Existing Building Energy Performance Ordinance Report.

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Abstract

This research examines the energy and environmental efficiency of buildings across many categories, uses a comprehensive dataset to gain valuable insights. The analysis focuses on building categories with high Total Greenhouse Gas Emissions, revealing possible differences in energy efficiency among different property kinds, and evaluating the distribution of Energy star scores across various categories. The research provides useful insights for the development of targeted initiatives to mitigate environmental damage, benefiting for urban planners, and property owners. The extensive information functions as a significant asset for making well-informed decisions, promoting a more energy-efficient and environmentally aware built environment.

Introduction

Energy is inevitable requirement nowadays and the usage of energy results in emission of pollutants into the environment. The emission are mainly greenhouse gases and these emission levels increasing day by day by the usage of excessive energy in various forms like gasoline, and it's by products, natural gas, and coal. People are more into electric energy consumption which also be an indirect reason for emission of pollutants into the environment. Present days all the corporate buildings are depending more on electricity and natural gases for their energy needs and there by becoming one of the major sources for emission of GHG's into the environment.

According to the Existing Buildings Energy Performance Ordinance, it is mandatory for nonresidential buildings with a minimum of 10,000 square feet of conditioned space and residential buildings with a minimum of 50,000 square feet of conditioned space to be assessed annually using Energy Star Portfolio Manager. Every non-residential facility mentioned must undergo an energy audit, retro commissioning, or create a decarbonization strategy at least once every 5 years. The data is obtained from the benchmark and energy audit reports that are provided to comply with Environment Code Chapter 20. The collection is comprised of tables that collectively offer fundamental attributes, adherence status, and publicly accessible log of claimed energy efficiency [1]. The data provided can be utilized for conducting research and presenting solutions.

- *Which categories of buildings have excess usage of Total GHG emissions?*

- *Is there a major difference in the amount of energy efficiency across the various sorts of properties?*
- *The distribution of energy star scores among different property categories*?

The potential advantages of addressing the research questions are.

- *This will be easy to analyze the excess usage of GHG emission which may lead to overcome the depletion of GHG emission.*
- *We can analyze the differences between the means or medians of the Site EUI and the Source EUI for the various categories of properties.*
- *We can find the mean, median, and distribution of ENERGY STAR numbers for different types of properties to get a better idea of how they are spread out.*

Dataset

The dataset has individual entries for each building, offering fundamental attributes such as dimensions and age. This provides the deadlines for conducting an energy audit or implementing a decarbonization strategy for commercial buildings. Each row in this data represents one year of benchmarking data for a specific building, resulting in numerous records per building. A one-year dataset contains information on compliance status, as well as energy usage data such as gas, electricity, steam, and EPA-estimated operating carbon emissions for compliant buildings. This dataset comprises the information from two views that have been combined based on the Parcel Number. It also comprises of the benchmark submitted date for buildings.

Data Types

- **Nominal:** Unique Identifier, Parcel Number, Building Name, Building Address, Postal code, Property Type- Self Selected and Energy Audit Status.
- **Ordinal:** Energy Audit Due Date, Benchmark Status and Reason for Exemption.
- **Interval:** Year Built, Benchmark Year and Percent Better Than National Median.
- **Ratio:** Energy Star Score, Site EUI (KBTU/ft2), Source EUI (KBTU/ft2), Weather Normalized Site EUI (KBTU/ft2), Weather Normalized Source EUI (KBTU/ft2), Total GHG Emissions (Metric Tons CO2e), Total GHG Emissions Intensity (kGCO2e/ft2), Electricity Use - Grid Purchase (kWh), Natural Gas Use (KBTU), District Steam Use (KBTU), Site Energy Use (KBTU) and Point.

Literature Review

This research aims to explore approaches for enhancing the efficiency of energy in existing buildings by classifying assessment techniques according to varying levels of data collecting, rather than relying on standardized methodologies. The proposed assessment framework consists of three distinct types. The first type, referred to as Type 1, involves a simplified approach that relies on technical documents and literature sources. The second type, known as Type 2, considers user characteristics and involves on-site audits and the collection of occupancy data. Lastly, the third type, referred to as Type 3, is a more detailed assessment specifically designed for retrofit or remodeling purposes and incorporates energy consumption data. This study uses diverse approaches to examine multiple buildings, emphasizing the influence of data gathering levels on estimates of energy performance. The study emphasizes the necessity of expanding the utilization of energy efficiency measures to other types of buildings, as well as including long-term maintenance planning and life cycle considerations. This approach is crucial for evaluating the cost-effectiveness and energy consumption of such measures at different stages during the life cycle [2].

The other research presents a novel integrated global building-material-emission model that consists of a dynamic building material model and a projected Life Cycle Assessment model. This model facilitates the assessment of environmental consequences linked to the utilization of materials in the construction of buildings on a global scale, as well as the examination of different methods pertaining to material usage and supply in relation to emissions. This study examines several building kinds, including residential and commercial structures, as well as seven essential construction materials, namely steel, concrete, brick, aluminum, copper, glass, and wood. The investigation encompasses both urban and rural environments throughout different areas worldwide. It acknowledges that although the construction-material database utilized is now the most superior option on a global scale, there exists potential for enhancement in relation to geographical precision, building classifications, and material inclusiveness. Furthermore, it is suggested that the Life Cycle Inventory database be enhanced by incorporating variables such as carbon sequestration in goods derived from wood, as well as implementing dynamic sub-models to accurately capture the temporal impacts of carbon intake and reabsorption [3].

This another article examines the obstacles associated with enhancing energy efficiency in the United States, with a specific focus on buildings, as they constitute a substantial proportion of energy usage. The authors emphasize the frequent oversight of numerous energy-saving prospects within the construction sector, while acknowledging the persistent issue faced by regulators in incentivizing building owners to adopt these enhancements. To this matter, regional jurisdictions have implemented ordinances pertaining to energy benchmarking and disclosure. These regulations mandate that building owners furnish energy-related data that is generally concealed from the market. The primary objective of these policies is to enhance the accessibility of energy data for those who are considering becoming renters or buyers, with the ability to impact their decisions regarding lease or purchase agreements. In addition, they have the potential to assist building owners in enhancing the transparency of energy expenditures, so helping endeavors to mitigate operational expenses [4].

Materials and Methods

This dataset was taken from data.gov website which is an official US government website. The dataset contains 34 attributes such as Year Built, Benchmark Year, Energy Star Score, Site EUI and many more. This research utilizes a range of data analytic technologies, including R, Python, and SQL.

The first method is data cleaning this was performed by python. The dataset contains many null values in the columns like energy usage and the natural gas usage. So, the null values in those columns were removed. There were some insufficient data and misleading data in the benchmark status. This inappropriate data was removed. Moreover, the column names have many spaces in it, and they have inappropriate labels. This would be problem when performing visualization has there are blank spaces. So, assigned a proper label for all the columns.

The second method is statistical analysis this was performed by SQL. The statistical analysis for buildings with highest greenhouse emission with their postal codes and the average GHG emission based on the category. Performed SQL queries to identify the important statistics for the study.

The last method is the visualization. This research uses R programming for visualizations. Visualizations for the highest greenhouse gas emission and highest site energy usage among different buildings. The benchmark status based on their energy star scores was visualized.

Results

1. Green House Gas Emission

Building_Adress <chr>	Postal_Code <int>	Category <chr>
351 CALIFORNIA ST	94104	Office
2727 MARIPOSA ST.	94110	Office
351 CALIFORNIA ST	94104	Office
351 CALIFORNIA ST	94104	Office
200 PAUL AVE	94124	Data Center

5 rows

Figure 1: Highest Greenhouse Gas Emission in Existing Buildings

A SQL Query to represent the address and category for the top five buildings with highest greenhouse gas emission. 351 California 9401 which is an office has the highest greenhouse gas emission.

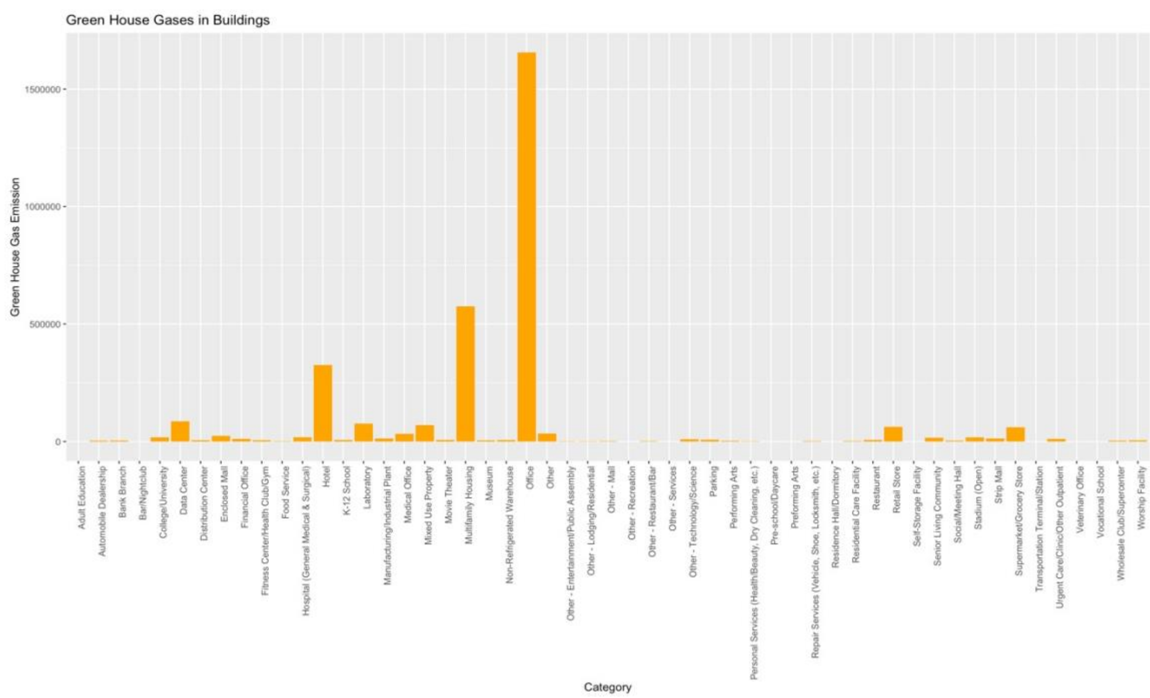

Figure 2: GHG Emission in Building Categories

The figure 2, help in comparing the levels of Greenhouse Gas Emission among various building classifications. The office category has the highest greenhouse gas emission among all the other categories. Most of the categories does not seem to have GHG emission which mean that there is very mild GHG emission. We can see that even multifamily housing has the high GHG emission when relate with other. After these two hotels have the highest GHG emission. By implementing strategies in those three areas may improve the environment and dappled the greenhouse gases. The excess use of natural resources in the offices is the main reason for the excess of these pollutants in the environment.

Category <chr>	Avg_GHG_Emission <dbl>
Data Center	21428.15000
Stadium (Open)	3425.50000
Hospital (General Medical & Surgical)	2491.10000
Laboratory	2319.09394
Financial Office	1489.30000
Other - Technology/Science	873.65000
Urgent Care/Clinic/Other Outpatient	838.88571
Enclosed Mall	816.73333
Office	691.62852
Parking	628.31818

Figure 3: Average GHG Emission In Buliding Categories.

The SQL query gives us an understanding of the average greenhouse gas emission based on their category. Here we can see that Data centers has the highest average emission even though office has highest emission according to the Figure 2.

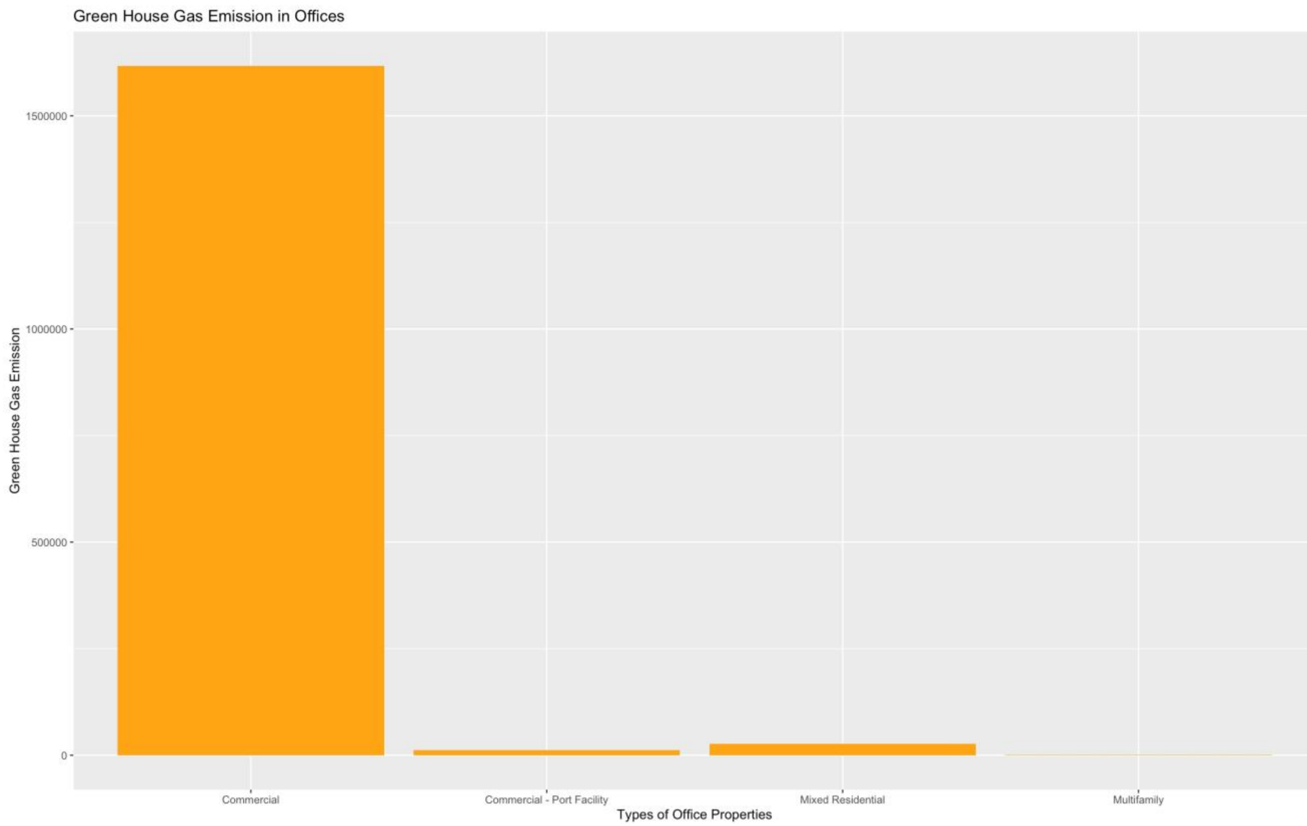

Figure 4: GHG Emission in Office ProperAes.

According to the Figure 2, the office category has the highest GHG emission . So the Figure 4,represnets the Greenhouse gas emission in the different proper=es of the Offices. The excess and almost total GHG emission is from commerical property of the office. The remaining proper=es are commerical-port facility, Mixed residen=al and Mul=family which have a mild GHG emission. By implemen=ng a necessary majors on commerical offices the pollutants can be reduced. As we can see that only office category has the highest emission and that to only in the commerical proper=es. Hence by, reducing these factors can lead to healty environment .

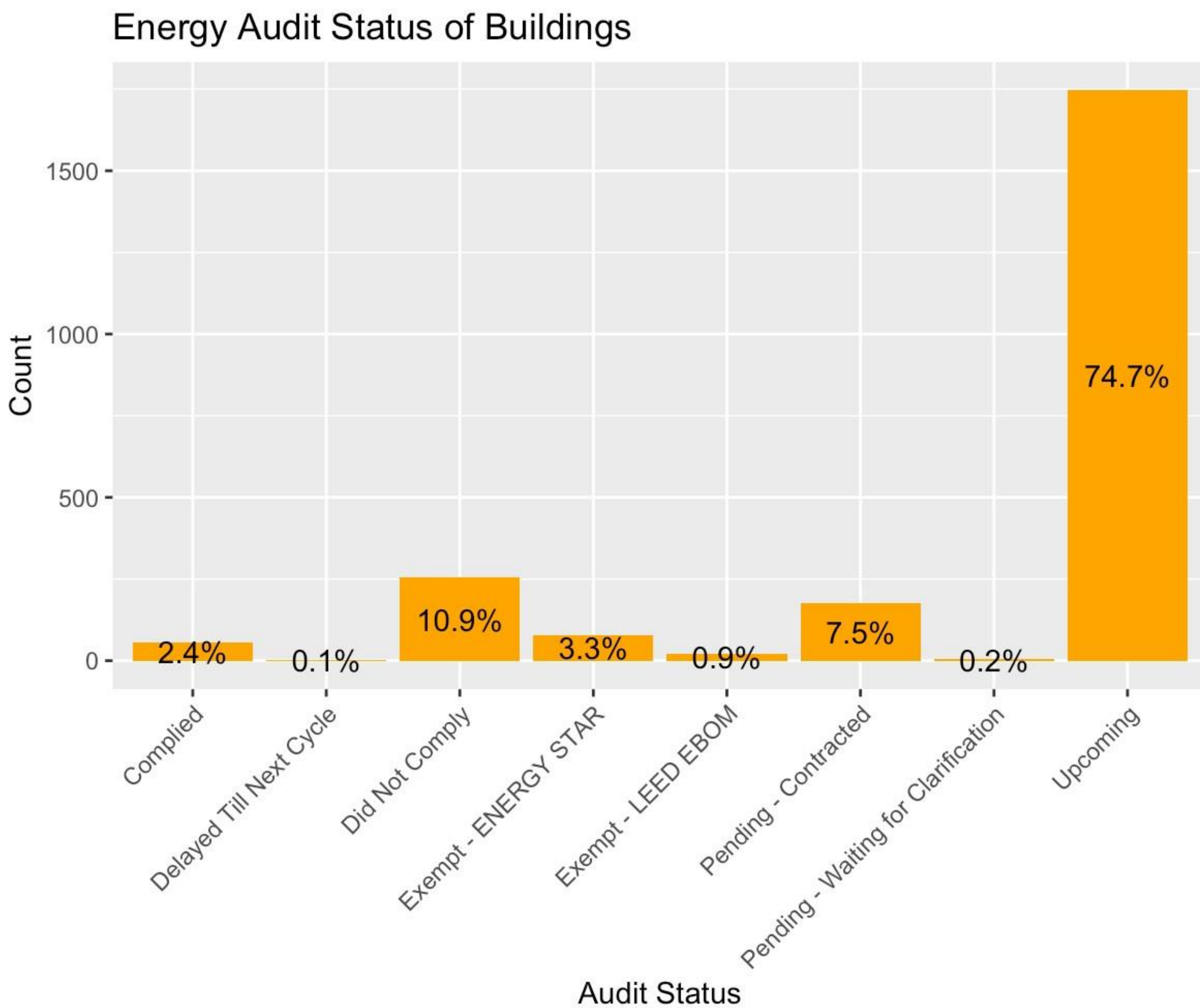

Figure 5: Audit Status of Offices.

The figure 5 tells us about the Energy audit status of the bulidings in the office category as office has the highest GHG emission. This would be helpful to understand their audit report and file them accordingly. Only 2.4% of the buliding in the office have complied their audit report and 74.7% of them are yet to be done. 0.1% of them have delayed their audit status to their next cycle. Moreover, 10.9% have not even comply their energy audit which is an important factor to be considered. Energy audit would be benefical to calculate their energy performace in the building but 10.9% have not complied so this would be hard to calculate the GHG emission.

2. Energy Efficiency

Property_Type <chr>	Avg_SiteEnergy <dbl>
Commercial	92.47274
Commercial - Port Facility	66.57660
Mixed Residential	44.24576
Multifamily	39.15944

4 rows

Figure 6: Average Site Energy .

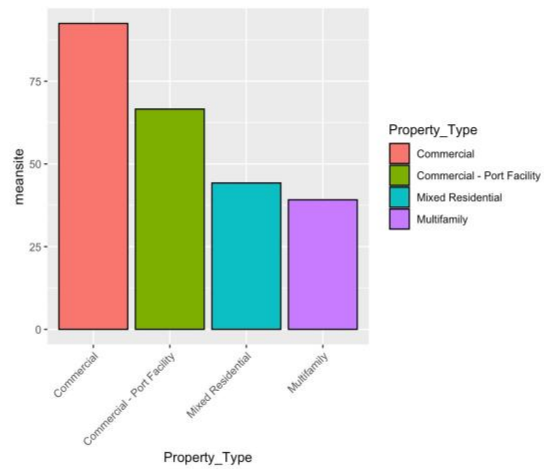

Figure 7: Average Site Energy in ProperAes

The figure 6 gives us an insights of the average site energy usage in the buildings. The commerical property have the highest energy usage in the buildings with the 92 average value. Moreover, the mixed residen=al and mul=family does not seem to have difference in their average. The Figure 7 gives us an graphical representa=on of the Figure 6 data. This gives us a easy understanding of energy usage of the buildings in the different proper=es. The site energy includes the electricty usage and the natural gas usage in the buildings. So, the commercial proper=es have the excess electrical and natural gas usage in the buildings.

If this is controlled excess usage of energy can be controlled and reduce the GHG emission.

Property_Type <chr>	Avg_SourceEnergy <dbl>
Commercial	156.40862
Commercial - Port Facility	141.23404
Mixed Residential	72.30367
Multifamily	70.55813

4 rows

Figure 8: Average Source Energy.

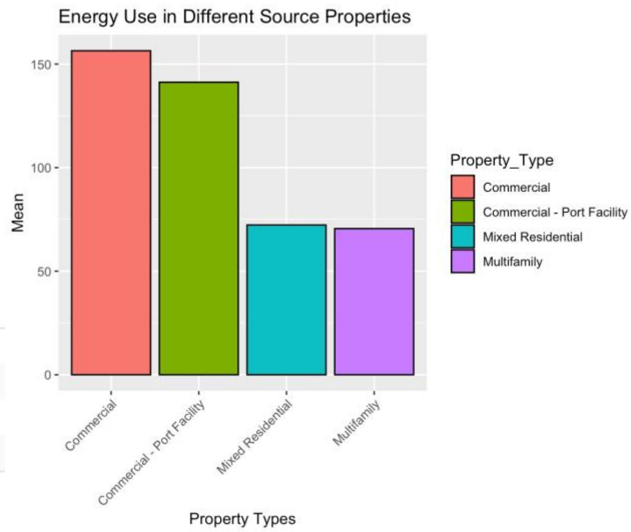

Figure 9: Average Source Energy in ProperAes.

The figure 8 provides us with a comprehensive understanding of the average energy use in buildings. Commercial proper=es exhibit the highest energy consump=on among buildings, with an average value of 156. Furthermore, there appears to be no discernible disparity in the average between mixed residen=al and mul=family proper=es. The Figure 9 provides a visual depic=on of the data presented in Figure 8. This provides us with a clear comprehension of the energy use of the buildings across various proper=es. The source energy encompasses the combined electricity and natural gas use within a collec=on of buildings. The business establishments exhibit excessive consump=on of electricity and natural gas within their buildings. If energy consump=on is regulated, it can effec=vely minimise greenhouse gas emissions.

Figure 10: Energy Star Scores in Buildings.

The graph serves as a valuable instrument for evalua=ng the compara=ve energy efficiency of various building styles. It can be u=lised to iden=fy property categories that are poten=ally suitable for energy-efficiency enhancements. This indicates a necessity to enhance the energy efficiency of mul=family buildings. This can be achieved through a range of strategies, including enhancing building systems, offering financial incen=ves to building owners, and teaching tenants on energy conserva=on. It is common for mul=family buildings to have a higher age compared to other types of structures, and older buildings oVen have worse energy efficiency. The average star score for commercial buildings is 76, which is the highest among all types of buildings. These findings indicate that, on average, commercial buildings exhibit the highest level of energy efficiency. Port Facility buildings are second highest in terms of average star score, with a score of 69. Although slightly below the commercial buildings, these buildings nonetheless demonstrate a notable level of energy efficiency.

3. Energy Star Score

Category <chr>	BuildingsCount <int>	AvgEnergyScore <dbl>
Other – Services	2	98.50000
Financial Office	5	87.20000
Museum	2	85.50000
Senior Living Community	22	80.22727
Other	9	78.88889
Office	1275	77.38431
Bank Branch	29	76.10345
Multifamily Housing	916	76.00655
Hotel	343	74.72886
College/University	1	73.00000

Figure 11: Average Energy Star Scores in Categories of Buildings.

The number of office buildings is 1275, which surpasses any other group. Subsequently, there are 916 buildings dedicated to Mul=family Housing and 343 buildings designated for Hotels. The following categories exhibit a lower number of buildings, with the category of "Other Services" having the most minimal count, consis=ng of only 2 buildings. Addi=onally, this data displays the mean energy score for each category. The average energy score quan=fies the level of energy efficiency exhibited by the buildings within that par=cular category. The Senior Living Communi=es exhibit the highest average energy score of 80.22727, followed by the "Other Services" sector with a score of 98.50000, and the "Museum" sector with a score of 85.50000. The average energy score of office buildings is 77.38431, which is the lowest among all types of structures. Bank Branches have a value of 76.10345, followed closely by Mul=family Housing with a value of 76.00655.

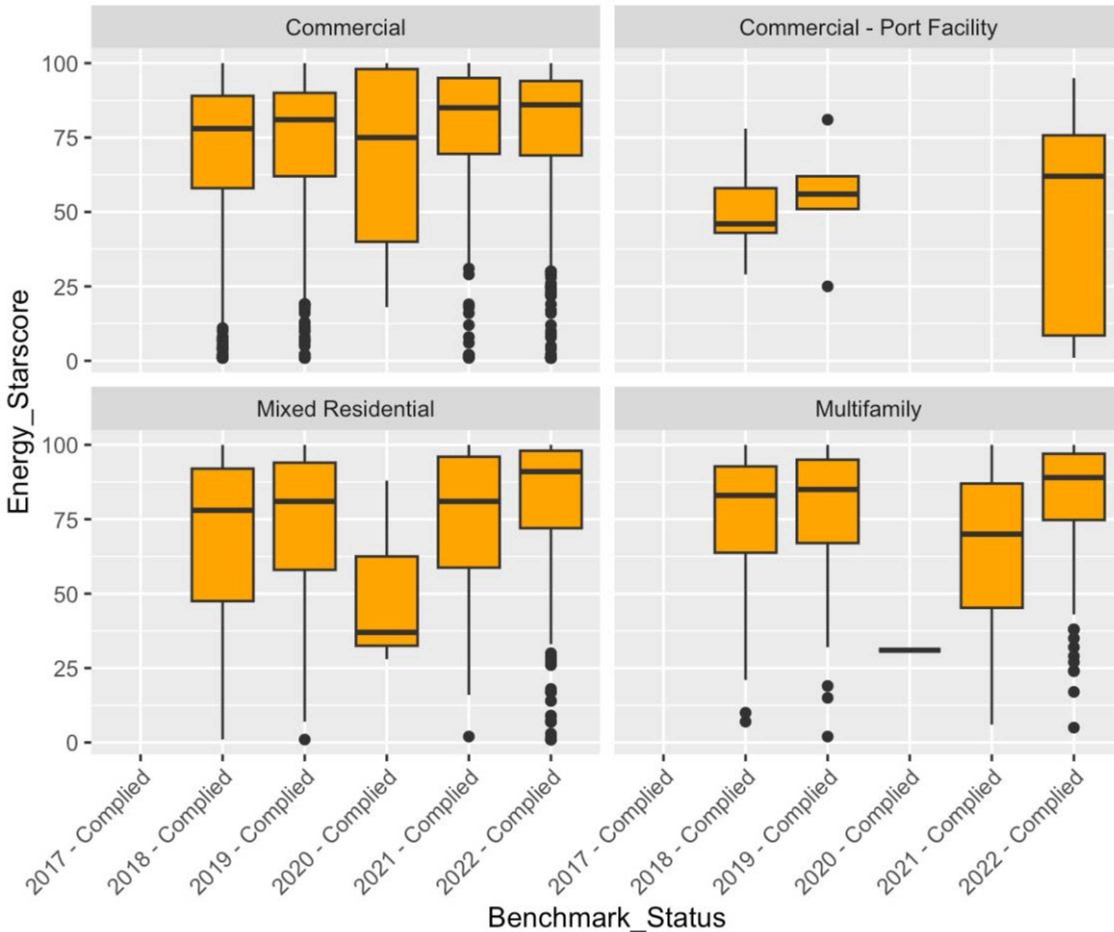

Figure 12:Energy Star Scores With their Bench Mark Status.

The boxplots indicate a notable difference in the energy efficiency ra=ngs between mixeduse residen=al and mul=family structures. Generally, mul=family structures have be^er ra=ngs and display less variability in their scores. The boxplot represent the energy star score for different proper=es and their benchmark status from the following years 2017 to 2022. We can see that in commercial property the energy star score is high in the 2020 complied . This implies that there are poten=al avenues for enhancing the energy efficiency of mixed-use residen=al buildings by adop=ng the strategies employed by mul=family structures.

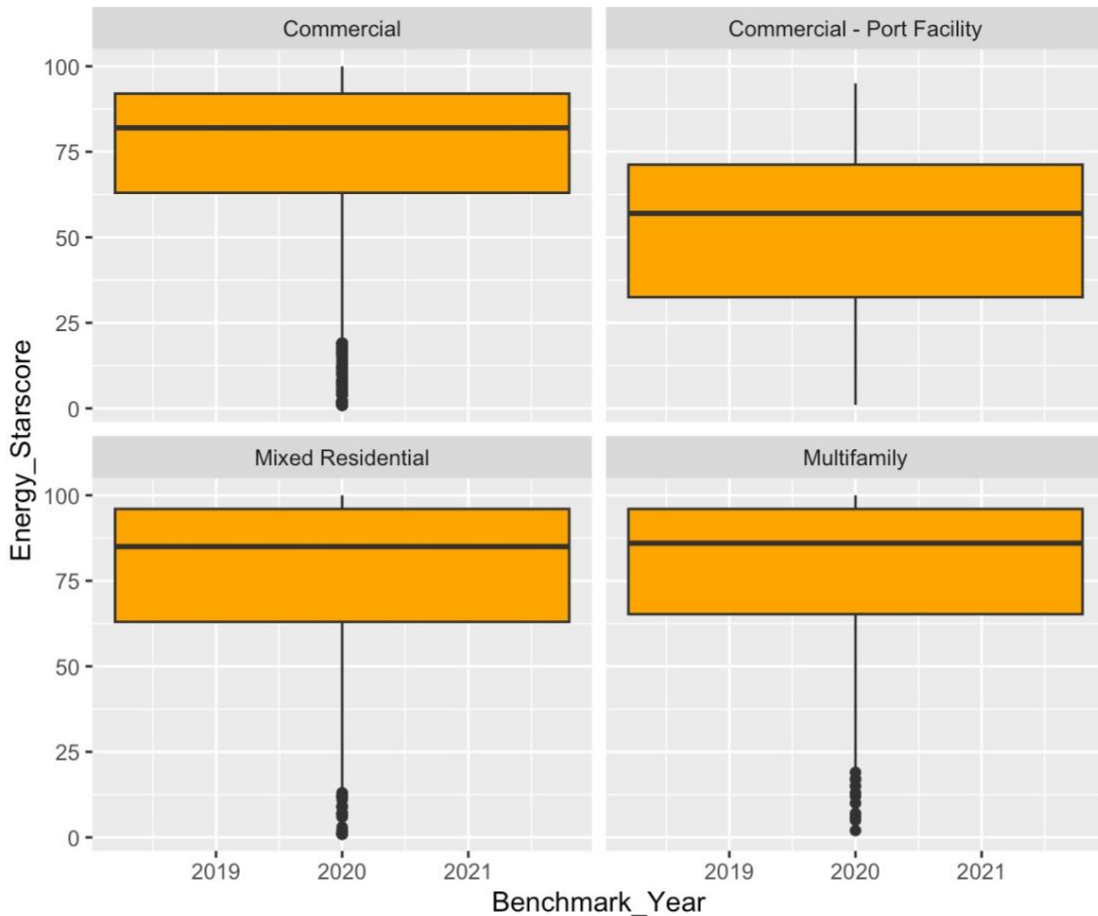

Figure 13: Energy Star Score With their Bench Mark Year.

The graph displays the energy efficiency as assessed by the Energy Star score. The graph illustrates that residen=al buildings exhibit greater energy efficiency compared to commercial ones.   The commercial port facility has the lowest star score compared to all other proper=es among the years.

Regression

```
Call:
lm(formula = analysis$GreenhouseGas_Emission ~ analysis$Site_EnergyUse)

Residuals:
    Min      1Q  Median      3Q     Max 
-818.92   -4.59   -1.17    3.95  124.78 

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)    
(Intercept)             1.627e+00  5.336e-01    3.05   0.0023 ** 
analysis$Site_EnergyUse 6.115e-05  1.194e-07  511.98   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 26.15 on 4215 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.9842,	Adjusted R-squared:  0.9842 
F-statistic: 2.621e+05 on 1 and 4215 DF,  p-value: < 2.2e-16
```

Figure 14: Summary Statistics.

The linear regression analysis demonstrates a strong and statistically significant positive correlation between Greenhouse Gas Emission and Site Energy Use. According to the model, the average increase in Greenhouse Gas Emission is 0.00006115 units for every additional unit of Site Energy Use. The model accounts for roughly 98.42% of the variation in Greenhouse Gas Emission, and both the intercept and the coefficient for Site Energy Use are statistically significant at a p-value of less than 0.05. Overall, the model is quite significant, as indicated by a significantly high F-statistic and a significantly low p-value.

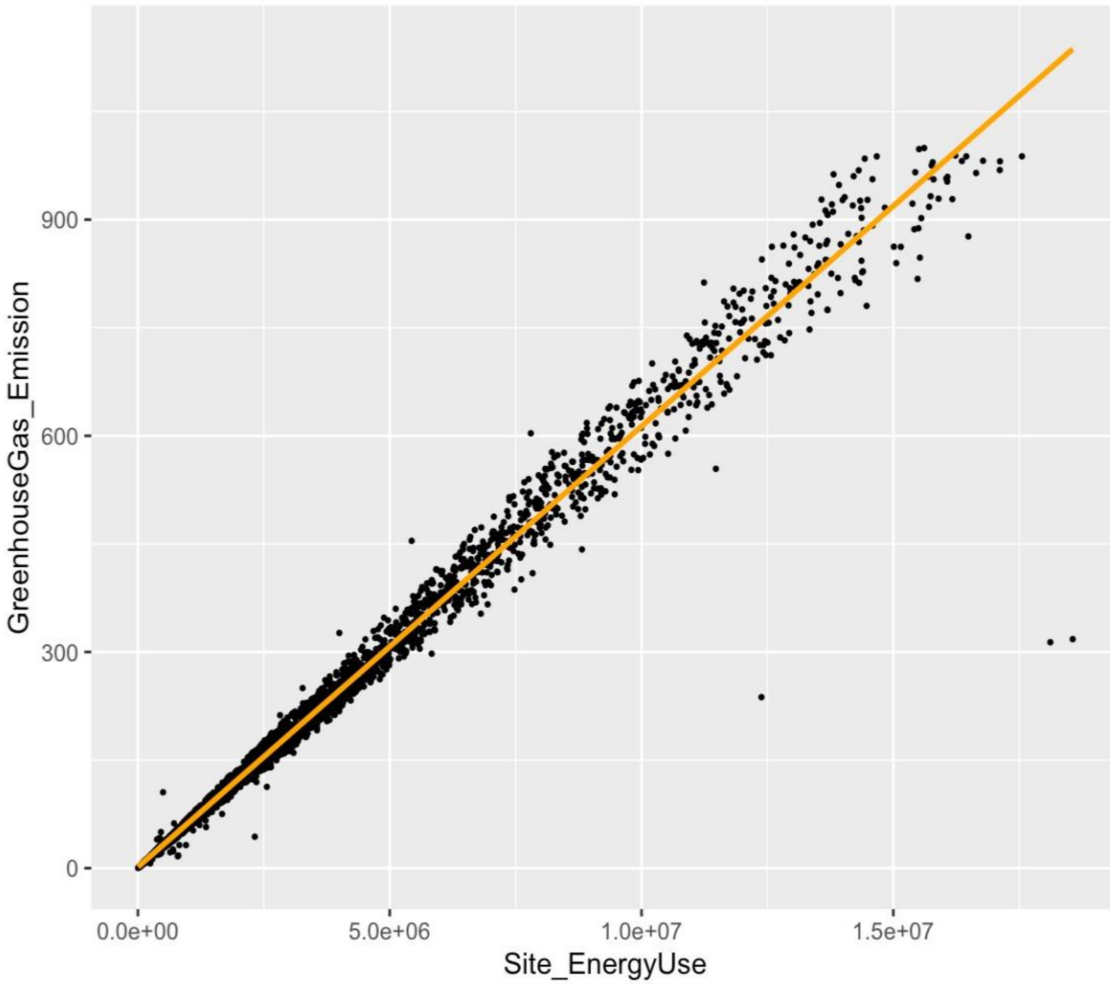

Figure 15: Regression Analysis.

The graph illustrates a direct rela=onship between greenhouse gas emissions and site energy use. Consequently, an increase in site energy consump=on directly corresponds to a rise in greenhouse gas emissions. Several poten=al reasons account for this associa=on. It is more probable for sites that consume higher amounts of energy to rely on fossil fuels, which release greenhouse gases upon combus=on.

Limitations And Future Scope

This dataset contains information on greenhouse gas emissions, but it does not include detailed details about the causes of these emissions. The dataset just encompasses the utilization of electricity and natural gas, although there could exist more possibilities for an increase of greenhouse gas emissions. Therefore, more data regarding the cause of the greenhouse gas is necessary. Furthermore, the dataset only included a selected group of buildings, while the remaining ones were disregarded. To determine the emission percentage, it is necessary to obtain data from each individual building. The data must be updated on an annual basis to do analysis.

Conclusion

This research aims to identify the primary cause of greenhouse gas emissions across different categories and characteristics. Commercial office buildings are responsible for the largest greenhouse gas (GHG) emissions among all types of office buildings. This could provide insight into the proportion of emissions that are emitted from buildings. It is evident that most office buildings do not release greenhouse gases (GHG). By regulating the utilization of natural resources in office business buildings, it is possible to reduce greenhouse gas emissions by fifty percent. Commercial buildings exhibit higher consumption of natural gas and electricity in comparison to other types of buildings. In summary, commercial offices should adopt ways to minimize their excessive consumption of energy and natural resources. Offices have consistently achieved the greatest energy star score, while colleges have consistently achieved the lowest. In addition, they are compiled there annually for comparison. A small percentage of the buildings have completed their audit status, while the majority have been deferred until the following cycle. By regression analysis we can identify that as the site overall energy increases the greenhouse gases increases over the years. The linear regression model indicates a strong and statistically significant correlation between Site Energy Use and Greenhouse Gas Emission. Overall, the commercial office should decrease the utilization of natural resources to mitigate the emission of greenhouse gases.

References

[1] "Existing Buildings Energy Performance Ordinance Report," Data.gov, Nov. 03, 2023. https://catalog.data.gov/dataset/existing-buildings-energy-performance-ordinance-report08392

[2] Kyung Hwa Cho and Sun Sook Kim, "Energy Performance Assessment According to Data Acquisition Levels of Existing Buildings," vol. 12, no. 6, pp. 1149–1149, Mar. 2019, doi: https://doi.org/10.3390/en12061149

[3] X. Zhong et al., "Global greenhouse gas emissions from residential and commercial building materials and mitigation strategies to 2060," Nature Communications, vol. 12, no. 1, Oct. 2021, doi: https://doi.org/10.1038/s41467-021-26212-z

[4] K. Palmer and M. Walls, "Using information to close the energy efficiency gap: a review of benchmarking and disclosure ordinances," Energy Efficiency, vol. 10, no. 3, pp. 673– 691, Sep. 2016, doi: https://doi.org/10.1007/s12053-016-9480-5