Evaluating the effect of the age of a skyscraper has on annual energy consumption

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Abstract:

New York City is the birthplace of the skyscraper, home to some of the most iconic buildings in the world and has set an example for many cities around the world. Since the completion of NYC's first skyscraper, the Flat Iron Building, skyscrapers have changed entirely from their size to the materials they use, and other technologies found within. As the strength, height and overall capacity of these buildings increased, it raised the question of whether these advancements with change in building construction influenced how much power they use relative to a certain area. With the **question** of: Do older skyscrapers consume more energy than newer ones? Our team decided to test if the age of a building influences how much energy it uses relative to its floor area. The team began by choosing 6 buildings that are classified as skyscrapers and built-in different decades. For one year the team used the buildings built in electric and gas meters to calculate how much energy they were consuming annually, followed by calculating their floor areas to understand how much kWh the building requires per square meter. After finding no common trend between the age of a building and the power it consumes, we can conclude that there is not really a relation between the age of a building and how much energy is consumed for every square meter of floor area it is more dependent on the technology found within the building.

Introduction:

As NYC is filled with a variety of skyscrapers, the first question that comes to mind (other than the height of these buildings) is what ways newer buildings have improved, and if so, are they more effective at reducing energy consumption? This is especially important to take into consideration when understanding the fact that these buildings are used for commercial space and energy cost is a major bill, especially when being in such a high-cost area. This study was performed with the goal of strictly measuring how much energy the buildings consume regardless of how efficient developers claim these buildings to be. The team conducted this experiment with the intent of helping those in the market for commercial space understand whether moving into a newer building vs an older one will help them save on their energy expenses and make a better environmentally conscious decision. While doing our study we focused strictly on the numbers that we measured and calculated accordingly, with the understanding that our findings may conflict with efficiency claims made by the developers/owners of newer buildings that were built in a more environmentally conscious era. It was originally hypothesized that newer buildings would consume more power since they are insulated far less than buildings that have a Limestone exterior like that of the first three buildings we looked at (all constructed prior to 1940).

Materials and Miscellaneous

- Electricity meter (buildings already have these installed)
- Gas meter (installed in the building)
- Building plans/blueprints
- Notepad and camera to record findings
- Flashlight
- Hard Hat/Safety glasses
- High Vis vest
- Proper identification
- Proper permits to enter buildings

Method:

1. A list of skyscrapers built within different decades was made. It was important to have several buildings within each decade since it was unclear whether the team would be allowed to conduct these studies since after all the owners of these buildings were doing us a favor by letting us access their meters to have accurate numbers.

2. Going down the list, every building was contacted; requesting permission to conduct the study and information on the permits required to enter the buildings. As expected, many buildings were unable to give the team permission to enter for several reasons. Unfortunately, the MetLife building and 30 Hudson yards did not allow us to conduct these studies.

3. After all organizing was completed, permission to enter the Flat Iron Building, Woolworth Building, Empire State Building, United Nations Headquarters, 1221 Ave of the Americas, 4 Times Square and 7 World Trade Center was granted. (see images 1-6)

4. Upon receiving permission and the permits necessary to enter these buildings; appointments to conduct our study were made. The dates agreed on were the final day of each month. This was the same time the buildings had their meters reset.

5. On the last day of each month data was recorded both on paper and digitally. Upon returning from the buildings data was uploaded and backed up to avoid any loss or corruption. Each visit didn't take longer than 20 minutes. The buildings were visited between 9am and 5pm on the final day of each month. This process was repeated 12 times to get a full year worth of data.

6. During this time, building plans were analyzed for floor area, dates of completion, building materials and a basic lookover of each buildings heating and cooling systems. Calculating floor area correctly was a major part of ensuring that our calculations are accurate.

7. Once all the data was collected computations began. All the Gas consumed was converted from Terms to kWh. Once all the energy measurements were in kWh, the buildings total amount of energy consumed was divided by floor area. kWh/m^2 was the final unit being solved for. These computations were repeated for each building.

Results:

Table 1

Building	Year Completed	Floor Area (M^2)	Annual Electricity use (kwh)	Annual Gas Energy use (Therm.)	Annual Gas Energy use (kWh)	Energy use kWh per M^2
Flat Iron Building	1902	17,043	4637000	53772	1575519.6	365
Woolworth Building	1912	82,754	22816000	224021	6563815.3	355
Empire State Building	1931	261,310	70917000	846224	24794363.2	366
UN headquarters	1952	117,911	32509000	319191	9352296.3	355
1221 Ave of the Americas	1972	233,035	62116000	893226	26171521.8	379
4 Times Square	1999	152,608	41676000	462217	13542958.1	362
7 World Trade Center	2006	151,988	41905000	411441	12055221.3	355

Our team put all of the key information into the table shown above. The reason the team chose to do our calculations this way was to eliminate the error of building size affecting our results, by dividing energy consumption by square meter we were able to have a number that is specific to each building and easy for occupants of commercial space to compute how much energy each square meter consumes.

The reason there are two columns for energy consumption is due to the fact that in order to compute how much kWh a building uses of both electricity and gas the amount of gas used gets converted to the energy units used for gas (Therms) those are then converted into kWh. Upon finding that number we added it to the total number of kWh of electricity that were used in a year and divided it by the buildings floor area.

Discussion:

To the team's surprise, the trend we expected to see is not present, meaning our hypothesis was incorrect. It turns out that there really is not an outlier as high as we expected. Additionally, there really isn't a pattern between the age of a building and how much power they consume per area. The reason we expected this data was primarily because older buildings are better insulated due to them having a limestone exterior. The same goes for new buildings; we expected them to have higher energy consumption since due to their glass exteriors they are more easily affected by exterior temperatures. However, we failed to take into consideration that many of these buildings (except for 7 WTC [6] and 4 Times Square [5]) have undergone modernization renovations. As a result, more technology packed into a building result in increased power consumption. Therefore, our team drew the conclusion that the age of a building does not really affect power consumption other than buildings built in the 1970s consume the most energy per square meter (see row for 1221 Ave of the Americas on table 1). Upon completing our study, we can say confidently that from the eyes of an occupant of commercial space, the age of a building will not affect energy use; it varies by building style and the specific technologies found within that building.

When analyzing this from a strictly mathematical view the buildings that consumed the least (see rows 2,4 and 6 on table 1) they tied for 355 kWh/m^2. These buildings were very different from each other especially when considering age, however they consumed the same amount of energy. The least efficient building (1221 Ave of The Americas) was completed in the 1970s and consumed 379 kWh. The difference between this building and those that consumed the least was 6.7%. Despite that there is no evidence of a buildings age affecting how much power it will consume.

Conclusion:

Our team began this study with a simple question of whether older commercial skyscrapers consume more energy than newer ones. After conducting simple research, we hypothesized that older buildings would consume less energy than buildings-built today. After conducting our study, we learned that our hypothesis was not correct. It turns out that the age of a building is not a determinant of how much energy it will consume. The technologies within that building that effect how much energy one consumes. Therefore, when renters of commercial space in a skyscraper are considering energy costs, they should focus on things like the buildings AC/Heating systems rather than strictly age despite newer buildings claiming greater efficiency.

Appendix:

1- **Flat Iron Building** Young, R.(2009)

2-**Woolworth Building** *Woolworth building* (2005)

3-**Empire State Building** Valadi, S. (2012)

4- **1221 Ave of the Americas** *1221 Avenue of the Americas (2016)*

5- **4 Times Square** Lindsey, N. (n.d.)

6-**7 WTC** *7 World Trade Center*. (2008).

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