A STUDY OF ENERGY USE IN NEW YORK CITY AND LEED-CERTIFIED BUILDINGS

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ABSTRACT
Since 2009, New York City’s Local Law 84 (LL84) has required both city-owned and private buildings of a certain size to report their actual (not calculated) annual energy and water use. This paper summarizes the LL84 data available at the time of this study, including the scope and quality of the reported data. We cross-reference the LL84 database with the database of known LEED-certified buildings in NYC to see how well LEED-certified buildings perform in comparison to non-LEED buildings. The validity of performing such a comparison based on the information currently available is discussed. We also provide a general review of how energy codes and standards have evolved over time, and how they may be affecting the trends in energy use data.

INTRODUCTION
In 2009, Local Law 84 (LL84) came into effect requiring annual benchmarking of energy and water use for buildings of a certain size in NYC. This is one of the four legislative pillars of PlaNYC’s “Greener, Greater Buildings” Plan, a plan instituted by the mayor’s office to force buildings to address energy and water consumption. NYC was the first municipality in the United States to require annual public disclosure of building energy and water use data. Since it was enacted, several other municipalities have followed NYC’s example, including Chicago, Boston, Philadelphia, Minneapolis, Austin, Washington DC, Seattle, and San Francisco. However, based on floor area, NYC’s data currently accounts for more than half of the data collected nationwide.

Prior to LL84, the 2003 Commercial Building Energy Consumption Survey (CBECS), funded by the U.S. Department of Energy, was the largest database of building energy use available. The 2003 CBECS database includes 5,215 buildings or 522 million square feet. By comparison, the 2013 NYC LL84 database includes 23,417 buildings or 2.5 billion square feet total. Besides the sample size, the primary difference between these data sets is that the 2003 CBECS is spread out around the United States, whereas the LL84 database is in a concentrated geographic region.

The aim of LL84 is to use measurable parameters to compare building performance amongst peer groups, and over time. For example, owners can compare their building performance to buildings of a similar size and occupancy type. More importantly, the data provides Owners and the city government with a direct means of measuring the impact of both individual building modifications/upgrades and the impact of citywide legislation/regulation (such as increasingly stringent energy codes). Owners can use the data to directly quantify the effectiveness of capital improvement projects and other upgrades aimed at improving energy efficiency – both in terms of BTUs and kWhs.

The authors recognized an opportunity to use the LL84 data to extract trends regarding energy use in LEED-certified buildings in NYC. LEED stands for Leadership in Energy and Environmental Design, and is a building performance rating program developed by the U.S. Green Building Council (USGBC). Since the USGBC publishes the addresses of all LEED-certified buildings, we compared these buildings to non-LEED buildings from the LL84 data set. A similar study was completed by Professor John H. Scofield of Oberlin College in 2013 (Scofield, 2013). In his study, Dr. Scofield compared non-residential buildings from the 2011 NYC LL84 database to the available list of known LEED-certified buildings in NYC. His prominent finding was that LEED-certified buildings showed no savings compared with non-LEED buildings. The authors aim was to replicate this study with the larger datasets available in 2015 to see if the trends have changed, or if they differ between non-residential and residential occupancies. This paper summarizes the data sets that we used to perform the comparison, the results of our study, the limitations of the study, and our interpretation of the results.

LOCAL LAW 84 (LL84) DATA
Buildings covered under LL84 include, with some exceptions, city (public) buildings greater than 10,000 sf and private buildings greater than 50,000 sf, or properties with multiple buildings on one lot that are greater than 100,000 sf in total. This accounts for over 23,000 buildings across NYC, or approximately half of NYC’s floor area.
The data is reported using the Environmental Protection Agency’s (EPA) “Portfolio Manager” online tool. Each year the NYC Department of Finance (DOF) publishes the benchmarking data online. The data includes but is not limited to the building address and square footage, its energy and water use normalized to the floor area, its Energy Star Score, and the reported facility type.

Since the city expected some “kinks” in the online reporting system initially, and to allow for time for outreach to the community, only city buildings were required to report their data in the first year. In the second year, city and non-residential properties were required to report, and in the third year all properties covered under LL84 were required to report. At the time of our study, four years of data were collected for all properties covered under LL84. See Table 1 below.

Table 1  
History of LL84 Data Published

<table>
<thead>
<tr>
<th>Buildings Required to Comply</th>
<th>Year Captured</th>
<th>Data Published</th>
</tr>
</thead>
<tbody>
<tr>
<td>City only</td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td>City and Non-Residential (NR)</td>
<td>2010</td>
<td>2011</td>
</tr>
<tr>
<td>City, NR, and Residential (Year 1)</td>
<td>2011</td>
<td>2012</td>
</tr>
<tr>
<td>City, NR, and Residential (Year 2)</td>
<td>2012</td>
<td>2013</td>
</tr>
<tr>
<td>City, NR, and Residential (Year 3)</td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td>City, NR, and Residential (Year 4)</td>
<td>2014</td>
<td>2015</td>
</tr>
</tbody>
</table>

We cross-referenced the LL84 list published in the fall of 2015 with the database of known LEED-certified buildings in New York City from the USGBC to see how well LEED buildings perform compared to buildings of similar occupancies.

According to the city’s Year 3 report, approximately 23,417 buildings are required to report under LL84 in May 2014. As of Year 3, compliance was about 84%, up from about 75% the year before. The data is divided into three major occupancy categories: 64% multifamily residential, 22% office, and 14% other. Since NYC is full of mixed-use occupancy buildings, to be considered multifamily residential, greater than 50% of the floor area must be residential space, and to be considered office, greater than 50% of the floor area must be offices.

Terminology

Before we introduce the data, some critical definitions that the reader should be familiar with are listed below.

Site Energy Use Intensity (EUI): Includes all annual energy (electricity, natural gas, etc. for all end uses) consumed at the building site in kBtus, normalized to building floor area. Units are kBtu / sf / year.

Source EUI: Total energy content of all raw fuel (e.g., natural gas, coal used to generate electricity, etc.) required to operate a property, including losses from generation, transmission, and distribution of the energy.

Weather normalized source EUI: The source EUI for a building, normalized for annual weather conditions. This metric corrects for year-to-year differences in weather by comparing the monthly average temperature to energy use. This is an important metric since energy use can vary greatly from year-to-year, and in the case of energy efficiency upgrades, comparing performance before and after the upgrade can produce misleading results if, for example, the winter before repairs was unusually warm and the winter following unusually cold. If the source EUI alone were used, the data may suggest that the building uses more energy after the upgrade than it did before – which may be true on a 2-year time frame but not on a longer time frame when weather conditions return to typical.

LL84 Data And Quality Control

The NYC Mayor’s Office partners with New York University Center for Urban Science and Progress (NYU CUSP) to “clean” the raw data received. Some of these steps include removing buildings that report zero square footage, missing data points, or have EUIs below 5 or above 1000 kBtu/sf. The NYC Mayor’s Office then publishes a report with trends observed based on the cleaned data (Lee et al., 2014).

LL84 Data Trends over Time

An interesting trend from the cleaned Year 3 NYC data is that older office buildings have a lower median source EUI compared to modern office buildings. For multifamily residential buildings, the median source EUI is approximately the same regardless of construction era. Figure 1 below shows these trends, which are counterintuitive to the general perception that newer buildings that comply with modern energy codes consume less energy.

Regarding compliance with LL84, Figure 2 shows that in Years 1, 2, and 3, the number of reporting properties has increased steadily, and the median
source EUI has decreased. This is likely because larger developers and signature properties that have higher EUIs tended to immediately comply with this local law. Whereas developers and managers of smaller, older buildings with lower EUIs may only comply after they receive a violation for not complying with the law.

### LL84 Data Used for Our Study

We then downloaded the 2014 (Year 4) unprocessed data set and completed similar cleaning steps as NYU CUSP to remove outliers from the data set before completing our study of the raw data. Note that NYC does not provide the cleaned data set for public use. Some shortcomings of the data set we used for our study include:

- **Multiple Service Addresses**: Buildings in NYC often have more than one service address, so energy data is divided among the addresses. We did not have access to the necessary information to be able to aggregate the data based on addresses.

- **Under-reporting of Gross Floor Area**: The city’s database used to determine which buildings are required to comply with LL84 does not include below-grade floor area as part of gross floor area. Therefore, property owners may report the database value for square footage instead of measuring or reporting the accurate value. We did not have the resources available to check which owners accounted for below-grade floor areas.

After cleaning the data, we found a total of 1,019 office and 7,395 multifamily buildings. Note that the LL84 dataset includes many other building types such as hospitals, supermarkets, churches, which were excluded from this study. The parameter that we focused our study on was the weather normalized...
source EUI. After cleaning the data, we calculated the average weather normalized source EUI.

**LEED-CERTIFIED BUILDINGS DATA**

At the time of our study, there were approximately 100,000 registered LEED projects worldwide (USGBC website), of which approximately 1,500 were in New York City. Note that many buildings were reported as confidential, so we could not determine the exact address for comparison with the LL84 database. We found approximately 91 LEED-certified office and multifamily buildings in New York City, of which, 66 are offices and 25 are multifamily. See Table 2 below.

<table>
<thead>
<tr>
<th></th>
<th>Office</th>
<th>Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYC LL84</td>
<td>1,019</td>
<td>7,395</td>
</tr>
<tr>
<td>Total LEED Certified (Includes Certified, Silver, Gold, and Platinum)</td>
<td>66</td>
<td>25</td>
</tr>
<tr>
<td>LEED Silver</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>LEED Gold</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>LEED Platinum</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

**COMPARISON LEED AND LL84 DATA**

We compared the weather normalized source energy use for these NYC-specific LEED buildings to the energy use for office buildings from the 2014 LL84 data. Figures 3 and 4 present these results.

We found that NYC LEED-certified office buildings appear to perform slightly worse than the wider office building stock, with average source EUIs approximately 7% higher. Similarly, LEED-certified multifamily buildings appear to perform worse than the wider multifamily building stock, with average source EUIs over 30% higher.

![Figure 3](image)

*Distribution of Weather Normalized Source EUI of NYC and LEED-certified NYC Office Buildings*
INTERPRETATION OF RESULTS

According to National Institute of Building Sciences, a high performance building is defined as a building with high performing attributes including energy efficiency, durability, life-cycle performance, and occupant productivity. LEED is a voluntary program that aims to produce high performing buildings, and does not focus solely on reducing energy consumption. According to LEED 2009, to be certified, a building must achieve a minimum 40 points out of a total possible 110 points. LEED has multiple categories with prerequisites and credits under which points can be earned, however not all points involve measurable metrics, nor do they have a direct impact on energy use. Most importantly, the energy points that a building earns are usually based on the results of a computer simulation of building energy use. There is a new prerequisite in LEED v4 for metering a building’s energy sources, which is then reported to the USGBC, but at this time there is no requirement to use the measured data to verify or validate the simulated performance.

The Energy and Atmosphere category in LEED 2009 has a total of 33 possible points. Points available in other LEED categories that would directly affect a building’s energy consumption include thermal comfort, lighting, daylighting, and water use. However, all combined it is likely cost prohibitive to achieve LEED-certification by focusing on the energy-related points alone. Therefore, project design teams focus on obtaining an optimal combination of points from various categories for certification. Because LEED’s other categories and points can be difficult measure and quantify, the general public often believes that a LEED-certified building is inherently an energy efficient building as well.

LEED and Energy Codes

LEED 2009’s Energy and Atmosphere prerequisite requires buildings to demonstrate that the proposed design uses less energy compared to a baseline standard building by using an energy model. The energy models are built based on ASHRAE’s Energy Standard 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings. This standard is continuously maintained and a new version is published approximately every three years.

Two early versions of LEED (v2.0 and v2.2) only required that a building meet the requirements of ASHRAE 90.1 (1999 and 2004, respectively), with optional points for exceeding that performance. It was not until the 2009 version that exceeding 90.1, in that case by 10%, was made a prerequisite rather than an option. This trend continued in the current version (LEED v4), and although only a 5% improvement is required, the reference energy standard is 90.1-2010.
which is itself more stringent than the 2007 version referenced by LEED 2009.

While ASHRAE 90.1 forms the basis for most current energy codes, individual states differ in the specific code that they require for new buildings, as well as the cycle on which they update. Many states have adopted the International Energy Conservation Code (IECC), which is very similar to ASHRAE but updates on a different 3-year cycle. The result is that the minimum standard for energy performance for a new building can vary greatly from state to state.

Figure 5 shows the relative stringency of ASHRAE 90.1, the IECC, and the baseline for a LEED building over time. The top of the scale, not shown on this graph, represents the first version of ASHRAE 90.1, published in 1975. This chart shows how the stringency of these various standards/codes follows a generally increasing trend over time, but is staggered depending on when each document is updated.

The result of these staggered code updates and LEED versions is that there are often times when the energy performance of a building built to the current code will exceed that of the same building built to meet the current edition of LEED. For example, the authors’ firm recently worked on a building in a jurisdiction that had adopted the 2012 IECC but was being certified under LEED 2009. In this case, the relative energy performance of the code-compliant building was actually better than that required to meet the LEED prerequisite. While this typically only occurs in a few short windows of time, based on the code and LEED update cycles, it furthers the point that a LEED building would not significantly outperform a similar non-LEED building that is constructed to meet prescriptive code requirements.

**Energy Models for LEED and Code Compliance**

Compliance with LEED prerequisites and statutory energy codes is often demonstrated using the results of a whole-building energy simulation. While simulation tools themselves are well-developed and provide accurate calculations if accurate inputs are known, procedures for estimating some of the factors that affect energy use are less firm. Occupant behavior plays a significant role in building energy use, and predicting the behavior of a large group of people can be difficult, if not impossible. A building that is modeled as being maintained at 68°F (20°C) in the winter and 76°F (24°C) in the summer will show a certain level of energy consumption. The actual performance of the building may be close to the simulation if those conditions are maintained exactly, but in practice, especially in the U.S., occupants likely maintain closer to 72°F (22°C) in the winter and 72-74°F (22°C-23°C) in the summer. Depending on the climate, those few degrees can make a significant difference in overall energy use. Other trends such as operating hours and lighting levels can make similar differences.

An additional factor, and in some cases a major one, in building energy use is the level of internal loading for a building, including lighting and “plug loads”. Although lighting is regulated by energy codes, there are no current regulations on plug load levels. This is primarily a practical limitation, since limiting plug loads would basically limit what an owner would be able to do with their building – raising a host of regulatory concerns. Although plug loads are not regulated, they are included in measured energy use, and therefore is a major reason why modelled and measured energy do not align. In looking at buildings that house office space and financial institutions, many of these buildings have a large internal load due to computers and related equipment, all of which adds to the plug loading for the building. In one example building in NYC, large areas of the building were dedicated “trading floors” for stock purchases/sales, with individual workstations having as many as 5 separate computer monitors active for 8-10 hours per day. In this case, even if the “paper” performance of the building exceeded 90.1 by 25%, that performance is independent of plug loads and will never be realized in practice given the use of the building. Note that this is true for all buildings, whether or not they are LEED-certified.

Due to these limitations, it is important to understand that energy models are often best suited for general comparison of building designs as opposed to prediction of absolute energy use. ASHRAE 90.1 recognizes this, and requires many inputs to be the same between models. For example, occupancy levels and operating hours/temperature set points must be the same between the “baseline” and “proposed” design models given the potential variation in those factors. This also prevents modelers from falsely achieving energy savings by modeling a more intensive (more occupants, longer hours) building as the baseline and reducing those levels in the proposed design. However, there are some cases where this limitation is detrimental and may tend to overestimate energy use. The primary example of this is building air leakage, which must be kept the same between two designs. On one hand, air leakage is very difficult to predict in the design of a building. On the other, a building that is significantly “tighter” than one built to the minimum code requirements may have greatly reduced energy use. This results in a potential energy savings being ignored in the analysis, albeit one that is difficult to calculate. Modelers need to recognize these limitations and work within the current guidelines as best as possible. At the same time the industry as a whole needs to continue researching these issues and developing a greater body of knowledge on the most
accurate way of quantifying the impacts of occupant behavior and other subjective factors.

Figure 5
Relative Stringency of Energy Codes and LEED Requirements over Time

General Trends in Energy Use
The data set for LL84 includes both new buildings and buildings constructed many decades ago. In reviewing the data by age of construction, we found that the trends in energy use between older and newer buildings are similar. This is contrary to the expectations of buildings becoming more efficient over time. One potential explanation for the apparent lack of improvement is a trend known as the “rebound effect”. In buildings, the rebound effect is a reduction in expected improvements in efficiency/reductions in energy use due to owner and occupant behaviors.

One classic example of this is the use of LCD monitors in modern offices. The Lawrence Berkeley National Laboratory (Roberson et al., 2002) performed a study of energy use between modern LCD monitors and older cathode ray tube (CRT) monitors. They found that for similarly sized monitors, LCD used 50 to 70% less energy than CRT. The reduction in savings diminished with increasing monitor size. In modern buildings, as noted above, it is common for occupants to have multiple monitors at their workstations, and the average size of each display is significantly higher than in the past. A single occupant with two, 24 in. LCD displays likely uses twice the energy of the same occupant a decade ago, with a single 14 in. CRT display. Other examples include the quickly-growing average size of single family residences (more efficient enclosure, but twice the area) and the increasing number of electronic devices found in homes and offices. A family of four in 1980 may have had a single computer, 1-2 telephones, and 1-2 televisions in their home. The same family today may have a computer, telephone, television, cell phone, tablet, etc. for each person. While the efficiency of each individual device has significantly improved in the last 30 years, new devices have been added and the sheer number of devices in use contributes to a net increase in per-person energy use.

Limitations
The primary limitation of this study is the relatively small available data set, not for the LL84 buildings but for LEED buildings within that set. A smaller data set will be more subject to skewing from outliers.

LEED is also a voluntary standard as opposed to an energy code, so the sample of LEED buildings may be biased as compared to the LL84 buildings – many of which were built under mandated energy codes requiring minimum performance levels. LEED has also only been around for about 15 years, while some buildings in the LL84 database are 100+ years old and predate modern energy codes by decades. Additional studies, once more localities are tracking energy use and a larger data set is available, should focus on both date-independent data as well as a comparison of LEED and non-LEED buildings built during the same 15-20 year timeframe (i.e., all new construction).

Conclusions
The primary conclusion that we draw from this study is that, based on the currently available data, LEED buildings are not necessarily more energy efficient than typical buildings in NYC. The data is limited due to the small sample size and the age range of
LEED-certified and NYC buildings. Future studies, when larger data sets are available, should specifically review buildings of the same vintage – built within the timeframe that LEED has been active.

Evaluating the data raises additional issues and difficulties with predicting energy use in buildings, including the unpredictability of occupants and the lack of established procedures for estimating/calculating the impacts of plug loads and air leakage on buildings. These factors are often responsible for the disparities between modeled and actual building performance.

Lastly, the trends toward flat or increasing energy use despite advancements in energy efficient technologies highlights the need for a fundamental shift in occupant behavior and values in order to effect real change. Improving the efficiency of lighting and mechanical systems is relatively simple when compared to convincing occupants to accept lower winter temperatures and higher summer temperatures, use smaller computer displays, and make other changes that while saving energy are perceived as uncomfortable/inconvenient.

It is important to remember that LEED is not solely focused on energy, but is a general guideline for sustainable buildings that includes a wide range of topics. While the authors believe that energy should be the primary focus of future versions of LEED, we do not discount the importance of the LEED program in bringing the concept of “green” or sustainable design and construction to wide audience in the industry and promoting innovation and experimentation with buildings.

REFERENCES