Benchmarking Buildings in New York City based on the Energy Usage

Assessing the relative Energy usage and Carbon Emissions of the buildings at New York City based on Block and Lot Level

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***Abstract* –As the City grows the demand for energy grows proportionally thereby increasing the Green House gas emissions. To Control the GHG emissions the government imposes regulations that restricts the energy usage and improves the sustainability and efficiency. In this paper, we shall try to perform an analysis on how the buildings perform based on the energy usage and try to create a benchmarking methodology to segregate the buildings based on the energy usage. We will try to derive a relationship between building energy use and public health, measured by the local asthma hospitalization rate and also find the correlation between neighborhood income and residential building energy use.**

Keywords—Green House Gases, Energy Use, Asthma Rate, Neighborhood Income

I. Introduction

It is the Skyscrapers that define the City of New York. With more number of people moving into the Big Apple, larger buildings are constructed to accommodate the growing population needs. It is expected that by 2040, NYC alone would accommodate 9 Million people. The population density of NYC stands at 27,000 people per square mile, which is the highest for any city in the United States [1]. Also, the other interesting fact is that more than 3 Million residents of NYC are foreign nationals who have moved into the city after 2000. Buildings being the building block of development of the NYC consumes the major proportion of energy consumed by the city. The Buildings in NYC consumes more than 79% of all the energy consumed in NYC and accounts for over 68 percent of citywide GHG emissions. The City's plan to reduce buildings-based emissions by 30 percent by 2025 from a 2005 baseline is a very welcoming move towards a sustainable and resilient NYC. This plan also called for a task force and technical study to identify the pathway New York City must take beyond 2025 to reduce further emissions toward the citywide goal of 80 percent reduction by 2050 from a 2005 baseline (80 x 50). This pathway will be aligned with efforts to reduce emissions from other sectors, including energy supply, transportation, and solid waste, as outlined in the City's comprehensive plan for 2050, One New York: The Plan for a Strong and Just City.

Most of the energy consumption in the buildings is being attributed to maintaining ambient temperature in the buildings. Hence it is necessary to find an alternative way to restrict the energy usage for the heating systems.

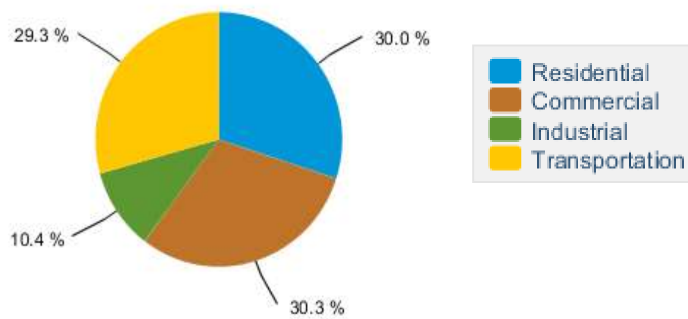


Figure 1: New York Energy Consumption by Sector [2]

Especially the refrigerants that are used in the Air Conditioning units are the most contributing factors for Global Warming.

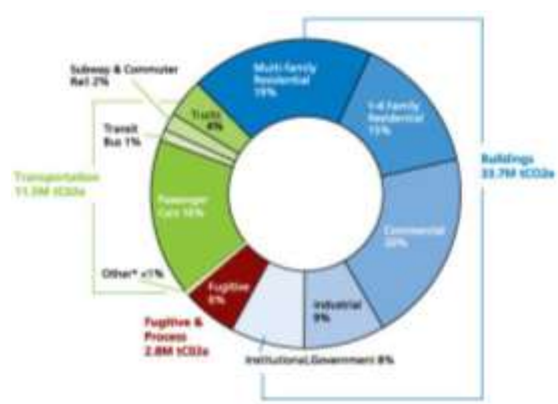


Figure 2: New York City CO_2 Emissions by Source [2]

II. Literature Review

Several Studies have been conducted globally to emphasize the need for benchmarking of buildings to grade them relatively in terms of the energy consumed by them. The LL-84 has been a very important source of information for performing this analysis for the city of New York. It has primarily been the effort of the Mayor's office under the leadership of the ex-Mayor Michael Bloomberg, that the city has focused on improving the sustainability and the resiliency of the city. This has been possible by collection of data from all the buildings in NYC having floor area over fifty thousand square feet as Local Law-84 data. This is the data that has been utilized to perform most of the studies in New York City.

The New York City's Energy and Water Use 2013 Report that was formulated by Urban Green Council and NYU's Center for Urban Science and Progress provides a comprehensive view of the energy and water usage across the buildings in NYC based on the LL-84 data. This report is a stepping stone towards the OneNYC commitment to achieve 80x50.This serves as an important report for cutting down the greenhouse gas emissions and encourage the expansion of detailed benchmarking to improve the energy efficiency of buildings across the five boroughs. [3]

The analysis in the report finds that between 2010 and 2013, greenhouse gas emissions from 3,000 consistently benchmarked properties with a 100 percent compliance rate which includes zero gaps between benchmarking periods dropped by eight percent, while energy use decreased six percent. [4]

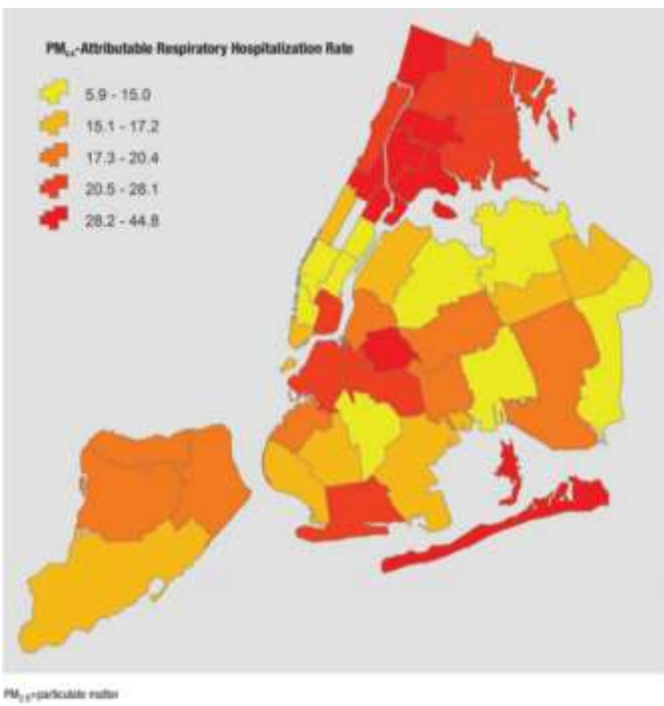


Figure 3 Asthma Hospitalization rate in NYC attributed towards PM2.5

The report on Air Pollution and the Health of New Yorkers: The Impact of Fine Particles and Ozone, drafted by New York City Department of Health and Mental Hygiene has presented air pollution as the leading environmental threat of Urban Population of NYC. Health Department estimates show that each year, PM2.5 pollution in New York City causes more than 3,000 deaths, 2,000 hospital admissions for lung and heart conditions, and approximately 6,000 emergency department visits for asthma in children and adults. A modest reduction of 10% in current PM2.5 levels could prevent more than 300 premature deaths, 200 hospital admissions and 600 emergency department visits annually. This study shows that despite improvements in air quality, air pollution is one of the most significant environmental threats to New Yorkers, contributing to approximately 6% of deaths annually.

Another Study conducted by Columbia University shows that Multifamily buildings comprise nearly half of the building sector's energy usage, and have tremendous potential for energy savings. Participation in multifamily programs is hampered by the complexity of the energy efficiency landscape and overlaps between programs. Current regulatory changes in New York's energy industry are causing uncertainty and disruption. Effective multifamily energy efficiency programs of other cities incorporate a single brand, one-stop shop, innovative financing options, and contractor incentives. Failure to understand building owners' priorities and decision-making processes inhibit effective outreach efforts. [6]

Figure 4 LL-84 Benchmarking data based on research carried out by Columbia University.

III. Data and Methods

The LL-84 (Local Law 84 of 2009) has been utilized in this analysis to obtain the energy consumption data of every BBL (Borough-block-lot) in New York City. We could obtain several information related to the building from the LL-84 such as the Building location, Year of Construction and the occupancy. LL84 has data of roughly 15,000 City-owned and privately-owned properties benchmark their energy and water use each year. While these properties account for fewer than two percent of properties citywide, they comprise 47 percent of New York City's total built square footage. Large, privately-owned buildings over 50,000 square feet in floor area make up 42 percent of the city's built floor area, or about 2.3 billion square feet, an expanse larger than the land area of Manhattan and Staten Island combined. In 2014, owners and managers of about 10,000 properties submitted enough detail about their 2013 energy and water use to be included in this report's analysis.

The information that has been utilized in this paper from the LL-84 file is related to the energy consumption of the building. We extract the data pertaining to the Energy Star Score of the building, Energy Use intensity normalized to the weather that is calculated by taking the energy consumption value per square feet for a given weather condition and also the consumption of energy based on a few primary individual fuel types. The LL-84 also has the data pertaining to the Green House gases where it has the overall, Direct and Indirect GHG Emission rates.

The Energy consumption would be different for the different category of buildings. For instance, the energy consumption of a Single-family home would not be the same as a Multi Storied office building or to that of a police station. To sort this issue out we try to benchmark the buildings based on the primary type of the property and see the variation in consumption of energy.

The PLUTO data and the US Census data were also used to perform the analysis. Using this data the geographic information and the income of each of the BBL were derived. The Asthma data from New York State Department of Health was utilized for this analysis. The data of no. of discharges (reporting Asthma) made in the 5 boroughs of NYC was taken into consideration for performing this analysis. The data of discharge from hospitals were taken for each of the Zip codes and the same was utilized for analyzing the effects of GHG emissions to asthma in the region.

Python was primarily used for this analysis and then Tableau was used to create regression models. The information of Block and Lot (BBL), Zip Code, Source EUI (kBtu/ft²), Weather Normalized Source EUI (kBtu/ft), Natural Gas Use (kBtu), Electricity Use - Grid Purchase (kBtu), Total GHG Emissions (Metric Tons CO2e), Energy Star Score & Largest Property Use Type was filtered out from the LL-84 data. Similarly the Land Area, BBL, Building Area, Census Tract 2010, Number of Buildings, Number of Floors, Year-Built and geometry dimensions data were utilized from the PLUTO data. Since the Pluto data is separate for all the individual Boroughs of NYC, they were all concatenated.

Then the data from the Pluto, LL84 and Asthma discharge records were merged. This data was combined with the income data obtained from the Census data set. Then we combine the Energy data with the Asthma data and Energy Use with the Median Income. A Dictionary is created keeping the Median Household income as a function of the Borough Block Level.

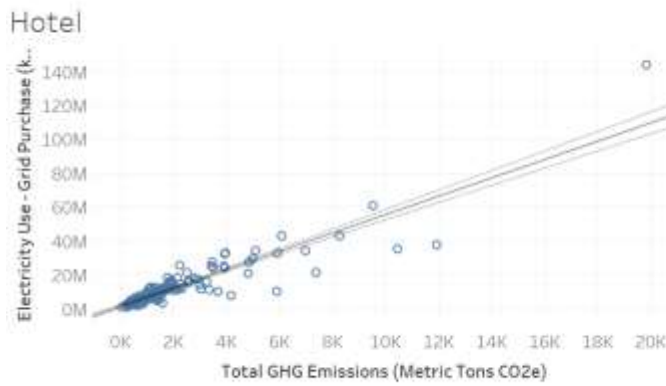
The data was cleaned by using the following attributes Electricity Use - Grid Purchase (kBtu) less than 4500000, Natural Gas Use (kBtu) use less than 10000000 and Total GHG Emissions (Metric Tons CO2e less than 1200.

IV. RESULTS

The analysis shows correlation between LL-84 energy data with the Total GHG Emissions. Let us consider four different building types:

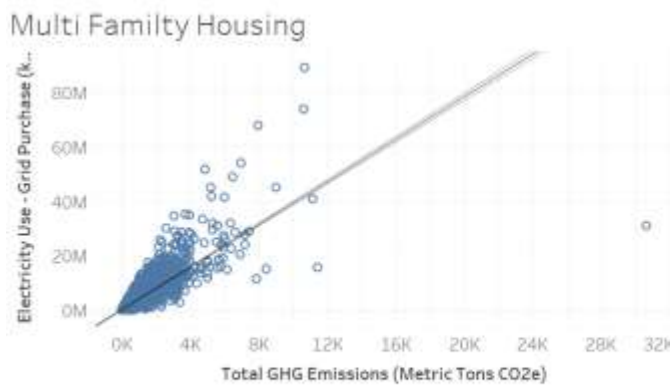
1. Hotels
2. Multi-Family Housing
3. Colleges & Schools
4. Offices

A. *A linear trend model is computed for **Electricity Use - Grid Purchase** (kBtu) given **Total GHG Emissions** (Metric Tons CO2e). The model may be significant at p <= 0.05.*



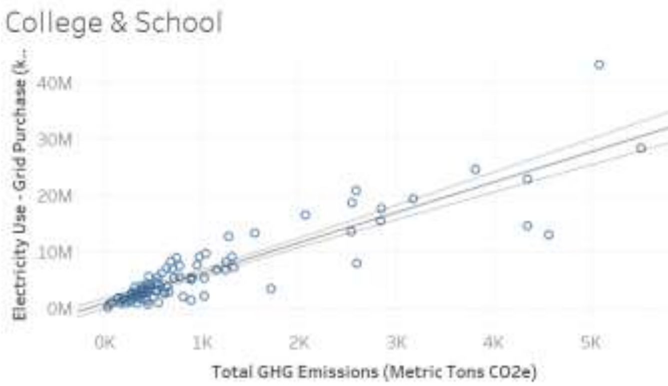
Total GHG Emissions (Metric Tons CO2e) vs. Electricity Use - Grid Purchase (kBtu). The data is filtered on Largest Property Use Type, which keeps Hotel.

Number of modeled observations:	180
R-Squared:	0.840591
p-value (significance):	< 0.0001



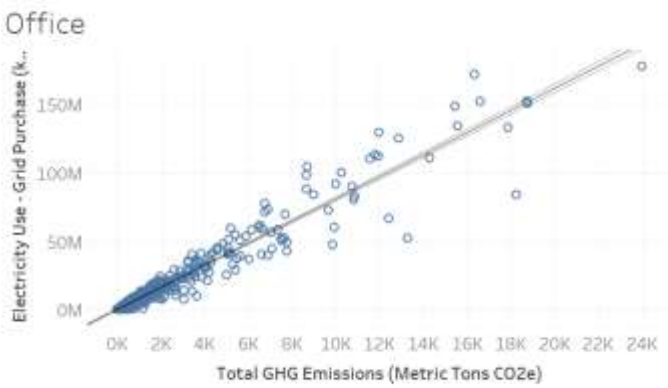
Total GHG Emissions (Metric Tons CO2e) vs. Electricity Use - Grid Purchase (kBtu). The data is filtered on Largest Property Use Type, which keeps Multifamily Housing.

Number of modeled observations:	**6052**
R-Squared:	**0.650431**
p-value (significance):	**< 0.0001**



Total GHG Emissions (Metric Tons CO2e) vs. Electricity Use - Grid Purchase (kBtu). The data is filtered on Largest Property Use Type, which keeps College/University, K-12 School and Social/Meeting Hall.

Number of modeled observations:	**92**
R-Squared:	**0.804716**
p-value (significance):	**< 0.0001**



Total GHG Emissions (Metric Tons CO2e) vs. Electricity Use - Grid Purchase (kBtu). The data is filtered on Largest Property Use Type, which keeps Office.

Number of modeled observations:	**670**
R-Squared:	**0.932645**
p-value (significance):	**< 0.0001**

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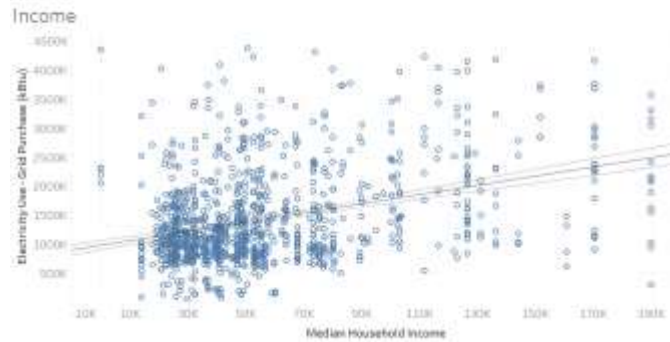
This model clearly stands by the factor that increase in the electricity usage is causing increase in the overall GHG emissions. This is observable in all the sub classes we have considered

Property Type	CO2 Emissions in Metric Tons		
	Low	Moderate	High
Hotels	< 2K	2K – 4K	> 4K
Multi-Family Housing	< 4K	4K – 6K	> 6K
Colleges & Schools	<1K	1K – 2K	> 2K
Offices	< 6K	6K – 10K	> 10K

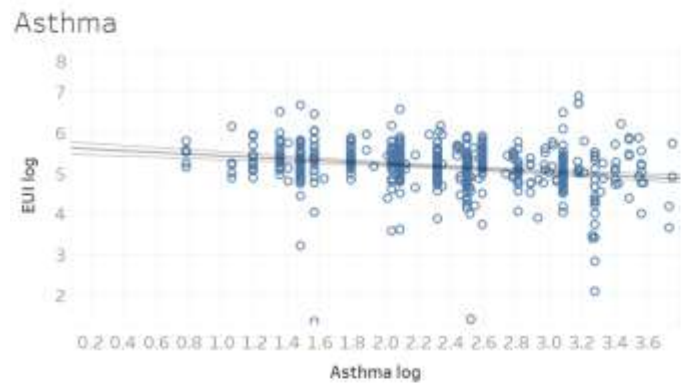
Table 1 Classification of Building Types based on CO2 Emissions



Median Household Income vs. Electricity Use - Grid Purchase (kBtu)

Number of modeled observations:	**1069**
R-Squared:	**0.134062**
p-value (significance):	**< 0.0001**

The above graph shows that the energy use increases as the household income increases. This is the data for Multi Family houses and the other residences. But the correlation is not strong enough to establish a steady relationship between the data.



Asthma log vs. EUI log. The data is filtered on Largest Property Use Type, which keeps Office.

Number of modeled observations:	**648**
R-Squared:	**0.0588246**
p-value (significance):	**< 0.0001**

This graph shows the plot between the logarithmic values of Energy Utilization index and the NYC Asthma Hospital Discharge data. There is no much correlation we can derive from this data.

V. Discussion and Conclusion

The performed analysis shows that the buildings in the NYC region can be benchmarked based on their primary occupancy type. We can classify buildings based on the CO2 emissions and this would be helpful in imposing regulations that would help in reduction of GHG. It is evident from the analysis that the offices are the buildings that consume the most amount of energy followed by Multi Family homes. It is very difficult to reduce the power consumption of buildings at one single shot. Hence a neatly planned strategy is needed in place for the changes to take place. The City's comprehensive plan for 2050, One New York: The Plan for a Strong and Just City is a very appreciated step put forward by the City of New York to reduce and control the GHG emission. It may seem like a very idealistic goal to reduce the emissions by 80% by 2050, but the regulations will guide way to achieve the same. To Achieve this target, we may have to focus more on renewable and non-polluting energy sources. The idea of having Building Management system installed across all the buildings in NYC and monitoring it through a central control center would be a welcoming approach in control of energy use in buildings. As a further step the next big rollout regulation shall be installation of BMS for all the buildings that are in the High range of CO2 Emissions. This would not only be useful give a comprehensive view of the energy consumption of buildings but could also be used to forecast energy usage and would be used to regulate building energy usage. A Sample of BMS utilized at University of IOWA that monitors the energy consumption in its buildings on a real-time basis. [7]

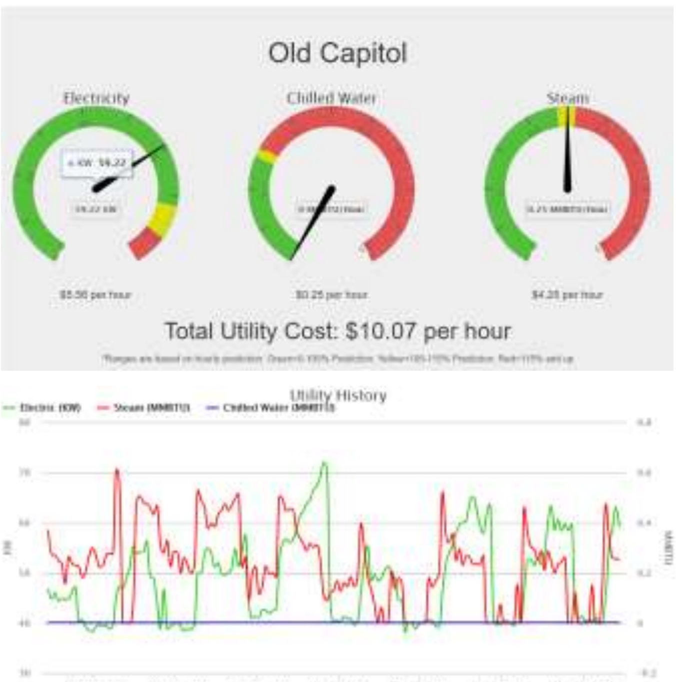


Figure 5 Building Energy Management System at University of IOWA

The not much high correlation value between the (i) Asthma rate and energy consumption and (ii) Income & Energy consumption shows that the Building Energy Consumption data may not be a very highly influential factor for causing Asthma. It may be more related to Air pollution caused due to PM2.5 Matter from Automobile Pollution. Similarly the Income may not force people to consume more energy, though rich neighborhood may have more energy consumption it does not affect much of an influence in our study. Hence the best benchmarking methodology would be to classify the building types based on the primary occupancy type and then regulate it based on the overall CO2 Emissions.

VI. References

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