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Predictive Modeling for Energy Use and Carbon Costs at the University of Stirling: Visualizing and Analysing Future Scenarios

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General Information

(Click the boxes to select them)

I confirm that the necessary Ethics Checklist or Approval application form has been submitted ☒

This project is industrially linked (<u>please select ONE</u>): <u>No</u>

If Yes:

- Name of industrial collaborator:
- The necessary Collaborative Project Agreement has been completed ☐

Please select which of these applies:

- Working at Stirling with idea from industry but little contact ☐
- Working at Stirling with idea from industry and regular liaison ☐
- Working on placement with industrial collaborator ☐
- Tier 4 student working on placement with industrial collaborator ☐

1. Problem Statement

The release of greenhouse gases is an important global concern due to their negative effects on the ecosystem and human well-being. It forms a layer in the atmosphere and traps heat on Earth, resulting in global warming, catastrophic climatic changes, rising sea levels, and other effects. As a result, learning about it has become fairly challenging. As a result, worldwide initiatives towards a sustainable environment have been in place for a long time, for instance, international organizations such as the United Nations and their members have adhered to the Paris Agreement [4] to create a low-carbon and sustainable future. Furthermore, as centers of learning and research, educational institutions have the skills and resources to effect long-term change; thus, educational institutions, like international organizations, are shifting to energy-efficient infrastructure and sustainable business practices. The University of Stirling has committed to having a net-zero carbon footprint by the end of 2040 as part of its sustainable practices. The **purpose of this project** is to analyze energy consumption and carbon emissions/costs using machine learning techniques, as well as to forecast future energy use and carbon costs under various scenarios. By exploiting historical data and taking into account many aspects that influence the issue, the study will assist us in providing important insights into future energy demand and related carbon footprints, allowing policymakers to create efficient approaches to optimize carbon costs.

2. Motivation

In the context of recent climate change mitigation and sustainability [1,] investigating energy consumption is crucial since it is a key contributor to environmental challenges such as global warming. The issue has received substantial attention from environmental organizations, businesses, and educational institutions. As a student at the University and an individual, **the primary motivation** that drove me to study energy use and carbon costs is a sense of environmental responsibility and the desire to put that awareness into action by contributing to my immediate surroundings, which is the University and its sustainability initiatives. While analyzing, the **University of Stirling** is situated on a 360-acre campus [2] with numerous buildings, lecture halls, libraries, offices, and dorms, as well as around 17000 students and 1500 employees [3], resulting in significant energy demand. Even though the University has some sustainable practices in place which contribute towards its sustainability goals, in order to adopt more efficient energy-saving measures and cut carbon emissions, a thorough understanding of its patterns and trends is required. This project will provide **insights and predictions** to help make rational choices in energy management and cost savings by developing a strong framework with machine learning models and algorithms. The solution offers the option of obtaining the most efficient techniques that contribute to sustainability challenges as well as optimizing resource allocation for energy consumption and cost reduction. Furthermore, in-depth studies can also be performed in **future works** to fulfill further goals. In addition, **technical challenges** may include developing accurate regression models and visualizing the relationships between energy use considering the utilization of a diverse set of data from various locations as well as the dependency of energy use on various external factors such as varying climate patterns, population growth as well as technical developments over time.

3. Literature Review

Given the importance of this subject and its social significance, many research initiatives have been undertaken over the years to analyze and predict carbon footprints. A few scenarios and the studies based on them are mentioned below,

The article **[5]**, explains (based on data from a campus building) how occupancy rate and other external factors and environmental conditions affect energy consumption and are compared using Regression and Artificial Neural Networks, also observed that ANN models are more accurate in predicting the results than Linear Regression models. Moreover **[8],** has used MLP, an Artificial Neural Networks technique has been used for forecasting net electricity energy consumption on a sectoral basis. The article **[6]** shows how IOT Technologies were applied to gather real-time energy data from challenging production

environments, as well as how Big Data analysis was performed and helped to better comprehend massive energy usage in industries or large areas in order to make more efficient decisions. Furthermore, **[7]** depicts a study of carbon footprint in a metropolis area, in which the energy consumption of a city based on residential types, transportation, and so on was analyzed to anticipate the carbon emissions of the densely populated region in the city. Including the mentioned works, several studies have been conducted to analyze energy consumption and greenhouse gas emissions, and all of them have suggested different methods they have dealt with the issue, and to some extent, the analyses conducted in the sector have aided in some contributions to energy management and to reduce carbon emissions and achieve cost optimization.

4. Objectives and evaluation

The main objectives are,

1. Analyse and visualize the predicted & existing energy use and carbon cost.
2. Analyse the carbon costs under different scenarios and circumstances.
3. Propose a model that can predict energy use and carbon costs based on historical data as well as for different scenarios.
4. Propose a predictive model to forecast carbon costs based on energy usage.

The accuracy and performance of the models will be validated using cross-validation techniques and the evaluation metrics such as R-squared, and MSE.

5. Technologies and Data Source

TensorFlow, Sci-kit Learn, NumPy, Pandas, and other Python packages will be used for data analysis and modeling, while PowerBI or Flask will be used for data visualization. Depending on the amount of the dataset, I will also use Google Colab for data analysis and model training. My supervisor will provide the data, which will be obtained from various sources or buildings at the University as well as data that is publicly accessible will be utilized.

6. References

[1] J. Chontanawat, “Relationship between energy consumption, CO2 emission and economic growth in ASEAN: Cointegration and causality model,” vol. 6, pp. 660–665, 2020, doi: 10.1016/j.egyr.2019.09.046. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352484719305517

[2] https://en.wikipedia.org/wiki/University_of_Stirling

[3] https://www.stir.ac.uk/about/our-people/

[4] https://unfccc.int/most-requested/key-aspects-of-the-paris-agreement

[5] M. K. Kim, Y.-S. Kim, and J. Srebric, “Predictions of electricity consumption in a campus building using occupant rates and weather elements with sensitivity analysis: Artificial neural network vs. linear regression,” vol. 62, p. 102385, 2020, doi: 10.1016/j.scs.2020.102385. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2210670720306065

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