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**“AI-Based Predictive Analysis For Energy Demand Forecasting  
In Pakistan: Incorporating Carbon Credit Indicators”**



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# **AI-Based Predictive Analysis for Energy Demand Forecasting in Pakistan: Incorporating Carbon Credit Indicators**



## ABSTRACT

Energy demand forecasting is highly important in the energy sector from generation planning, fuel procurement, and tariff calculation point of view in Pakistan due to the high economic cost of mismatch between energy supply and demand. Non-linear patterns are hard to predict using traditional forecasting approaches and climate-policy signals are not explicitly included in these approaches, which are becoming more important in energy markets. This research compares the accuracy of predictive models based on artificial intelligence (AI) techniques namely gradient boosting (XGBoost), and long short-term memory (LSTM) networks and assesses whether they enhance the accuracy of electricity demand forecasts in Pakistan, and whether carbon credit indicators, such as carbon prices from EU Emissions Trading System (ETS) provide value as an indicator of electricity demand.

Secondary monthly time series data from January 2015 to December 2024 was used and a quantitative, longitudinal research design was adopted. Electricity demand and consumers data was gathered from NEPRA, energy prices from OGRA and PPIS, carbon prices from EU ETS, and temperature from PMD. The modelling framework included benchmark models (multiple regression, SARIMAX) and AI models, with the models validated using time-ordered out-of-sample tests. The performance was evaluated using MAE, RMSE and MAPE.

The Boost model significantly outperforms SARIMAX model, with a MAE of 290 MW compared to 380 MW for SARIMAX. The second most important predictor was economic activity which supported its positive association with demand (H1). Adding carbon price features increases the accuracy of the forecasts by 13.4% ( $p = 0.03$ ) and is among the top five most important features, thereby supporting H2. The importance of temperature did not change (33.5%). The results of LSTM were comparable but not significantly better than Boost.

The study findings conclude that the use of AI -forecasting techniques, especially gradient boosting, greatly improves the accuracy of energy demand forecasting in Pakistan. Even in the absence of a domestic carbon market, it is important that carbon credit indicators include relevant predictive information, and that they should be included in energy planning scenarios. The recommendations are to switch to Boost for operational forecasting, to track international carbon prices, and to enhance the energy data infrastructure in the country.

Keywords: Energy demand forecasting, Artificial Intelligence, Machine Learning, Carbon credits, carbon price, Pakistan energy sector, national electricity demand.

## Table of Contents

|                                                                                           |           |
|-------------------------------------------------------------------------------------------|-----------|
| <b>CHAPTER 1: INTRODUCTION .....</b>                                                      | <b>1</b>  |
| 1.1 Background of the Study .....                                                         | 1         |
| 1.2 Research Gap .....                                                                    | 2         |
| 1.3 Problem Statement .....                                                               | 3         |
| 1.4 Research Questions .....                                                              | 4         |
| 1.5 Research Objectives .....                                                             | 5         |
| 1.6 Significance of the Study .....                                                       | 5         |
| 1.7 Scope and Delimitations .....                                                         | 6         |
| 1.8 Chapter Summary .....                                                                 | 7         |
| <b>CHAPTER 2: LITERATURE REVIEW .....</b>                                                 | <b>9</b>  |
| 2.1 Introduction to Energy Demand Forecasting Literature .....                            | 9         |
| 2.2 Traditional Approaches to Energy Demand Forecasting .....                             | 10        |
| 2.3 Emergence of Artificial Intelligence and Machine Learning in Energy Forecasting ..... | 11        |
| 2.4 AI-Based Energy Demand Forecasting in Developing Economies .....                      | 12        |
| 2.5 Carbon Credits and Carbon Pricing: Conceptual Foundations .....                       | 13        |
| 2.6 Carbon Price Forecasting and Machine Learning Applications .....                      | 14        |
| 2.7 Relevance of Carbon Credit Indicators for Pakistan .....                              | 16        |
| 2.8 Integrating Carbon Credit Indicators into Energy Demand Forecasting .....             | 17        |
| 2.9 Synthesis of Literature and Identification of Research Gap .....                      | 18        |
| 2.10 Theoretical Framework .....                                                          | 19        |
| 2.11 Research Hypotheses .....                                                            | 20        |
| 2.12 Chapter Summary .....                                                                | 21        |
| <b>CHAPTER 3: RESEARCH METHODOLOGY .....</b>                                              | <b>23</b> |
| 3.1 Introduction to the Chapter .....                                                     | 23        |
| 3.2 Research Philosophy .....                                                             | 23        |
| 3.3 Overall Research Design .....                                                         | 24        |
| 3.4 Population of the Study .....                                                         | 24        |
| 3.5 Unit of Analysis .....                                                                | 24        |
| 3.6 Sampling Strategy .....                                                               | 25        |
| 3.7 Sample Size .....                                                                     | 26        |
| 3.8 Research Approach .....                                                               | 27        |
| 3.9 Data Sources and Variable Construction .....                                          | 27        |
| 3.10 Data Preparation and Preprocessing .....                                             | 29        |
| 3.10.1 Frequency Alignment .....                                                          | 29        |
| 3.10.2 Handling Missing Values .....                                                      | 29        |
| 3.10.3 Transformation and Scaling .....                                                   | 30        |
| 3.10.4 Lag Construction .....                                                             | 30        |

|                                                                |           |
|----------------------------------------------------------------|-----------|
| 3.11 Modelling Framework .....                                 | 30        |
| 3.11.1 Benchmark Models.....                                   | 30        |
| 3.11.2 AI Based Forecasting Models.....                        | 31        |
| 3.13 Evaluation Metrics .....                                  | 31        |
| 3.14 Ethical Considerations .....                              | 32        |
| 3.15 Methodological Limitations .....                          | 33        |
| 3.16 Chapter Summary.....                                      | 33        |
| <b>CHAPTER 4: DATA ANALYSIS &amp; FINDINGS .....</b>           | <b>35</b> |
| 4.1 Introduction to the Chapter .....                          | 35        |
| 4.2 Descriptive Statistics.....                                | 35        |
| 4.3 Time Series Plots and Seasonal Patterns .....              | 37        |
| 4.4 Correlational Analysis .....                               | 38        |
| 4.5 Stationarity and Time Series Properties.....               | 39        |
| 4.6 Benchmark Model Results.....                               | 40        |
| 4.6.1 Multiple Regression (with Lags and Differencing) .....   | 40        |
| 4.6.2 ARIMAX / SARIMAX Model .....                             | 41        |
| 4.7 AI Model Results .....                                     | 41        |
| 4.7.1 Gradient Boosting Model (Boost).....                     | 41        |
| 4.7.2 LSTM Model.....                                          | 42        |
| 4.8 Model Comparison.....                                      | 43        |
| 4.9 Testing the Contribution of Carbon Credit Indicators ..... | 43        |
| 4.10 Hypothesis Testing Summary .....                          | 44        |
| 4.11 Chapter Summary.....                                      | 45        |
| <b>CHAPTER 5: DISCUSSION &amp; CONCLUSIONS .....</b>           | <b>46</b> |
| 5.1 Discussion of Findings.....                                | 46        |
| 5.1.1 AI Models versus Traditional Benchmarks.....             | 46        |
| 5.1.2 Role of Economic Activity.....                           | 46        |
| 5.1.3 Carbon Credit Indicators .....                           | 47        |
| 5.1.4 Control Variables .....                                  | 47        |
| 5.2 Answering the Research Questions.....                      | 48        |
| 5.3 Meeting the Research Objectives.....                       | 48        |
| 5.4 Theoretical Implications .....                             | 49        |
| 5.5 Practical Implications.....                                | 49        |
| <b>CHAPTER 6: RECOMMENDATIONS .....</b>                        | <b>51</b> |
| 6.1 Recommendations for Policymakers .....                     | 52        |
| 6.2 Recommendations for Future Research .....                  | 52        |
| 6.3 Limitations and Caveats.....                               | 53        |
| <b>References .....</b>                                        | <b>54</b> |

## List of Tables

|                                                   |    |
|---------------------------------------------------|----|
| Table 1:Literature Gap Identification Table ..... | 19 |
| Table 2:Variable Definition Table.....            | 27 |

|                                                            |    |
|------------------------------------------------------------|----|
| Table 3 :Descriptive Statistics Table .....                | 36 |
| Table 4: Regression Coefficients with 95% Confidence ..... | 40 |
| Table 5: Model Performance Comparison Table.....           | 43 |

## List of Figures

|                                                        |    |
|--------------------------------------------------------|----|
| Figure 1:Conceptual frame work .....                   | 20 |
| Figure 2: Correlation Matrix Heatmap.....              | 39 |
| Figure 3: Forecast Accuracy Comparison Bar Chart ..... | 44 |