Title

2020 Baltimore City Building EUI Analysis with ST & LT ROI

Summary

Baltimore City is one of the more efficient cities in the nation, however the city bleeds money in inefficient energy use in many building spaces. Areas of focus are amongst the police department, warehouse and storage spaces as well as museums. Solutions with quick 2-3 yr ROI are to invest in high speed doors in warehouses and energy saving lighting controls and long term solutions are to retrofit Heat Mirror windows in high EUI spaces which are buildings 50+ years in age.

Problem Statement by Baltimore City DGS

How energy efficient are Baltimore city buildings split by size, sector, and age and of the buildings under Baltimore City control, what measures can be taken to create energy-efficient solutions?

Background

Baltimore City DGS is interested for three reasons. One, efficiency, fiscally, and sustainability. In FY19 Baltimore City spent 19M on utilities and found that buildings made up the largest amount of energy consumption. The goal is to reduce the spend on energy as well as decrease the carbon footprint.

Current Status of Baltimore vs Model City

Baltimore City

1. Installation of energy-efficient equipment (HVAC, replacement of doors/windows, etc.
2. Energy audits

Model City - Manhattan

1. Climate Mobilization Act - most aggressive climate bill in the nation
    a. The goal cut carbon emission by 80% by 2050
    b. Building owners will get fined if they do not cut 40% by 2030
2. They can contract ESCOs to perform reduction efforts
    a. Heating, cooling, hot water, and lighting are the primary loads in most buildings
    b. Incentivize buildings to try to produce more electricity than they consume
    c. Retrofit the buildings envelope (windows, roof, insulation, infiltration)
3. Empire State: 6k windows changed, insulated, and optimized for natural light within 3 years. Energy efficiency reached 40%, annual cash savings hit 4.4M[1], cost per window was $700[2]
4. Money to fund can come from organizations like NICE to bridge the gap

Why does this matter for Baltimore citizens?

- Much of the natural resources are being depleted.
- It is important to get the same amount of work done with less energy use
- Can save citizens lots of taxpayer dollars that would not have to be spent otherwise, or could be diverted to other programs

[1] https://www.cnn.com/videos/business/2020/01/10/new-york-city-buildings-energy-gec.cnn-business/video/playlists/business-global-energy-challenge/

[2] https://www.cnet.com/news/empire-state-building-refaced-for-savings/

- Lower taxes
- Can improve air and water quality
- Cost savings from maintenance

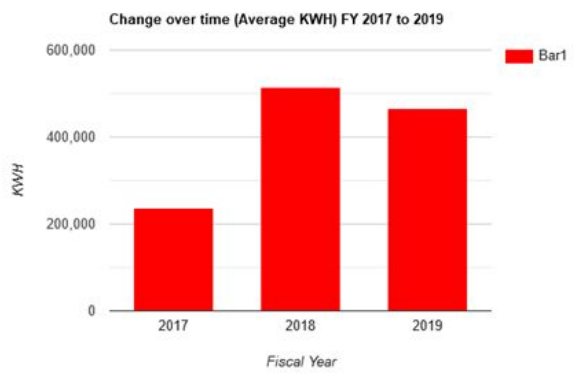
  But provide a warning--what happens if we do nothing about this problem? Why does the reader need to pay attention to what you're about to write?

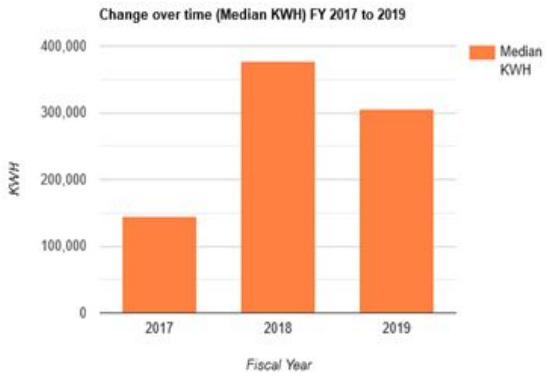
Data Findings and Interpretations

Our main goal is quite clear: How can Baltimore DGS improve energy efficiency across DGS-owned buildings? Before we delved into this question, however, we wanted to investigate a few key questions: How has energy efficiency varied over time across DGS-owned buildings, and how have these buildings fared in comparison to the national median EUI? Insights into these questions illustrate a clear picture of the current state of energy efficiency across Baltimore DGS buildings, which we can then utilize to make recommendations.

Our analysis begins with a mapping of total KWH, by fiscal year, across Baltimore DGS buildings, to gain a sense of electricity use over the 2017, 2018, and 2019 fiscal year, and to determine any potential outliers. Although certain building types are more energy draining, particularly large buildings like the First Mariner arena, the MECU building is a peculiar case, with the second highest total KWH over the three fiscal years[3], despite it's "smaller" footprint (square footage). From this point, we pivoted into an analysis of thermal data, culminating into a final analysis of site and source EUI. We kept the MECU building in mind as a potential candidate for energy efficiency improvements.

Additionally, it was in our analysis of total KWH that we concluded that the *average* and median KWH across DGS buildings have decreased, at least in the 2018 to 2019 fiscal year. Analyses into climate data our in-person visitation data to determine if the decrease in total KWH was a fluke would be helpful in further analyses of energy efficiency. If the data remains similar, then perhaps conscious efforts to decrease energy use in the Baltimore area is the greatest aid to achieving a more energy efficient Baltimore.





[3] See Appendix for github image link

In our analysis of thermal usage across Baltimore DGS buildings, our analysis proved to be quite different from our KWH analysis. Across the three fiscal years, we identified the "Fleet Central Main Garage" as a potential candidate for energy efficiency improvements (which fed into some of our recommendations regarding RiteHite and garage buildings). Our analysis here was hindered by missing data for certain buildings across all three fiscal years, so it was difficult to come to a conclusion for this step.

Once we totaled KWH and thermal data into total BTU and converted into site and source EUI, we were able to come to certain conclusions that aided us in our ability to make concrete recommendations for Baltimore DGS. We decided to map out source EUI by building type, and came across a few valuable insights[4]: In the 2018 and 2019 fiscal year, source EUI across various building types displayed a similar range of EUIs (is this perhaps an "acceptable range" of EUIs across Baltimore DGS buildings?), the Department of Transportation Main Impound Facility's source EUI is outrageously high, and that the median EUI across Baltimore DGS buildings was lower than the national median. Overall, Baltimore DGS and the city of Baltimore has done a promising job of attempting to tackle energy efficiency!

Two of the biggest caveats to our analyses include missing data (for certain buildings), missing data for the 2017 fiscal year, and lack of steam and chilled water data, both of which are included in source EUI calculations. Although source EUI is a great measure for comparing energy efficiency across different buildings, we believe that some of these DGS-owned buildings use more than just electricity and thermal energy to operate, making our source EUI calculations inaccurate (therefore, our median EUI calculations may be incorrect).

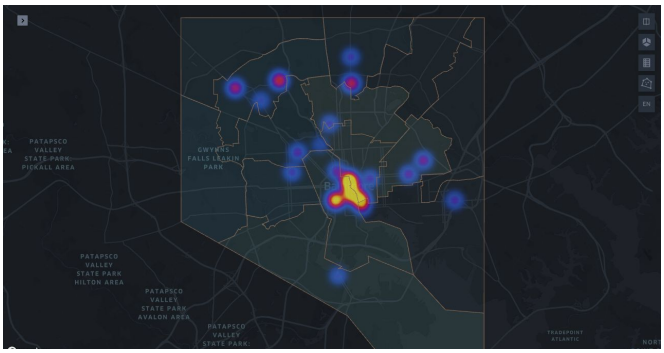
Making a concrete statement about Baltimore's energy efficiency plan over time is immensely difficult. With more data points and filled in data (for the missing points), we can provide a more accurate analysis of how energy efficiency has changed over time in Baltimore, and the current state of energy efficiency across Baltimore DGS buildings. The insights we can make from here, however, is that Baltimore DGS buildings follow a range of EUIs, at least over the past two years, which may or may not be coincidental. Moreover, it seems that Baltimore DGS is attempting to decrease energy use across its buildings (data sets on building use or how long these buildings were open for over each fiscal year in 2018 and 2019 would be helpful), which is a great mindset going forward.

Another aspect of our analysis and attempt to better understand energy trends in Baltimore buildings involved conducting a geospatial analysis of the dataset. Python was used here for data cleaning and data merging, along with a python library (Kepler GL). While doing this, we realized that an evolving dataset such as ours really requires a living and interactive user interface to be able to easily change the analysis given different points of interests. As such, we have also provided json and html files which will allow Baltimore DGS to continue playing with the dataset in a more organized manner. Before we begin, there is a caveat to note. The provided data contained missing information for the first half of the 2017 fiscal year. We first attempted to continue with fiscal year based calculations as instructed. However, it was

[4] See Appendix for github link

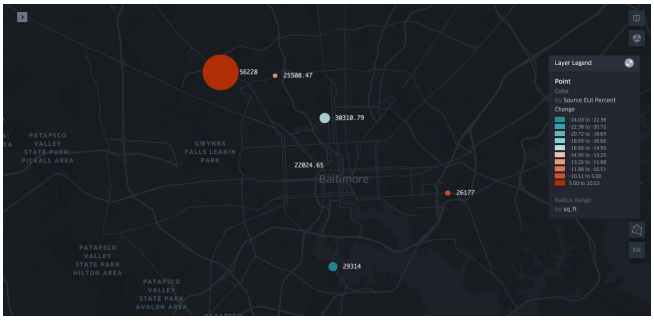
difficult to draw generalizations on this due to the gap in data. Since much of the analysis below is qualitative, we decided to obtain EUI data based on groupings of all 2017 year, 2018 year, and 2019 year. In the python scripts we have provided, this can easily be changed to line up with internal formatting.

The first analysis we conducted here was a simple heat map visualization of the 2019 Source EUI for Baltimore buildings, overlaid with council district boundaries. The resulting visualization is displayed below. The main takeaway here is that council districts 11 and 12 have the highest reported Source EUI in 2019. This is self-explanatory as the Downtown/Inner Harbor region contains the highest density of DGS owned and operated buildings as well as the greatest population density with regards to workforce. As such, this was a good logic check to better inform our analysis down the line.



Baltimore 2019 Source EUI Heat Map

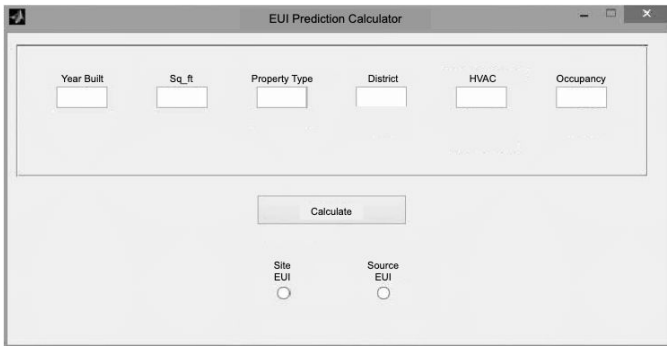
During the data cleaning and analysis process, one key metric we wanted to calculate was the percent change in source and site EUI from 2017 to 2019. One thing to note here is that only half of the fiscal year's data was available for the 2017 and 2019 fiscal years. As such, it is important to take these results with a grain of salt. Looking at all the buildings in Baltimore, only one building demonstrated a positive percent change in Source EUI, meaning that it was the only building whose source EUI increased over the three fiscal years. This was the Baltimore City Police Department in the Northwestern District. Amongst all the police departments in Baltimore City, this was the only one which shows an increase in Source EUI. Coincidentally, this is also the largest police department in Baltimore City by square footage. The interesting thing here was that in terms of raw Source EUI, this department showed among the lowest. However, it is still important to understand why the Source EUI has increased by almost 20%.



Police Departments with Source EUI Percent Change

At the same time, we also wanted to take a look at Site EUI percent change. Aside form the previously mentioned police department, only 2 other buildings demonstrate a positive change in Source EUI from 2017 to 2019. First is the Carroll Mansion Museum. This was built in 1812, so the increase in EUI could simply result from needing to update the HVAC unit on site. The other building is the Eastside Career Center. The percent change here is not large, but still it is something to consider as the building was only built in 1955. It is also important to note that almost all buildings built after 1970 have a negative change in Source and Site EUI, so they are definitely doing something right.

Lastly, we also wanted to explore the possibility of adding some degree of predictive capability for future fiscal year EUI estimates. The idea here is to use certain metrics such as building square footage, year built, property type, council district, HVAC model, and building occupancy to predict what a certain building's Site and Source EUI would be in a given calendar year. To do this, we trained several machine learning models on 2017 and 2018 data and attempted to predict the EUI for the 2019 data. We used only the first four mentioned metrics for this task. The results were not promising here. At best, we achieved an RMSE of 0.33 because of the limited quantity of data and also the small number of input variables. Adding more data and additional metrics can certainly improve this predictive capability. At the end, we can envision a calculator-type GUI such as the one displayed below which takes in values for certain key metrics and outputs estimated building Source and Site EUI. The python files for this will be included with the report.



Proposed EUI Prediction Calculator

Concrete Recommendations and Impact for Baltimore City/Department

Baltimore City needs to take steps to reduce energy efficiency and follow model cities which aim to have a goal of cutting carbon emissions by at least 40% by 2030 and 80% by 2020. To achieve these goals it is important to first target buildings/ sites that have a high EUI due to inefficient use. The following will lay the next steps both in the short and long term to cut unnecessary energy use and save money.

Short Term - doors on loading dock entrances

Option 1 - High speed doors at loading docks

Audit all garages, warehouses and self storage locations to identify if exterior envelope is leaking cooled interior air. Multiple locations have loading docks which are open to the elements and simply need a shutter/ door that can go up/ down when necessary. If this solution is implemented can see energy savings between $700-4k with an ROI in 2 years. The spaces will notice an energy use decrease between 20-30%.

Recommended company to seal areas: RiteHite - door called (FasTrax High Speed Door)[5]
Initial area to target based on analysis:

1. Northeast DGS Fleet Substation Garage
2. DGS Public Building Maintenance Garage

Option 2 - Wireless Lighting Control

With the lights on 24x7 and significant daylight available on the upper levels, a lighting control system can help cut energy use up to 40%. This can happen by controlling lights in the daylit perimeter areas of the upper levels in response to changing daylight levels. A simple device can be installed and Baltimore City can see an ROI within 2 years.

Contract Company: Audora Technologies[6]
Initial area to target based on analysis:

1. Parking Authority Offices

Long Term

The best way to reduce energy use in buildings is to seal the envelope of the building. Meaning that air from the outside should not enter the building, nor should the air from inside escape. This long term strategy will yeild major saving however has an ROI of 10 years on buildings aged 50+ years. The most cost effective solution is to retrofit all windows of these buildings with a new technology called *Heat Mirror®.* The initial building to target is the MECU building.

Conclusion

Overall, there are three strategies to reduce energy use amongst high EUI Baltimore city buildings. The first short term solutions are to seal loading dock entrances and have efficient lighting systems in garages. The long term solution is to retrofit all windows of 50+ year old buildings which may be leaking cooled air. Furthermore, it is important to identify which HVAC systems lead to highest ROI and understand why the DOT main building has the highest EUI with such a small sqft.

[5] https://www.ritehite.com/en/am/solutions/solutions-by-need/energy-savings

[6] https://cltc.ucdavis.edu/sites/default/files/files/publication/20110100-adura-wipam-parking-garage.pdf

Appendix

Figure 1 Github Image Link and File name:

https://github.com/bdmello1/BaltimoreCityDGS_EUI_efficiency/blob/master/KWH%20Visuals/KWH%202017.PNG under KWH Visuals

Figure 2 Github Image Link and File name:

https://github.com/bdmello1/BaltimoreCityDGS_EUI_efficiency/blob/master/KWH%20Visuals/KWH%202018.PNG under KWH Visuals

Figure 3 Github Image Link and File name:

https://github.com/bdmello1/BaltimoreCityDGS_EUI_efficiency/blob/master/KWH%20Visuals/KWH%202019.PNG under KWH Visuals

Figure 4 Github Link (Must view Dataset, image too large):

https://github.com/bdmello1/BaltimoreCityDGS_EUI_efficiency/tree/master/SourceEUIByBuildingTypeAndCouncilDistrict

Under “SourceEUIByBuildingTypeAndCouncilDistrict”

Step-By-Step Guide

Python Analysis: Please view the following link

https://github.com/bdmello1/BaltimoreCityDGS_EUI_efficiency/tree/master/Code

Excel Analysis:

1). From the original building data set given, address, lot, lat/lon, agency and neighborhood are deleted (used instead in python analysis).

2). Create a new spreadsheet for total KWH. Copy data over from Original Building Data excel file, no need to clean the data. Using all of the data, create a pivot chart and table, where you can filter the data into utility type (bge), consumption month, and consumption year, with building id in "rows" and bge_kWh_used in "columns.

3). Split data in bl_id, name, and a "Total KWH FY2017 column," then create a pivot table and pivot chart. Use buildings as row and Total kWh as column. Perform the same steps for fy 2017 to 2019.

4). Perform similar data manipulation for Total therms used.

5). For BTU calculations, create a new spreadsheet and split data into bl_id, name, Total KWH 2017, 2018, and 2019. For each FY calculation, multiply KWH by by 3.412 for 2017, 2018, and 2019.

6). Do the same for Therm data.

7). Add the newly calculated data into a "TOTAL BTU" column, preferably on a new spreadsheet, and do it for FY 2017 to 2019.

8). Use the newly calculated total BTU and divide by square footage by building to obtain Site EUI.

9). Multiply Site EUI by conversion factors (2.80 and 1.05 for Electricity and Natural Gas, respectively)

10). Map out Source EUI by building type by creating a pivot table and pivot chart.

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Thank you for the opportunity to work with Baltimore DGS!