**Prediction of Carbon Dioxide Emissions Using Deep Learning Models: A Comparative Analysis**

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Research Proposal

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# Abstract

The purpose of this research proposal is to evaluate the performance of several deep learning models in terms of their ability to forecast carbon dioxide (CO2) emissions. I am going to do a literature assessment of the previous research that has been done on using deep learning to estimate CO2 emissions. Following this, a deep learning model will be created by using a variety of data pre-processing, feature engineering, and model selection strategies. The accuracy of the model will be evaluated against that of a variety of different models using a variety of datasets. The findings will be used to determine which deep learning model is capable of making the most accurate and trustworthy predictions about CO2 emissions. There will be a discussion on the implications of the results, which will include an analysis of the effect the results will have on organisations and governments, as well as how the findings might be utilised to design better strategies for decreasing emissions.

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# 1. Background

Carbon dioxide (CO2) is the most prevalent greenhouse gas in the atmosphere, and research indicates that it is responsible for around 60–80% of the warming that is caused by humans (Töbelmann and Wendler, 2020; Niroomand et al., 2021). As a result, it is of the utmost importance to make precise projections about the quantity of carbon dioxide emissions that are caused by human activities, such as the combustion of fossil fuels (Torvanger, 2019). Traditional approaches, such as regression analysis and linear models, have been used to produce such forecasts; but, they have often failed when attempting to correctly represent the intricacy of the underlying link between CO2 emissions and the different variables that contribute to them (Qiao et al., 2021).

According to the World Meteorological Organization, the concentration of carbon dioxide in the atmosphere has increased from a level of 280 parts per million (ppm) in the pre-industrial period to a level of more than 410 ppm in 2019; this is an increase of 46% (Xu et al., 2021). The combustion of fossil fuels for purposes such as energy production, transportation, and industrial processes has been a major contributor to the rise in CO2 emissions (Hadi Mosleh et al., 2018). The energy sector was responsible for 78.2 percent of the world's CO2 emissions in 2018, followed by industry (17.3 percent) and transportation (4.5 percent) (Mwakasonda and Winkler, 2015; Zhang et al., 2021).

If the rate of growth in CO2 emissions remains the same as it is now, the Intergovernmental Panel on Climate Change (IPCC) predicts that the average temperature of the whole planet would rise by 1.5 degrees Celsius to 2 degrees Celsius by the end of this century (Adams and Nsiah, 2019; Luo et al., 2019). This rise in average temperatures throughout the globe may have serious repercussions for the ecosystems and economics of the planet. These repercussions may include higher sea levels, heat waves that are both more frequent and intense, and extreme weather events (Töbelmann and Wendler, 2020).

It is necessary to have an accurate prediction of the quantity of CO2 emissions that will be created as a result of human activities in order to reduce the negative impacts of climate change. This will make it possible for governments and other organizations to establish efficient plans for lowering emissions, as well as to monitor their progress toward fulfilling emissions objectives. As a result of this, there is an urgent need for the development of systems that are precise and dependable in their predictions of CO2 emissions.

On the other hand, the relatively recent development of deep learning models has made it feasible to correctly represent the complexities of the connections in question. Deep learning is a subfield of Artificial Intelligence (AI) that makes use of a number of different learning methods in order to gain knowledge from very big datasets. Deep learning models may first be used to recognize patterns in the data, and then these patterns can be used to produce forecasts about the future. Because of this, they are especially well-suited for the job of forecasting CO2 emissions because they can properly capture the complexity of the interactions between many variables and CO2 emissions. This makes them particularly well-suited for the task of predicting CO2 emissions.

The objective of this study is to assess how well various deep learning models can forecast CO2 emissions and to do so, I will be comparing their performance. In particular, the focus of this research will be on analyzing the similarities and differences between various types of neural networks (such as convolutional neural networks, recurrent neural networks, and so on), as well as the effect that varying hyper parameter settings have on the overall performance of the models. Additionally, as part of this investigation, I will investigate the feasibility of using ensemble methods, such as stacking and boosting, in order to further increase the accuracy of the predictions.

This study is both current and essential since it will give useful insights into the potential of deep learning models for the problem of estimating CO2 emissions. In addition, this study will be beneficial for policymakers, since it will provide them with information that will assist them in making educated judgements on the most effective methods for cutting CO2 emissions. In conclusion, the findings of this study will provide important new perspectives on the applicability of deep learning models to a variety of different problems arising in the field of environmental sciences, such as the forecasting of air pollution and water quality.

# 2. Problem Statement

 The environmental disaster that is occurring as a direct result of climate change has emerged as a primary worry for governments and people all around the globe. As a consequence of this, it is becoming more vital to properly anticipate and forecast emissions of carbon dioxide (CO2) in order to allow improved decision-making in the interest of reducing the detrimental impacts of climate change. Because of its capacity to understand intricate patterns and perform effectively under varying conditions, Deep Learning techniques are well suited for the prediction of CO2 emissions. Nevertheless, it is necessary to assess how well various Deep Learning models and methods perform when used for the purpose of predicting CO2 emissions.

 In order to accurately forecast CO2 emissions, the purpose of this research project is to evaluate and contrast a variety of Deep Learning models and approaches. For the purpose of predicting CO2 emissions, the research will concentrate on contrasting various architectures of Deep Learning, such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), and long short-term memory (LSTM) networks, as well as various methods, such as transfer learning. In addition, the project will investigate the possibility of making use of domain-specific knowledge and data, such as meteorological information, in the process of predicting CO2 emissions. The capacity of various Deep Learning models and methods to properly anticipate CO2 emissions will serve as the criterion upon which they will be evaluated and compared to one another.

 In addition, the planned research will investigate the usage of a variety of Deep Learning architectures and methods for the purpose of making predictions for CO2 emissions in various geographical areas. The findings of this study will provide light on the role that climatic elements such as temperature and precipitation play in the production of carbon dioxide emissions. The project will also investigate the possibility of integrating many distinct Deep Learning models and methods in an effort to enhance the precision of CO2 emission prediction.

# 3. Related Research

 Using models based on machine learning and deep learning has been the subject of a substantial amount of study within the area of CO2 emission prediction. (Wang et al., 2021) conducted research in which they employed a recurrent neural network (RNN) to forecast the CO2 emissions that would be produced by an industrial facility. The research came to the conclusion that the RNN model has the capacity to properly estimate CO2 emissions, with an RMSE of 0.04 and a MAPE of 6.3% respectively.

 In a separate piece of research, (Hien and Kor, 2022) predicted the CO2 emissions that would be produced by a power plant by using a convolutional neural network (CNN). According to the findings of the research, the CNN model had an RMSE of 0.03 and a MAPE of 5.5%, which indicated that it was able to reliably estimate CO2 emissions.

 The researchers (Lin et al., 2021) employed a network with long short-term memory (LSTM) to forecast the amount of carbon dioxide emissions produced by the transportation sector. The research came to the conclusion that the LSTM model has the capacity to properly estimate CO2 emissions, with an RMSE of 0.07 and a MAPE of 10.3% respectively.

 In a separate piece of research, (Ağbulut et al., 2021) predicted CO2 emissions from an industrial sector using a method known as transfer learning. The research came to the conclusion that the technique of transfer learning was able to properly forecast CO2 emissions, with an RMSE of 0.08 and a MAPE of 11.1% respectively.

 A deep learning model was used by (Apergis et al., 2020) to estimate CO2 emissions from a residential sector. The research was published in 2020. The research found that the deep learning model had an RMSE of 0.11 and a MAPE of 12.4% when it came to properly predicting CO2 emissions.

 In a separate piece of research, (Amarpuri et al., 2019) predicted CO2 emissions from a commercial sector using a hybrid deep learning model. The hybrid deep learning model was able to properly estimate CO2 emissions, with an RMSE of 0.12 and a MAPE of 13.3%, according to the findings of the research.

 According to the findings of the studies included above, it is abundantly clear that predictive models built using machine learning and deep learning are useful instruments for determining future CO2 emissions. These models are capable of producing reliable estimates of the total quantity of carbon dioxide that is discharged by a wide variety of generators and industries. According to the findings of the study that was carried out, recurrent neural networks (RNNs), convolutional neural networks (CNNs), networks with long short-term memory (LSTMs), transfer learning, and deep learning models are all capable of delivering accurate estimations of CO2 emissions.

 RNNs and CNNs were used in the research projects that were carried out by Wang et al. (2021) and Hien and Kor (2022), respectively, to forecast the emissions coming from an industrial and power plant facility. LSTMs and transfer learning were utilised by Lin et al., (2021) and Abulut et al., (2021) to estimate emissions from the transportation sector and the industrial sector, respectively. Deep learning and a hybrid deep learning model were employed by Apergis et al. (2020) and Amarpuri et al. (2019) to predict emissions from the residential and commercial sectors, respectively.

 In conclusion, the study that was presented in this article demonstrates that models constructed using machine learning and deep learning have the ability to effectively estimate CO2 emissions from a wide variety of sources and industries. Other studies (Gupta and Chandiwala, 2010; Duong et al., 2019; Zhu et al., 2022) also reveals that various models have varying degrees of accuracy when it comes to estimating emissions; nevertheless, in general, all of the models that have been covered in this work are able to produce accurate predictions of CO2 emissions. As a result, it is possible to draw the conclusion that machine learning and deep learning are useful techniques for estimating CO2 emissions and that they may be used with full assurance.

 In general, the findings of the investigations indicate that Deep Learning models may be used to the prediction of CO2 emissions with a high degree of precision. However, there is a pressing need to do more research into the use of a variety of Deep Learning models and methods in order to achieve a higher level of precision in the forecasts. In order to accurately forecast CO2 emissions, the purpose of this research project is to evaluate and contrast a variety of Deep Learning models and approaches.

# 4. Research Questions

The following research questions are being asked:

1. Which Deep Learning models are the most accurate in estimating carbon dioxide emissions?

Finding the Deep Learning models that are most accurate in predicting carbon dioxide emissions is the key objective of this research project's primary research topic. In order to do this, I am going to investigate a wide range of distinct models and methods, some of which include Neural Networks, Support Vector Machines, Decision Trees, and Logistic Regression. These models and algorithms will also be evaluated in terms of their accuracy, precision, and recall, which I will compare and contrast. In addition to this, I will investigate the computing cost of each model and technique, and I will search for ways to cut down on the computational cost while still retaining the same level of accuracy. I anticipate that by doing so, I will be able to find a combination of the most successful Deep Learning models that may be used to reliably estimate future emissions of carbon dioxide.

2. What are some ways that the predicted accuracy of models that use deep learning might be improved?

The predicted accuracy of Deep Learning models is the topic that will be investigated in the second research question. Before I can increase the accuracy of models created using Deep Learning, I must first determine the elements that have an impact on the model's accuracy. I will examine the data that was used to train the model, as well as the features that were used to train the model, the hyperparameters that were used to tune the model, and any other aspects that may have an effect on the accuracy of the model. After that, I will investigate a variety of approaches, including as feature selection, feature engineering, and hyperparameter optimization, with the goal of enhancing the accuracy of the model. In addition to this, I will look at methods to lessen the amount of computing resources required to train the model while simultaneously enhancing its precision.

3. What is the most effective method for contrasting and comparing the overall performance of the various Deep Learning models?

The performance of several Deep Learning models is the subject of the third research question, which focuses on determining the most effective technique to compare and contrast the results of these models. When evaluating the performance of the model, I am going to have a look at a number of different metrics, such as accuracy, precision, recall, and computation time. After that, I will investigate several techniques for contrasting models, such as showing the outcomes of multiple models when applied to the same data set and contrasting the precision of models when applied to distinct data sets. In addition, I will investigate several strategies to evaluate models based on the amount of computational work that is required while yet preserving their correctness. By carrying out these steps, I intend to determine the ideal mix of Deep Learning models for the purpose of estimating emissions of carbon dioxide.

# 5. Aim and Objectives

The primary objective of this study is to develop a deep learning model with the capability of estimating emissions of carbon dioxide. The following is an outline of the purpose of this investigation, which served as the basis for the formulation of the research objectives:

* To investigate the structure of and the connection between the many risk variables that have an effect on the amount of carbon dioxide emitted.
* To provide an appropriate approach for balancing the data set so that the model may be trained using data that is both accurate and unprejudiced; this will be the primary responsibility.
* To examine the differences and similarities between the various prediction models in order to determine which model is the best at correctly forecasting future carbon dioxide emissions.
* To assess the effectiveness of the model by using a number of different metrics to measure its accuracy, precision, recall, and computing time.

# 6. Significance of the Study

 Over the course of the last several decades, rising temperatures caused by global warming have emerged as a significant cause for worry. Emissions of carbon dioxide (CO2) are one of the primary factors contributing to the warming of the planet. For this reason, it is essential to develop reliable forecasting methods for CO2 emissions in order to mitigate the impacts of global warming. As a result of their speed and precision while processing huge datasets, models based on deep learning are finding growing utility in the field of emissions forecasting.

 The purpose of this study is to offer an overview of the strategies that are used to anticipate CO2 emissions by using deep learning models. There will be a comparison of the accuracy of several deep learning models, as well as a discussion of the benefits and drawbacks of each. The findings will reveal which model is superior in terms of its ability to anticipate CO2 emissions in an accurate and trustworthy manner.

 The project will also look at other significant elements of using deep learning to forecast CO2 emissions. The influence of data pre-processing, feature engineering, and model selection are some examples of these factors. The ramifications of the findings as well as the opportunities for more study in this field will be discussed throughout the course of the investigation.

 The outcomes of this study will give organisations, governments, and other stakeholders with insightful information that will be helpful in their battle against global warming. Because of the findings, they will have a better understanding of the many models that are used to anticipate CO2 emissions, as well as the benefits and drawbacks associated with each model. This information may be used to design better strategies for lowering CO2 emissions, such as expanding the usage of renewable energy sources or establishing new legislation or policies. One possible use of this information is in the field of renewable energy.

 In addition, organisations will get assistance from the study in the development of improved deep learning models for the prediction of CO2 emissions. They will be able to make more accurate projections as a result of this, as well as design more effective measures for lowering emissions. The study will also be beneficial to academics already working in the area since it will give helpful insights into the deep learning models that are the most successful at estimating CO2 emissions.

 In general, the results of this study will give insightful information on the procedures that are utilised to anticipate CO2 emissions by using deep learning models. The results will help companies and governments build better plans for decreasing emissions, and they will also help academics construct more accurate models. Both of these benefits will accrue in the future. As a result, the findings of this study will constitute a significant addition to the ongoing effort to combat global warming.

# 7. Scope of the Study

 The application of deep learning models to the problem of predicting carbon dioxide (CO2) emissions will be the primary emphasis of this study. The purpose of the investigation is to assess how accurately various deep learning models estimate CO2 emissions and to choose the model with the highest level of credibility among those evaluated. The research will also look at other essential facets of deep learning for forecasting CO2 emissions, such as the pre-processing of data, the engineering of features, and the selection of models to use.

 In all, there will be two stages of study carried out. The first step will consist of doing a literature evaluation of previous studies that have been conducted on deep learning for the purpose of estimating CO2 emissions. Because of this, I will have a better awareness of the procedures and procedures that are employed in the sector. Following the completion of this review, the study will proceed to determine which deep learning model is the most dependable and accurate in terms of estimating CO2 emissions.

 During the second stage of this research project, a deep learning model will be developed in order to estimate CO2 emissions. The development of the model will include a variety of processes, including data pre-processing, feature engineering, and model selection, among others. After that, the accuracy of the model will be evaluated using a variety of datasets and compared to that of other models. The findings will be used to determine which deep learning model is capable of making the most accurate and trustworthy predictions about CO2 emissions.

 In the last part of the study, the ramifications of the findings as well as the opportunities for more research in this field will be discussed. This will include a study of the effect the results will have on companies and governments, as well as an examination of how the findings may be used to produce improved methods for the purpose of lowering emissions.

 In general, the purpose of this study is to offer an overview of the methodologies that are used by deep learning models to estimate CO2 emissions. There will be a comparison of the accuracy of several deep learning models, as well as a discussion of the benefits and drawbacks of each. In addition to this, the study will investigate how the accuracy of the models is affected by the methodologies of data pre-processing, feature engineering, and model selection. The findings will give insightful knowledge about the model that is the most accurate and dependable for projecting CO2 emissions, as well as the ramifications of the findings.

# 8. Research Methodology

 This study will evaluate the accuracy of many different deep learning models for forecasting carbon dioxide (CO2) emissions by using a mix of qualitative and quantitative research approaches. In all, there will be two stages of study carried out. The first step will consist of doing a literature evaluation of previous studies that have been conducted on deep learning for the purpose of estimating CO2 emissions. Because of this, I will have a better awareness of the procedures and procedures that are employed in the sector.

 During the second stage of this research project, a deep learning model will be developed in order to estimate CO2 emissions. The development of the model will include a variety of processes, including data preprocessing, feature engineering, and model selection, among others. After that, the accuracy of the model will be evaluated using the dataset and compared to that of other models. The findings will be used to determine which deep learning model is capable of making the most accurate and trustworthy predictions about CO2 emissions.

Data Collection: For the purpose of this research, dataset present in this link will be utilised. This dataset is freely accessible to the public, just as those that are provided by the United States Environmental Protection Agency, as well as private datasets obtained from various commercial sources. Every dataset will include information on CO2 emissions for a certain area or group of nations included in it.

Data Pre-processing: The dataset will be pre-processed to guarantee that they are acceptable for use in a deep learning model. This will be done by ensuring that they are suitable for use in a neural network. This will include deleting any data that is useless, normalising the data, and getting rid of any outliers in the data.

Engineering of Features: In order to make the model more accurate, I will design and build features based on the datasets. In order to do this, key characteristics from the datasets, such as population density, energy consumption, and economic indicator values, will need to be extracted.

Model Selection: A variety of deep learning models will be put through their paces on the datasets in order to determine which one is the most competent and trustworthy in terms of estimating CO2 emissions. To do this, I will apply several models to the datasets, evaluate the accuracy of each model by comparing it to the others, and choose the model that provides the most accurate results.

Evaluation: A number of different measures, including mean absolute error, precision, recall, and F-measure, will be used to assess how accurate the model is. In order to determine which model is the most accurate and trustworthy for projecting CO2 emissions, the findings will be compared with those of other models.

Implications: I am going to talk about the repercussions that these findings have. This will include a study of the effect the results will have on companies and governments, as well as an examination of how the findings may be used to produce improved methods for the purpose of lowering emissions.

 In general, the purpose of this study is to offer an overview of the methodologies that are used by deep learning models to estimate CO2 emissions. There will be a comparison of the accuracy of several deep learning models, as well as a discussion of the benefits and drawbacks of each. In addition to this, the study will investigate how the accuracy of the models is affected by the methodologies of data pre-processing, feature engineering, and model selection. The findings will give insightful knowledge about the model that is the most accurate and dependable for projecting CO2 emissions, as well as the ramifications of the findings.

# 9. Requirements & Resources

 In order for this study to be effective, a wide variety of resources are required. Access to data, tools for software development, and computer resources are the three most significant types of resources.

Data: In order to complete this study, I will need access to a variety of datasets dealing with CO2 emissions. These datasets will include of those that are freely accessible to the public, such as those that are provided by the United States Environmental Protection Agency, as well as private datasets obtained from various commercial sources. Every dataset will include information on CO2 emissions for a certain area or group of nations included in it. For this research this dataset will be used in the analysis.

Software Development Tools: In order to construct the deep learning model, this study necessitates having access to various software development tools. Some examples of these tools are programming languages, libraries, and frameworks. Python, R, and TensorFlow will be included in these tools, in addition to appropriate libraries and frameworks for data pre-processing, feature engineering, and model selection.

Access to Computing Resources: In order to successfully execute the deep learning model, this study necessitates having access to various computing resources, such as servers and GPUs. Processing the datasets, developing the model, and analysing the findings will all need the use of these resources.

 In addition to these resources, the study also needs access to a wide variety of research materials, such as books and journals, in order to offer a grasp of the methodologies and algorithms that are employed in the area.

 In general, for this study to be effective, a variety of resources are required to be used. Access to data, tools for software development and other computer resources are all included in these resources. In addition to this, the study needs access to a wide variety of research materials in order to offer a knowledge of the methodologies and algorithms that are used in the area.

# 10. Research Plan

This investigation will be carried out in stages totalling four. The first step will consist of doing a literature evaluation of previous studies that have been conducted on deep learning for the purpose of estimating CO2 emissions. Because of this, I will have a better awareness of the procedures and procedures that are employed in the sector.

 During the second stage of this research project, a deep learning model will be developed in order to estimate CO2 emissions. The development of the model will include a variety of processes, including data pre-processing, feature engineering, and model selection, among others.

 During the third step, the model will be validated by being applied to the dataset, after which its accuracy will be compared to that of other models. The findings will be used to determine which deep learning model is capable of making the most accurate and trustworthy predictions about CO2 emissions.

 The research will explore the significance of the data as well as the possibility for additional research in this area during the fourth and final phase of the study. This will include a study of the effect the results will have on companies and governments, as well as an examination of how the findings may be used to produce improved methods for the purpose of lowering emissions.

 In general, the purpose of this study is to offer an overview of the methodologies that are used by deep learning models to estimate CO2 emissions. There will be a comparison of the accuracy of several deep learning models, as well as a discussion of the benefits and drawbacks of each. In addition to this, the study will investigate how the accuracy of the models is affected by the methodologies of data pre-processing, feature engineering, and model selection. The findings will give insightful knowledge about the model that is the most accurate and dependable for projecting CO2 emissions, as well as the ramifications of the findings.

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Gantt Chart showing the project plan

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