Investigating Utility Cost Variation at 13 Brilliant Detroit Sites

Prepared in partial fulfillment of the requirements for
the Graham Sustainability Institute Scholars Program
at the University of Michigan

Mel Arreola, Tasneem Berki, Leah Kidder, Lute Smith
November 18, 2024

Executive Summary

Brilliant Detroit is a community organization in the City of Detroit dedicated to helping Detroit families with children <8 to be school-ready, healthy, and stable. They operate out of renovated homes that are located in the communities that they serve. These homes, designated “hubs” by community members, are used to provide programming and services. There are currently 18 of these hubs in Detroit. In 2023, Brilliant Detroit noticed that energy and water utility costs varied significantly across these 18 sites. They partnered with the Graham Sustainability Institute and created the project “Investigating Utility Cost Variation at 13 Brilliant Detroit Sites”. They requested a report detailing the causes of these cost variations, a list of recommendations to help reduce utility costs, and an educational guide for Brilliant Detroit staff and community members on energy and water efficiency.

The first phase of the project involved data collection and analysis. We collected grid-purchased electricity, natural gas, and water usage and cost data for 13 of the properties in Detroit. We then calculated energy and water usage and cost metrics, which allowed us to compare each property's energy and water efficiency. The second phase involved identifying the primary drivers of energy and water use at each property. This involved consulting with experts in the home energy field. Finally, we synthesized our methods and findings into a report. Based on our budget conversations with Brilliant Detroit, we used our results to create a list of energy and water “best practices” that addressed the usage drivers we identified. We will use these recommendations as the basis of the educational guide we plan to provide to Brilliant Detroit.

We identified several outlying properties with respect to energy and water efficiency. Our analysis revealed that heating was a primary driver of energy use at most properties. As a result, the majority of our recommendations for saving on energy costs revolve around efficient heating and cooling of the home. We also found that there was not a main driver of water usage. Instead, we found that water utility cost variance came largely from isolated events that did not follow an annual pattern. We postulated that investigating this issue further would involve collecting qualitative data at outlying low-efficiency sites to determine the specific causes of these fluctuations. Our recommendations took the form of energy and water “best practices”: inexpensive and relatively simple solutions that could be implemented without requiring external consulting e.g. an energy audit.

Introduction

We were tasked to investigate the factors causing energy and water utility cost variations across 13 Brilliant Detroit sites in Detroit, MI in the interest of operating more sustainably and efficiently. In our assessment, we provide the following:

- A report naming the causes of electricity, gas, and water usage and cost variations
- Recommendations for addressing cost variations and improving operations to be more sustainable
- Assistance in the implementation of some of the recommendations
- An educational guide on energy and water efficiency for staff and community members

The purpose of this document is to present our findings and recommendations.

Methods

The first stage consisted of benchmarking energy and water data for all 13 properties. We used Energy Star, a free home energy benchmarking service created by the EPA, to create a portfolio for Brilliant Detroit. First, we added all 13 properties to the portfolio. We then collected information for each property, including the year built, Gross Floor Area (GFA), renovation date, HVAC system, and the city of Detroit building ID. Table A-1 in Appendix A contains this information.

Once all of the properties were successfully added to the profile, we began to enter energy and water utility cost data. Hourly grid-purchased electricity data and daily natural gas data were available on the website of the service provider, DTE. Monthly indoor potable water data were found through Brilliant Detroit's Detroit Water and Sewage Department (DWSD) customer portal. In each property's portfolio, we added all of the energy and water meters present onsite. For each meter, we added a monthly entry for every billing period which included the beginning read date, the end read date, the total amount used, and the total cost.

The second stage involved the calculation of Energy, Water, and Cost Metrics for the year 2023. First, we used Energy Star to calculate the source energy use associated with each property in 2023. We then used the GFA to calculate the source energy use intensity (source EUI). Similarly, we used Energy Star to calculate the total water use in 2023 associated with each property. Again, we used the GFA to calculate the water use intensity. We then calculated the cost use intensity for energy and water using the total cost associated with each property's energy and water use in 2023 and the GFA of each property. We repeated these calculations for the current year, which is currently defined as the year ending on 6/30/2024. We also calculated the total cost of grid-purchased electricity, natural gas, and water for each property during this period.

We used Source EUI, electricity use intensity, and natural gas use intensity to compare the energy, water, and cost performance of all 13 properties in 2023. First, we used Excel to calculate the mean and standard deviation of the Source EUI for each property. We quantified the relationship between each property's Source EUI and the mean Source EUI using a Z-score. A Z-score is a statistical tool that measures the number of standard deviations a value is away from the mean. We identified each property with a Source EUI greater than one standard deviation from the mean, or a Z-score greater than 1, as exhibiting less efficiency. A Z-score of less than -1 indicated high efficiency. We then plotted each property's Source EUI Z-score in a histogram to visualize the distribution. Then, we repeated this process for each property's electricity and natural gas use intensity.

Next, we identified each property with a Source EUI greater than the national median Source EUI determined by the Commercial Buildings Energy Consumption Survey (CBECS). First, we used Energy Star to calculate the percent difference between each property's Source EUI and the national median Source EUI normalized to that property's specific fuel mix. We then identified all of the properties that had a positive percent difference and plotted our results.

For water, we compared each property's water usage in 2023 and 2024 to the average water use of a Detroit household with three people, estimated to be around 3,000 gallons per month. This allowed us to determine the difference in water usage between each Brilliant Detroit site and the average Detroit household. We also calculated the number of times a given property used over 3,000 gallons of water per month. Ultimately, we identified the properties that consistently used an above-average amount of water.

We examined the relationship between heating and cooling demand and energy use at all 13 properties in 2023. First, we converted all 13 properties' hourly electricity data from 2023 into daily data. We then plotted natural gas usage and heating demand at each property to determine if heating was a significant driver of energy consumption. We also did the same with electricity use and cooling demand to determine whether cooling was significant. Heating and cooling demand were estimated using the metrics heating degree days (HDD) and cooling degree days (CDD), respectively, which are discussed in Appendix C. We then recorded the slope and R^2 value of the resulting relationships as an indication of the strength of the correlation. This approach worked for 12 of the 13 properties, however since Hub #13 is heated using electricity, we plotted the electricity of this property with HDD instead of natural gas.

Results and Discussion

We identified that Chander Park, Hub #7, and Hub #9 had the highest source energy usage among all 13 properties. Predictably, Hub #13 used the most electricity per square foot by far as it is used to heat and cool the property. Hub #7 used the most natural gas per square foot. Hub #9 used an above-average amount of electricity and natural gas per square foot. Overall, nine properties used more source energy and had a higher annual total energy cost than the national median for properties with similar fuel compositions.

Hub #13, Hub #7, and Hub #9 had Source EUI Z-scores of 2.1, 1.0, and 0.89, respectively, which indicates that their Source EUI is significantly higher than average. The mean and standard deviation of all properties Source EUI were 125.5 and 60.8 kBtu/ft^2. Figure 1 shows the distribution of each property's Source EUI Z-score. All properties Source EUI and Z-score values can be found in Appendix B Table B-1.

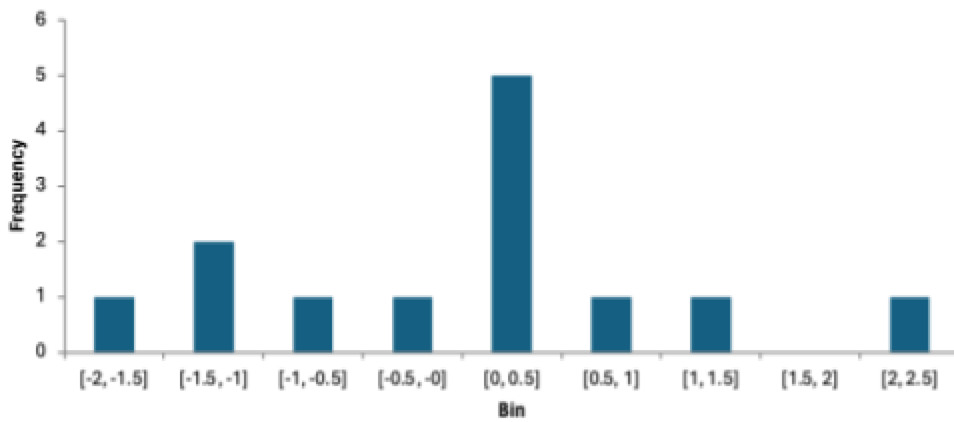

Figure 1: Property Source EUI (kBtu/ft^2) Z-score Distribution

Hub #2, Hub #9, and Hub #3 had electricity use intensity Z-scores of 1.8, 1.4, and 1.2, respectively, which indicates that their electricity use is significantly higher than average. The mean and standard deviation of all property's electricity use intensities were 11.4 and 5.4 kBtu/ft^2. Figure 2 shows the distribution of each property's electricity use intensity Z-score. All properties of electricity use intensity and Z-score values can be found in Appendix B Table B-2.

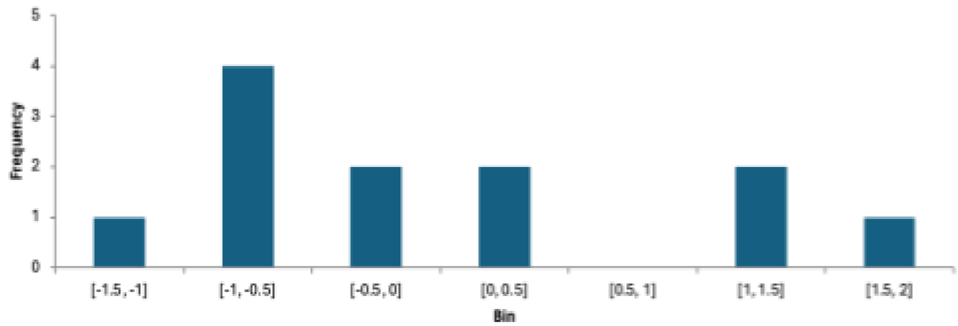

Figure 2: Property Electricity Use Intensity (kBtu/ft^2) Z-score Distribution

Hub #7 and Hub #9 had natural gas use intensity Z-scores of 2.1 and 1.0, respectively, which indicates that their natural gas use is significantly higher than average. The mean and standard deviation of all property's natural gas use intensities were 81.7 and 37.5 kBtu/ft^2. Figure 3 shows the distribution of each property's natural gas use intensity Z-score. All properties of natural gas use intensity and Z-score values can be found in Appendix B Table B-2.

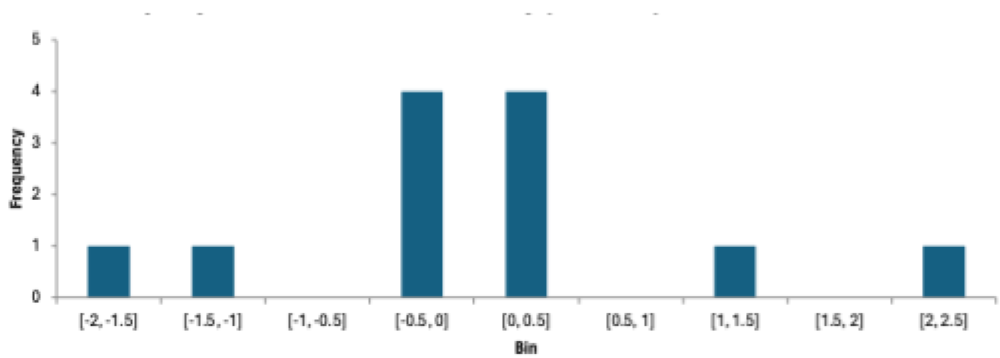

Figure 3: Property Natural Gas Use Intensity (kBtu/ft^2) Z-score Distribution

Hub #13, Hub #7, and Hub #9 had the highest percent differences from the national median energy cost for properties with a similar fuel mix. Figure 4 shows that nine properties in total had a positive percent difference, indicating that their annual energy cost was higher than the national median.

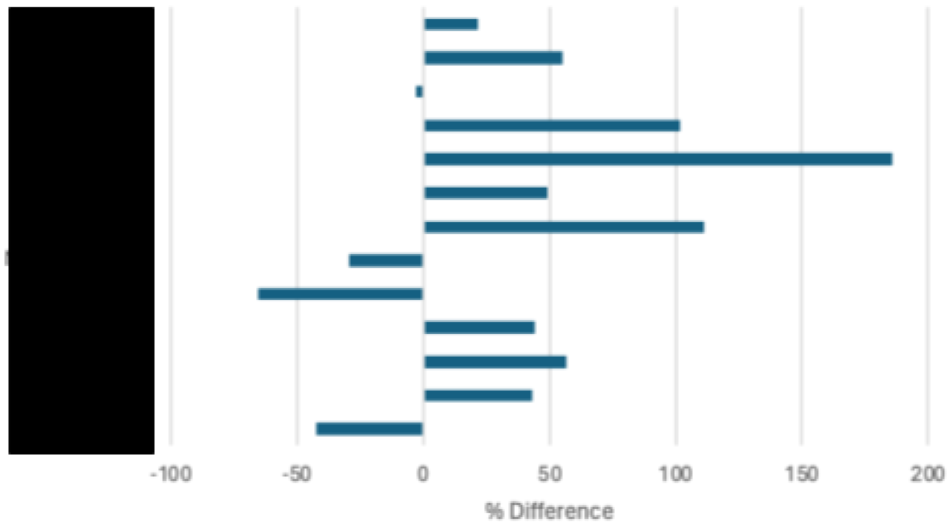

Figure 4: Percent Difference from National Median Energy Cost

Hub #12, Hub #9, and Hub #1 used the most water on average per month. Figure 5 shows the difference between the average monthly water use of each property and the average water usage of a Detroit household.

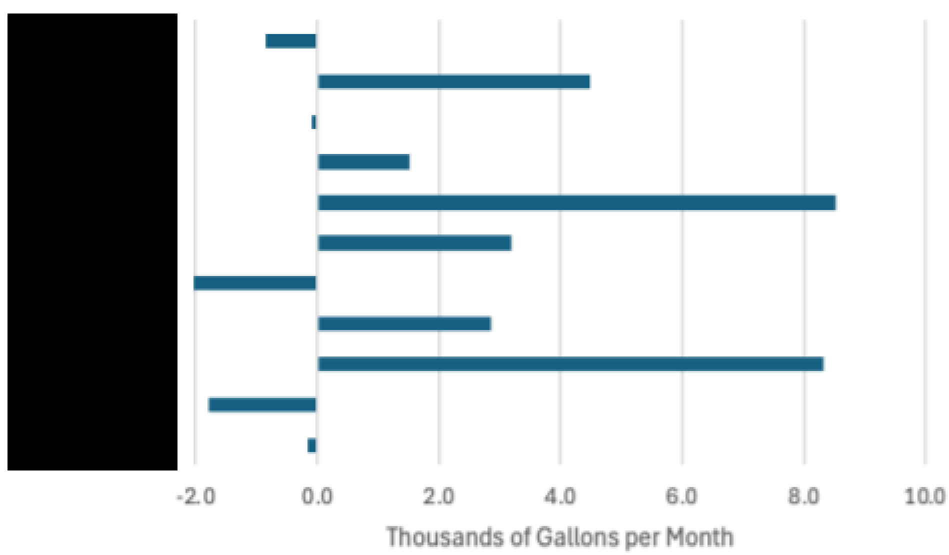

Figure 5: Difference from Monthly Water Use for Average Detroit Home

McDougal Hunt, Hub #9, and Hub #1 consistently exceeded 3,000 gallons of water per month. This suggests that these properties are experiencing significant water inefficiencies whose

cumulative effects have increased the property's baseline water usage. However, since the data do not show any discernable trends, it is difficult to identify the causes of these variations.
The demand for heating in the City of Detroit was much greater than that for cooling in 2023. For most properties, heating was a primary driver of energy use. However, cooling did not have nearly as significant an effect on energy use. In 2023, the demand for heating in the City of Detroit was at least five times greater than the demand for cooling. Table 1 shows the average heating demand and cooling demand for all 13 properties in 2023, expressed as HDD and CDD.

Table 1: Average Heating and Cooling Demand for all 13 Properties in 2023

Average Cooling Demand (CDD) (°F)	Average Heating Demand (CDD) (°F)
928	4925

Heating is a primary driver of energy use at most properties. Figure 6 shows the relationship between electricity use and heating demand at Hub #13. A high R^2 value like 0.908 indicates a strong correlation, suggesting that days with a significant heating demand correspond to increased energy use on that day.

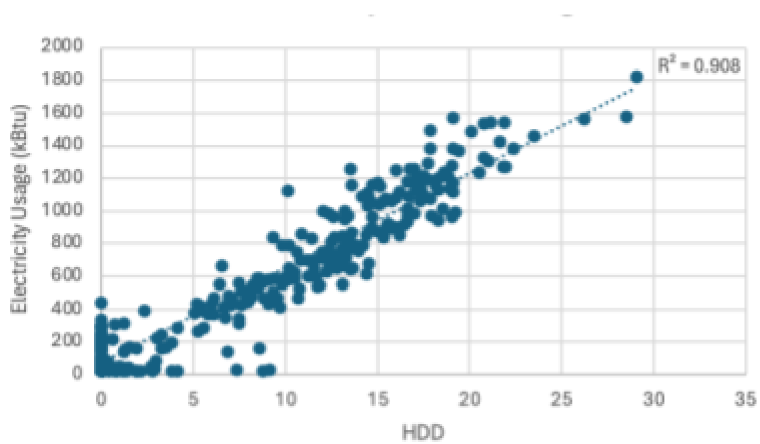

Figure 6: Hub #13 Daily Electricity Use vs Daily Heating Demand in 2023

Almost all properties experienced a similarly strong positive correlation between natural gas use and heating demand. However, most properties displayed weak or no correlation between electricity use and cooling demand. Table 2 shows the R^2 values for all 13 properties.

Table 2: Effect of Heating and Cooling Demand on Energy Use

Property	Natural Gas Use vs HDD	Electricity Use vs CDD
	R^2	
Hub #2	0.849	0.004
Hub #3	0.882	0.238
Hub #4	0.869	0.717
Hub #5	0.878	0.023
Hub #6	0.76	0.472
Hub #7	0.667	0.134
Hub #8	0.921	0.037
Hub #13	0.908	0.235
Hub #1	0.886	0.046
Hub #9	0.877	0.483
Hub #10	0.906	0.029
Hub #11	0.853	0.254
Hub #12	N/A	N/A

There is not a main driver of water usage among the Brilliant Detroit properties. Variations in individual properties are likely the result of isolated events. These events cannot be captured with quantitative data analysis, and must instead be identified using qualitative methods. Due to time constraints, we were unable to delve further into this issue. As a next step, we recommend interviewing staff and community members who were present during one or more of these isolated events to gain further insights.

Recommendations

Brilliant Detroit asked that the recommendations we provide should be inexpensive and relatively simple to implement. We created a list of energy and water efficiency “best practices” that we believe will help address the utility cost variances they are experiencing based on our findings. Our recommendations are provided in a separate supporting document linked below.

Supporting Document I. Energy and Water-Saving Recommendations

Worked Cited

Energy Star Portfolio Manager. U.S. Energy Use Intensity by Property Type. Technical Reference. https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf

"Mayor, DWSD Announce Detroit's First Income-Based Water Affordability Plan." City of Detroit, 28 June 2022, https://detroitmi.gov/news/mayor-dwsd-announce-detroits-first-income-based-water-affordability-plan

Appendix

Appendix A: Property Data

Table A-1: Property Details

Property Name	GFA (ft^2)	Year Built	Renovation Year	HVAC System
Hub #1	10000	1930	2016	Boiler
Hub #2	1242	1946	2018	Forced Air
Hub #3	1777	1928	2019	Forced Air
Hub #4	1935	1926	2019	Forced Air
Hub #5	3066	1930	2019	Forced Air
Hub #6	2100	1930	2022	Forced Air
Hub #7	1104	1930	2023	Forced Air
Hub #8	1698	1930	2021	Forced Air
Hub #13	2142	1930	2021	Electric
Hub #9	904	1948	2016	Forced Air
Hub #10	2640	1910	2016	Forced Air
Hub #11	1613	1921	2019	Forced Air
Hub #12	1405	1930	2021	Forced Air

Appendix B: Energy Data

Table B-1: Source EUI

Property Name	Source EUI (kBtu/ft²)	Z-score
Hub #5	30.90	-1.56
Hub #1	51.40	-1.22
Hub #6	63.00	-1.03
Hub #10	86.50	-0.64
Hub #12	108.50	-0.28
Hub #2	127.90	0.04
Hub #4	128.70	0.05
Hub #8	133.10	0.12
Hub #11	138.50	0.21
Hub #3	139.90	0.24
Hub #9	179.90	0.89
Hub #7	188.50	1.04
Hub #13	255.20	2.13

Table B-2: Electricity and Natural Gas Use Intensity

Property Name	Electricity Use Intensity (kBtu/ft²)	Z-score	Natural Gas Use Intensity (kBtu/ft²)	Z-score
Hub #1	6.16	-0.98	66.78	-0.40
Hub #2	21.17	1.80	65.39	-0.43
Hub #3	17.87	1.19	85.60	0.11
Hub #4	12.26	0.15	89.89	0.22
Hub #5	5.13	-1.16	15.78	-1.76
Hub #6	9.38	-0.38	34.98	-1.24
Hub #7	7.47	-0.73	159.56	2.08
Hub #8	9.96	-0.27	100.24	0.50
Hub #9	19.20	1.44	120.12	1.03
Hub #10	6.64	-0.89	64.72	-0.45
Hub #11	13.32	0.35	96.36	0.39
Hub #12	8.58	-0.53	80.45	-0.03

Appendix C: Degree Days

Degree Days (DD) is a metric to quantify heating and cooling demand. Heating Degree Days (HDD) quantify the demand for heating, while Cooling Degree Days (CDD) quantify the demand for air conditioning.

HDD and CDD are calculated using the temperature, t, as it relates to a "base temperature", t_b. The base temperature of a region is defined as the outside temperature above which a building needs no heating and below which a building requires no cooling. In the US, the base temperature is $t_b = 18$ °C. On a given day, if the average temperature, $\bar{t}$, is lower than the base temperature, t_b , a demand for heating exists, which is $HDD = t_b - \bar{t}$. Otherwise, if $\bar{t}$ is higher than t_b, a demand for cooling exists, which is $CDD = \bar{t} - t_b$.