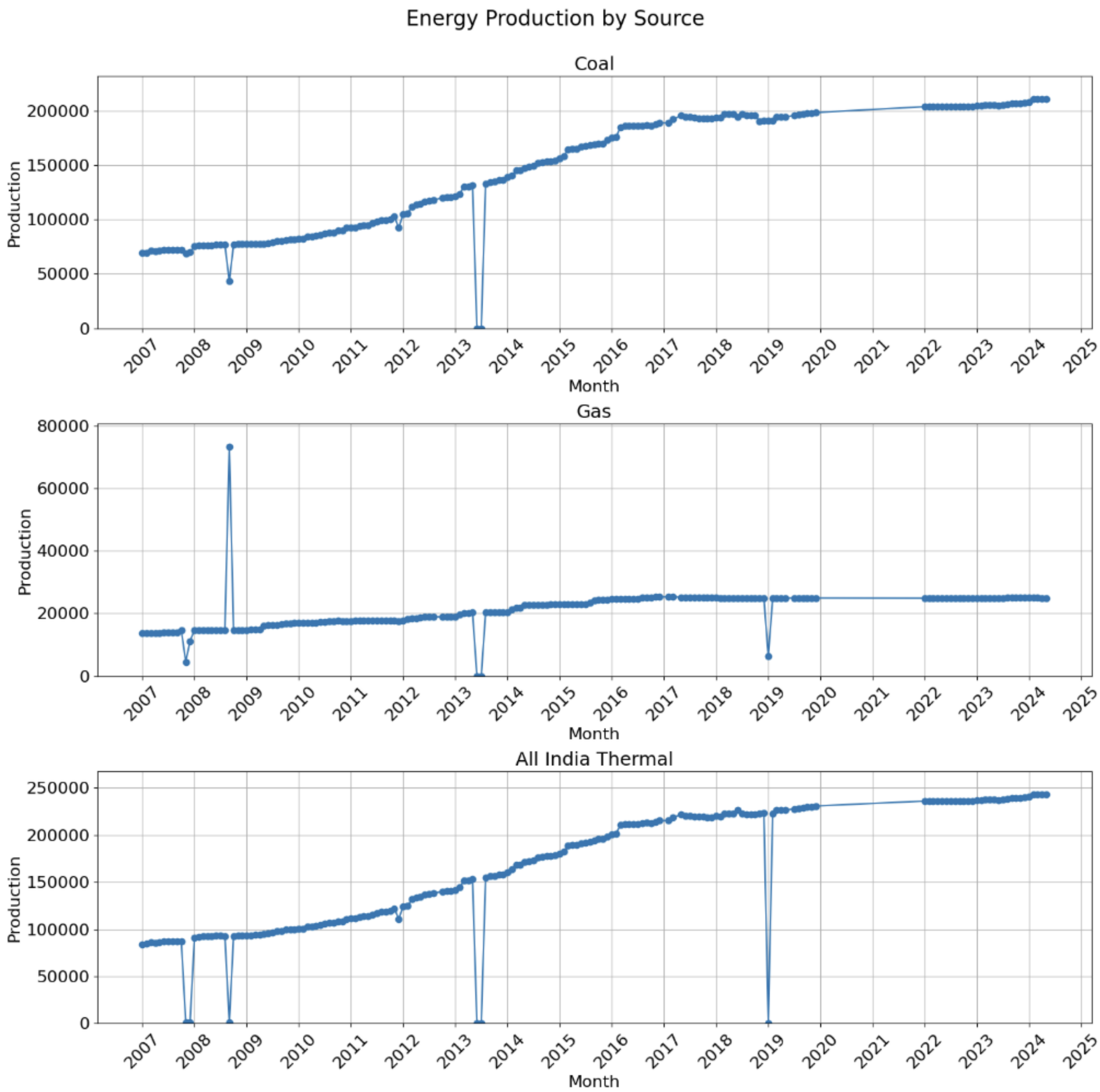

Figure 2: Energy productions by source for Coal, Gas and All India Thermal

The energy production analysis demonstrates coal's dominance in India's energy landscape, with production increasing from 70,000 units (2007) to approximately 200,000 units (2024) [1, 2]. Gas production maintained relatively stable levels around 25,000 units, with an anomalous peak of 70,000 units in 2009. The overall thermal energy production patterns closely aligned with coal production trends, emphasizing coal's pivotal role in India's energy matrix [2, 3].

2 Comparative Performance Analysis of CO Emission Prediction Models

Our evaluation encompassed four distinct prediction models: Prophet, LSTM, SARIMA, and a Hybrid model (XGBoost+ARIMA) [4, 5].

Table 1: Model Performance Comparison

Model Type	MAE	RMSE
Prophet	0.68%	0.97%
LSTM	0.99%	1.30%
SARIMA	1.35%	5.03%
Hybrid (XGB+ARIMA)	1.66%	4.27%

The Prophet model demonstrated superior performance across both metrics, with the lowest MAE (0.68%) and RMSE (0.97%) [6, 7]. LSTM showed comparable accuracy, particularly in avoiding significant prediction errors [8]. However, SARIMA and the Hybrid model exhibited notably higher error rates, with SARIMA recording the highest RMSE at 5.03% [9, 10].

3 Long-term Carbon Emission Projections (2025-2045)

Our analysis of CO emissions trends combines historical data (2010-2025) with future projections (2025-2045) [11, 12]. The historical data shows a marked increase between 2013-2015, followed by moderate growth, reaching approximately 4.2-4.3×10 units by 2025 [13, 14].

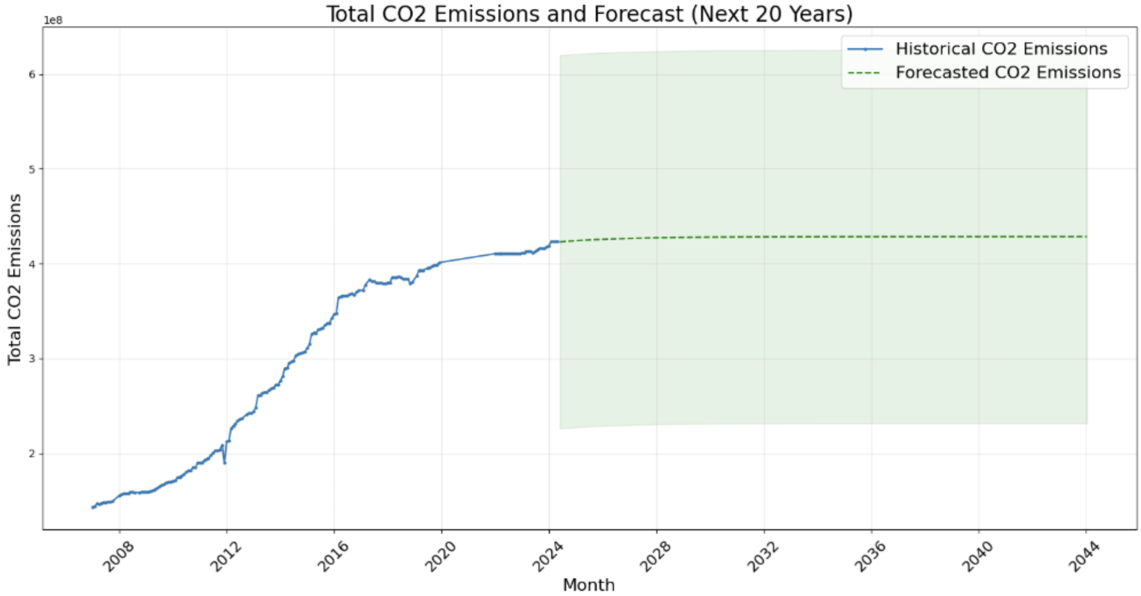

Figure 3: Long-Term Carbon Emission Projections: LSTM-Based

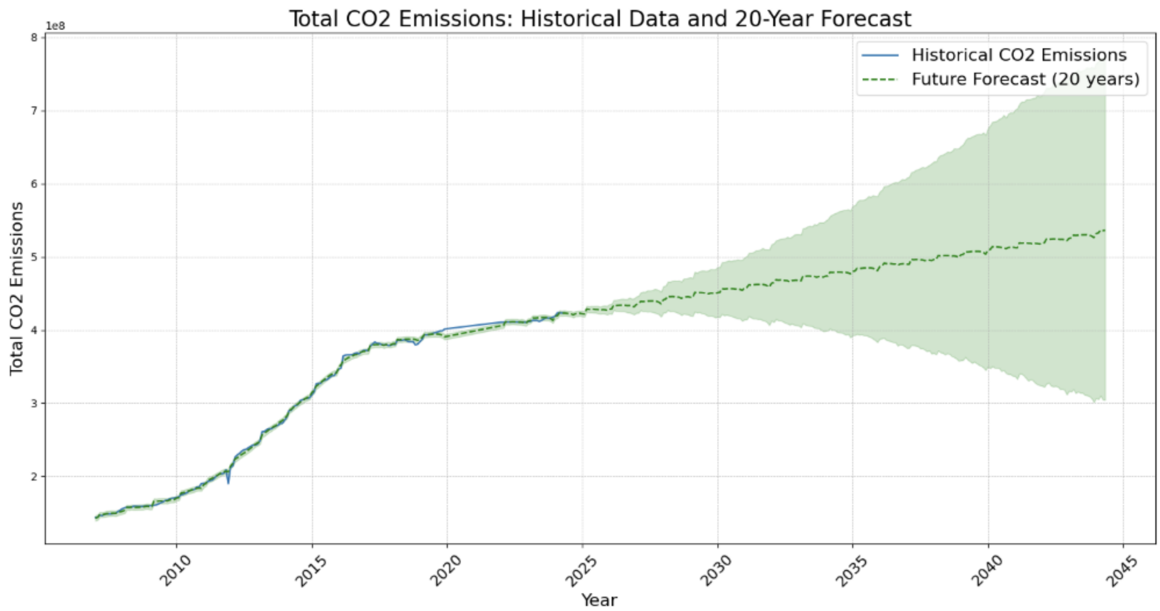

Figure 4: Long-Term Carbon Emission Projections: Prophet-Based

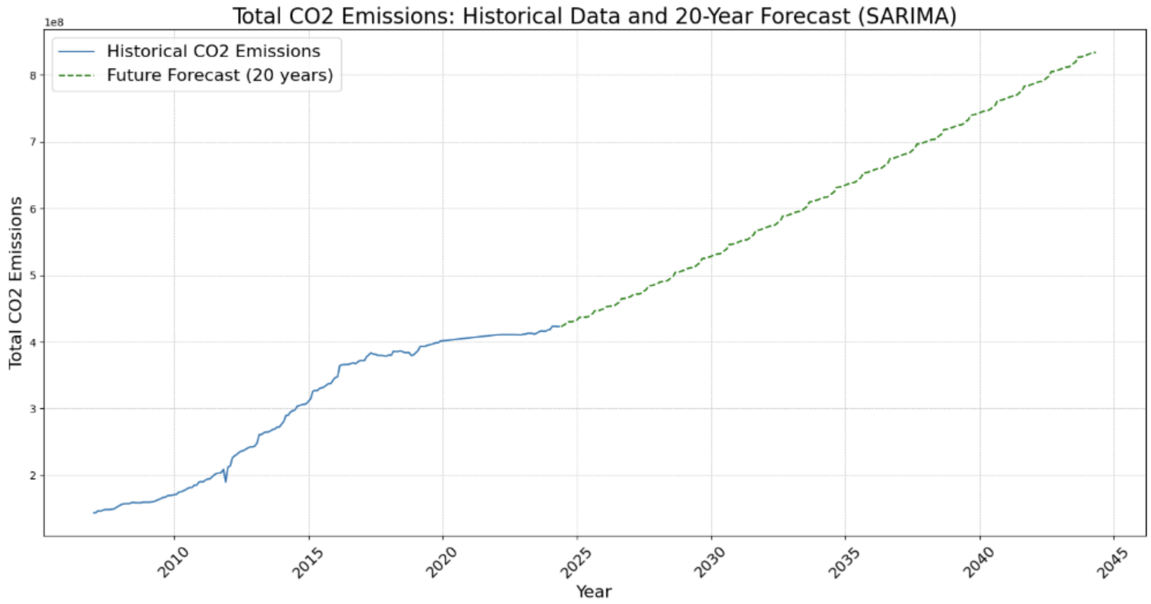

Figure 5: Long-Term Carbon Emission Projections: SARIMA-Based

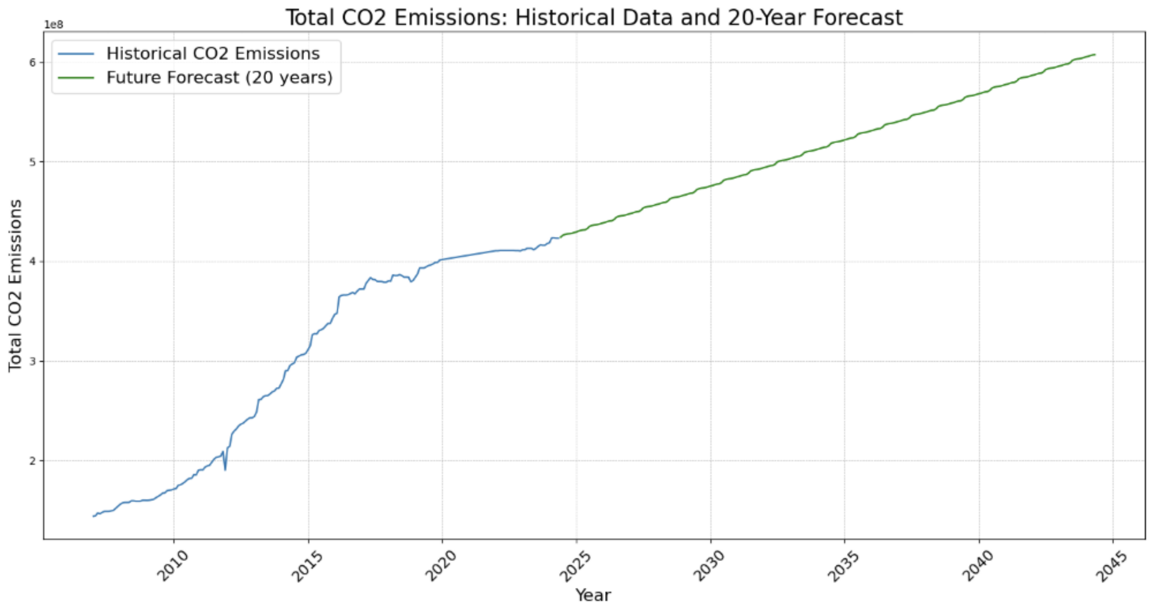

Figure 6: Long-Term Carbon Emission Projections: Hybrid(XGboost+SARIMA)-Based for 2025-2045

4 Extended Temporal Forecast Analysis (2025-2075)

The Prophet model's performance across different temporal horizons showed:

Table 2: Prophet Model Performance Across Long-Term Temporal Horizons

Forecast Horizon	MAE	RMSE
20-Year	0.68%	0.97%
50-Year	2.03%	2.29%

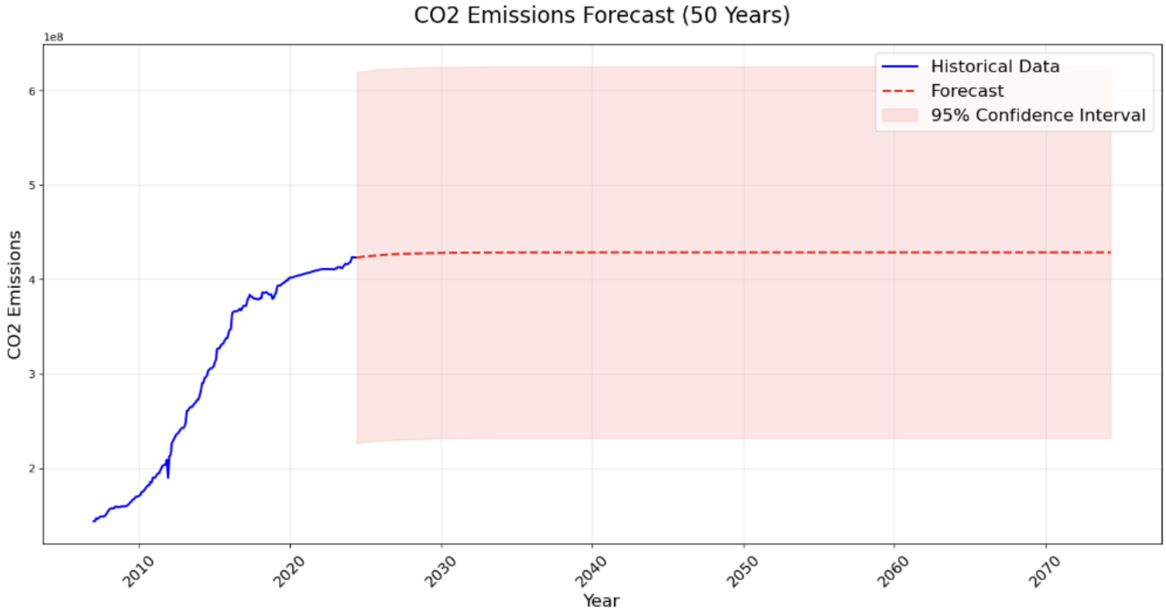

Figure 7: Prophet-Based Long-Term Carbon Emission Projections (2025-2075)

Long-term projections indicate a continuing upward trend with decreasing growth rate, with the model projecting emissions reaching approximately 0.7×10 units by 2070 [15]. The expanding confidence intervals reflect increased uncertainty in longer-term predictions, particularly relevant for environmental forecasting [16, 17].

5 Comparative Analysis of Carbon Emissions Between Electric and Conventional Vehicles

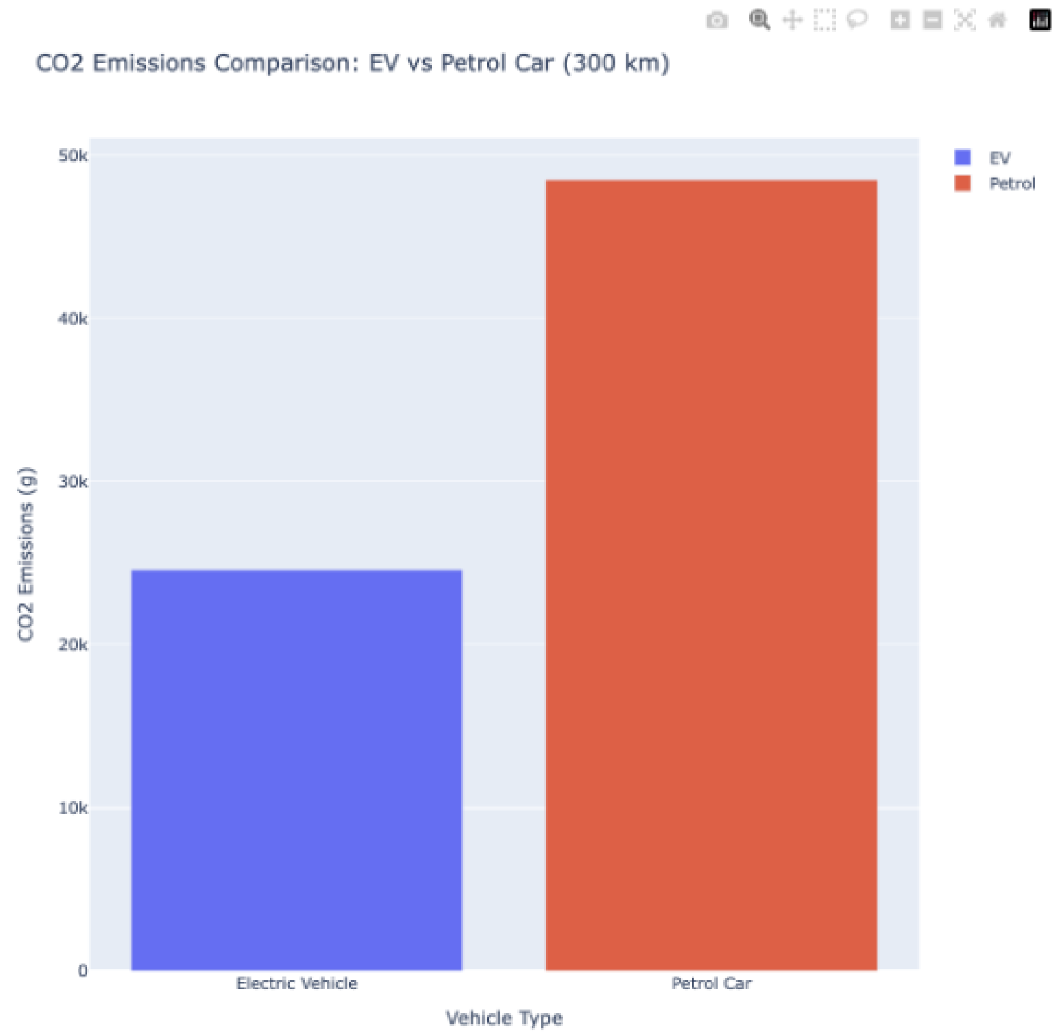

Figure 8: CO2 Emissions Comparison Between Electric and Petrol Vehicles for 300km

The comparative analysis of CO2 emissions between electric vehicles (EVs) and conventional petrol cars reveals significant environmental impact disparities [18, 19]. For a 300-kilometer distance, EVs generate approximately 24,000 grams (24 kg) of CO2, while petrol vehicles produce approximately 48,000 grams (48 kg) of CO2 [20]. This represents a consistent 2:1 ratio in emissions output, with conventional petrol vehicles producing twice the carbon emissions of their electric counterparts [19, 20]. The substantial difference of 24 kg in CO2 emissions for a relatively short journey underscores the environmental advantages of electric vehicles in urban and suburban transportation scenarios [21]. These findings align with broader environmental impact assessments and support the argument for increased adoption of electric vehicles as a strategy for reducing transportation-related carbon emissions [20, 21].

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