# Developing a Rapid Assessment System for Evaluating the Energy Efficiency of University of Delaware Buildings

**Agatha Uchi[1], Michael J. Chajes[2], Christopher Williams[3], Jeffrey Summerhays[4]**

[1] *REU Student, Rowan University*
[2] *Dean of the Honors College*, University of Delaware
[3] *Associate Provost for Sustainability, University of Delaware*
[4] *Director of Sustainable Operations, University of Delaware*

## Abstract

Using the U.S. Department of Energy's (DOE's) Asset Score Scale (EERE, 2023), the energy efficiency of two buildings at the University of Delaware (UD) were analyzed and rated. In addition to a rating, the U.S. Department of Energy's Asset Score Scale provides insights into potential retrofit opportunities and improvements to enhance building energy efficiency. The research assessed the buildings' energy performance and identified potential upgrades for enhanced sustainability on campus. The research methodology involved on-site visits and data collection, including building characteristics, climate conditions, and construction details. The collected data was used as input for the DOE Asset Score Tool (www.energy.gov/eere/buildings/building-energy-asset-score) generating detailed reports for each building. The Honors College achieved a current score of 6.5 and a potential upgrade score of 9.5, with an estimated savings of 28%. The Visitors Center received a current score of 6.0, with a potential upgrade score of 9.5, with an estimated savings of 31%. The study proposed cost-effective upgrades, including LED lighting, occupancy sensors, insulation improvements, and low-flow faucets. This research lays the foundation for a future energy efficiency assessment system for the campus, contributing to more sustainable building practices and environmental responsibility. Addressing challenges related to HVAC data complexity and limited building footprints is crucial for accurate assessments in the future. The proposed system can be used to guide funding allocation, prioritize energy-saving initiatives, and promote a greener and more sustainable university campus.
**Keywords:** Energy efficiency, Building assessment, University campus, Sustainability, HVAC systems.

## Introduction

Energy efficiency in buildings is critical in addressing environmental sustainability and reducing energy consumption. The goal of this research is to analyze and rank the energy efficiency of buildings at UD using a tool provided by the U.S. Department of Energy (DOE). The pilot buildings for this project are the Honors College and the Visitors Center, located in Newark, Delaware. These two buildings were selected as representatives for the energy efficiency analysis to provide insights for future retrofits and investments to enhance sustainability on campus.

Over the past few years, there has been a rising focus on sustainable building practices and energy-efficient design. Green building practices at UD, along with public policy and building industry professionals, classify green buildings into five categories, one of which is energy efficiency. This category focuses on demarcating energy use patterns for new constructions, energy reforms, and improvements, intentions of use, energy operations, and occupation of the area. Moreover, initiatives such as the Asset Score Scale, developed by the U.S. Department of Energy, and the Leadership in Energy and Environmental Design (LEED) certification system have emerged as valuable tools for assessing and promoting building energy efficiency. The Asset Score Scale, a widely recognized tool for assessing energy efficiency at a national level, provides a scoring system to evaluate a building's energy performance (EERE, 2023), while LEED offers a comprehensive framework for sustainable building design and operation (USGBC, 2023). Moreover, New York City has also taken significant steps to improve energy efficiency and reduce building carbon emissions through the "Zone Green" initiative and the Greener, Greater Buildings Plan to enhance the construction sector's environmental performance and sustainability practices (DCP, 2023).

This research project aimed to enhance energy efficiency practices at the UD by analyzing and ranking the energy efficiency of the Honors College and Visitors Center buildings. The findings revealed substantial estimated savings potential in both buildings, underscoring the importance of this research in achieving the university's sustainability goals. Moreover, the proposed energy efficiency assessment system offers a strategic approach to guide funding allocation for retrofits and improvements campus-wide, prioritizing projects with significant energy savings and contributing to a greener and more energy-efficient campus. This proactive initiative reflects the institution's commitment to sustainability and responsible resource management.

During the research, a limitation was encountered as there was uncertainty about the HVAC systems in the buildings and plans for determining geometric footprints were not available. Addressing these challenges is crucial for more accurate and comprehensive energy efficiency assessments in the future.

In conclusion, this research project has laid the foundation for a future energy efficiency assessment system for the UD campus. This study contributes to sustainable building practices and environmental responsibility by analyzing the pilot buildings and proposing practical upgrades. The system's potential for guiding funding allocation holds significant promise in enhancing energy efficiency campus-wide and fostering a greener and more sustainable university.

## Literature Review

### Asset Score Scale

The Asset Score Scale is a tool developed by the US Department of Energy to assess the energy efficiency of buildings at a national level. It provides a scoring system ranging from 0 to 10 points, where 0 represents the worst-case scenario, and 10 represents the best-case scenario. The score reflects the expected energy use of a building without relying on renewable energy sources, using current energy efficiency technologies. If a building scores below 10, the tool generates a report that includes the current and potential scores if the user implements the recommended program suggestions. An example of the score given by the system is in Figure 1, which shows the current score as 6.0 and a potential score as 7.5, with an estimated savings of 24 %. The Asset Score report also provides building details, energy use intensity, energy saving potential, associated costs for updates, breakdown of energy use by end-use, and system-level assessments. The Asset Score is a free and voluntary tool that aims to improve the energy efficiency of buildings and homes. It is available for anyone interested in enhancing their building's energy performance (EERE, 2021)[1]

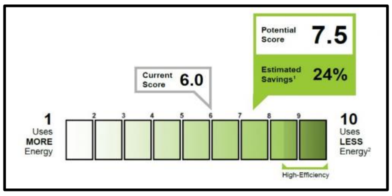

Figure 1— Comparison of Current and Potential Asset Scores with Estimate Savings (Adapted from EERE, 2021)

To use the tool, users provide general details such as the number of floors, footprint size, orientation, and type of use. In addition, the tool considers specific factors related to the building envelope, such as the roof, insulation levels, external walls, and floor types. Details on fenestration (arrangements of windows and doors at building elevation), including skylights, windows, and shading, are also considered. The user can enter data about the types of lighting fixtures, the number or percentage of the floor area they cover, and information about the lighting controls. In addition, the tool considers mechanical components, including types of cooling and heating, controls, and equipment efficiency. Users have the option to input data about service water heating, including details about the fuel type, distribution type, and equipment efficiency. By incorporating these inputs, the Asset Score tool generates a comprehensive assessment of a building's energy efficiency, providing information to users and helping them identify potential efficiency improvements (EERE, 2021) [2].

**Leadership in Energy and Environmental Design (LEED)**

The Leadership in Energy and Environmental Design (LEED) is a certification system established by the U.S. Green Building Council (USGBC) to encourage environmentally friendly construction practices, enhance human experience, and improve construction efficiency. LEED sets the standard for green buildings and ways to address the climate crisis. LEED incorporates a comprehensive set of strategies that are implemented throughout the entire lifecycle of a building, from its initial planning and site selection to the design, construction, and ongoing operations. The project incorporates a range of strategies, including water conservation, energy efficiency, material selection, project location, and indoor environmental quality. These strategies are carefully considered throughout each process stage to ensure the adoption of sustainable and environmentally friendly practices (USGBC, 2023).

LEED recognizes and rewards buildings that embrace green building practices. Based on the number of points they earn in the credit scoring system; buildings can achieve different levels of certification. The project must fulfill the prerequisites, which form the fundamental requirements for all LEED projects. Once the prerequisites are satisfied, the project team chooses the specific credits they aim to earn. The sum of the credits contributes to the project's overall score. LEED certification levels are categorized by the total credits earned. It begins with LEED Certified, indicating a minimum score of 40-49 points. Next is LEED Silver, achieved with a score between 50-59 points. Moving up, we have LEED Gold for projects scoring between 60-79 points. Finally, the highest level is LEED Platinum, reserved for projects surpassing 80 points, representing outstanding sustainability and environmental design performance.

**NYC Green Building Laws & Regulations**

In 2008, the New York City Planning Department (2008) reported that buildings were the primary contributors to the city's carbon emissions, accounting for approximately eighty percent of the total emissions and costing residents $15 billion annually in heating and energy expenses. New York City (NYC) has been implementing laws and regulations to achieve its sustainability goals to become one of the most sustainable large cities in the world. Notably, the "Zone Green" program aims to improve the overall environmental performance of buildings by facilitating energy-saving investments for new constructions or retrofits. It allows for provisions for external insulations, solar energy installations, rooftop greenhouses, and wind energy generation (DCP, 2023). Beyond that, the Greener, Greater Buildings Plan, which encompasses laws such as Local Law 86 (LL86) and Local Laws 31 and 32, focuses on enhancing energy efficiency and promoting sustainable practices in the construction sector (DCP, 2023; Office of Environmental Coordination, 2023).

The New York City Energy Conservation Code (NYCECC) was enacted with Law 85/09 to regulate the energy efficiency of building envelopes, lighting, and mechanical systems. All new and renovated construction, regardless of size or scope, must comply with NYCECC requirements to ensure maximum energy efficiency (New York City Department of Buildings, 2009). Additionally, Local Law No. 87/09 requires energy audits every ten years for buildings totaling more than 50,000 square feet, allowing building owners to identify areas for improvement (New York City Department of Buildings, 2016). Local Law 88/09 focuses on lighting and electrical upgrades for buildings larger than 50,000 gross square feet to achieve cost savings on electrical expenses (NYC Mayor's Office of Sustainability, 2009). The City of New York Law for the Year 2016, No. 3, requires New York City-owned buildings and developments funded by the city to meet a minimum level of LEED certification, surpassing energy conservation requirements by 20 percent or more (NYC Mayor's Office of Sustainability, 2016).

Additionally, Local Law 32 of 2016 focuses on energy efficiency reporting for specific municipal buildings, with annual reports publicly accessible on the city's website (NYC Mayor's Office of Sustainability, 2016). Furthermore, compliance with Local Law 97 of 2019 establishes emission limits for different types of buildings, aiming to hold building owners accountable for their energy consumption and emissions. New York City aims to achieve its sustainability goals and become one of the most sustainable large cities worldwide.

**Sustainable Delaware**

The University of Delaware has taken steps to promote sustainability, including creating documents assessing the institution's status and proposing improvements and guidelines to enhance sustainability at the university and in the surrounding community. Various documents cover areas such as Sustainability Plans (UD Sustainability Plans 2017 and 2022), Climate and Related Action Plans (2018 FREAS Report submitted to Faculty Senate to assess conversion to 100% renewable energy: "Renewables, Carbon Neutrality at the University of Delaware" and the 2009 University of Delaware Climate Action Plan), greenhouse gas inventories, transportation (2022 Transportation Survey Report, 2022 Bike Sharing Program Report 2022 and 2017 Transportation Survey Report) and other miscellaneous papers (2017 GRITS Review on Energy Savings from Chapel Renovation at Brown: Drake Labs). These documents provide a solid basis for addressing issues related to energy efficiency in university buildings and guiding future action.

According to the 2022 report titled "UD Sustainable Operations Energy and Buildings," UD buildings make up seventy-two percent of the total energy consumed. Figure 2 illustrates the total emissions of UD measured in metric tons of CO2. The most significant portion of emissions is attributed to university buildings (around ninety-seven percent), followed by commuting (around twenty-one percent). The data is adapted from the 2017-2018 UD Greenhouse Gas Inventory. The university's new buildings meet the LEED Silver certification for energy efficiency. However, older buildings require retrofitting and upgrades to improve energy efficiency. The UD Sustainability Plan (2022) states that improving the energy efficiency of buildings is essential for reducing carbon emissions. Improvement proposals are related to lighting, temperature control, metering, and building envelope upgrades.

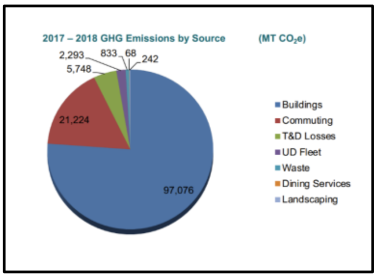


Figure 2- Total Emissions of the University of Delaware in 2017-2018 (MT CO2e).

# Methodology

**Research Plan**

This study analyzed and rated the energy efficiency of buildings at UD using the tool provided by the U.S. DOE. The research method utilized for the development of this study was a literature review with a typical purpose approach, which according to Snyder (2019), is to overview the research area and track development over time. The research plan consisted of several phases. The first phase involved conducting a literature review, including scientific articles, government and private initiative websites, and UD (Sustainable Delaware) reports. The objective was to gather case studies, legislation, and tools related to energy efficiency in buildings.

The second phase focused on determining the method for ranking the buildings. Initially, there was an intention to develop a custom ranking system encompassing key sustainability aspects such as water consumption, waste management, and energy use. Due to time constraints, it was decided to focus on energy efficiency, and the U.S. DOE tool was chosen. A spreadsheet and questionnaire (appendix 01) were developed in the third phase to collect on-site data. The questionnaire contained crucial points to be observed during the site visit, essential for generating a model using the selected tool. The technique utilized for data collection involved indirect data collection through bibliographical research, as well as direct data collection and intensive direct observation. The data collection process included visiting the site, employing the checklist, making additional notes, and capturing photos and videos to document essential supplementary information and accurately depict the characteristics of the building.

After the site visits, the data was analyzed, and the model was projected using the Office of Energy Efficiency and Renewable Energy (EERE) tool. The "AS Buildings" option was selected to build the model of the buildings in the tool, as the primary objective of this project is to classify the buildings. The "add a building" feature was used to input new buildings into the program, followed by providing the data gathered during the on-site visit. Following data processing, the tool generated a score, a potential upgrade score, and a comprehensive report suggesting improvement measures. The research concludes by presenting proposed improvements based on the generated report and providing scores for the Honors College and UD Visitors Center buildings.

**Pilot Buildings**

One of the buildings chosen for this pilot project was the Honors College at UD, as shown in Figure 3. This building was selected based on its size and the accessibility of obtaining data. It is located at 186 S. College Ave., Newark, DE 19716. According to the Honors College, the building initially functioned as a fraternity house during the mid-1900s. It later served as a house for the university's English department before becoming the Honors College.

Figure 3- Honors College Building (Adapted from Google Maps 2023)

Another building chosen for this pilot project was UD's Visitors Center (Figure 4). The building is located at 210 S. College Ave., Newark. This building was built in the year 2008. According to UDaily (2008), The building has 24,000 sqft., costs $12 million to build, and has two separate areas. The front section of the building, designed as a public area, comprises the main lobby, a presentation room, and an interview room; the other part of the building accommodates the offices and operations.

Figure 4 - University of Delaware Visitors Center (Adapted from Google Maps 2023)

# Results

**Honors College Building**
During the on-site visit, the Honors College building was identified as office space with a gross floor area of approximately 2,785 square feet. The building is located in a region with a Mixed Humid climate, and data collection took place on July 22, 2023. Subsequently, all the gathered information was input into the Asset Score Tool, which generated a report based on this data (appendix 02).

The Asset Score Report revealed that the Honors College building achieved a current score of 6.5 and a potential upgrade score of 9.5, indicating a substantial estimated savings potential of 28%. However, some discrepancies were observed in the data input during the evaluation process. While the number of occupants declared to the Tool was ten, the report listed the number of assumed occupants as 13. Moreover, the report calculated the number of weekly hours, originally set at 45, as 48.6 hrs/wk. Regarding the estimated Source of Energy Use (kBtu/ft2/yr) and Carbon Emission (kg CO2e/ft2/yr), the current values were recorded as 130 and 4.39, respectively. If implemented, the program calculated potential upgrades that could significantly reduce the Source Energy use to 94 and emissions to 3.11.

The cost upgrade opportunities outlined several potential upgrades to improve energy efficiency. For the building envelope, the report recommended adding air barriers to reduce air leakage, a significant source of heat loss. Roof insulation upgrades, particularly in the Attic Ceiling area, were suggested, falling within the low to medium-cost range. Furthermore, the addition of cool roofs, constructed with reflective materials to reduce heat absorption, was proposed, also categorized as low to medium cost. Regarding lighting systems, the Asset Score Report recommended upgrading all floors to LED fixtures and installing occupancy sensors for interior lighting control. LED lighting is recognized as the most energy-efficient option, lasting longer and consuming 75% less energy than conventional lamps. This upgrade could reduce energy consumption and enhance overall lighting efficiency.

Regarding the service hot water systems, the report proposed adding low-flow faucets by installing faucet aerators and flow-reducing shower heads, where applicable, to reduce water usage. Additionally, the report suggested decreasing the service hot water temperature where viable. These modifications were classified as having low energy savings potential but medium cost. Overall, implementing these recommended upgrades can lead to substantial energy savings and improved energy efficiency in the Honors College building.

**University of Delaware Visitors Center**
The UD Visitors Center is an office space with a gross floor area of 22,820 square feet for the score calculation (excluding the basement area). Like the Honors College building, the tool classified the climate as Mixed-Humid. The data collection took place on July 27, 2023. The generated current score was 6, and the potential upgrade score was 9.0, with an estimated savings of 31 percent.

The building accommodates a relatively low number of 20 occupants, mainly due to the post-pandemic shift towards hybrid work arrangements, where many individuals work remotely and visit the building only a few times a week. The current estimate for source energy use stands at 144 (kBtu/ft2 /yr) and implementing the suggested upgrades from the report could lead to a slight reduction to 100 (kBtu/ft2 /yr). Similarly, concerning Carbon Emission, the current value is 6.50 (kg CO2e/ft2 /yr), and the application of upgrades could reduce by 5.04 (kg CO2e/ft2 /yr).

The building envelope section offers two key suggestions for the cost-effective upgrade opportunities identified. First, sealing the building envelope to reduce air infiltration is recommended, with a low investment cost and a moderate impact on energy savings. Second, upgrading wall insulation is proposed, providing additional energy savings potential at a medium to high estimated implementation cost. These upgrades can contribute to improved energy efficiency in the building while considering budgetary constraints. The report suggested replacing the current fluorescent lighting system with LED lighting. According to the tool, the estimated cost of implementing this upgrade is low, while the potential for energy savings is considered medium. Additionally, both buildings in the study were advised to implement occupancy sensors for interior lighting control. The program categorized this upgrade as a low to medium-cost option, with the impact on energy savings as low. Nevertheless, incorporating occupancy sensors can reduce unnecessary energy usage by automatically adjusting lighting based on occupancy and optimizing energy consumption during periods of low activity or when spaces are unoccupied.

The HVAC system received a "good" rating in the building systems ranking, indicating its overall efficiency and performance. However, the interior lights were rated as "fair," suggesting the potential for improvement in energy efficiency and lighting design. The building envelope received an overall rating of "good," reflecting its effective thermal performance and insulation. Notably, the category "Walls + Windows U-value" (Btu/ft2 ·h·°F) received a "superior" rating, highlighting the building's well-insulated walls and windows, despite the presence of numerous windows. The Building Window Wall Ratio was measured at approximately 13%, indicating a moderate proportion of windows to the total wall area.

Like for the Honors College building, installing low-flow faucets is also recommended for this building, particularly in the L-shaped block behind the front block. In conclusion, the assessment results for the Visitors Center building shows opportunities for enhancing energy efficiency.

**Discussion**

The tool assumed the number of occupants, surpassing the value provided by the user. For instance, the user-specified 10 occupants in the Honors College building, yet the tool estimated the number of occupants as 13. Similarly, a situation arose with the Visitors Center, where the tool estimated 114 occupants. This value may have been a mistake during data entry, possibly stemming from the model's consideration of two distinct blocks. And one of these blocks was treated as having two floors.
Regarding estimated source energy use, the current and upgraded states were considered for each building. The current source of energy use for the Honors building was close to that of the Visitors Center, with values of 130 and 144 kBtu/ft2/yr, respectively. After upgrading, the Honors building would be reduced to 94 kBtu/ft2/yr, whereas the Visitors Center's reduction would be comparatively smaller at 100 kBtu/ft2/yr. Carbon emissions were also examined in the study. The carbon emissions for the Honors building were 4.39 kg CO2e/ft2/yr, which would be reduced to 3.11 kg CO2e/ft2/yr after upgrading, representing a potential reduction of 1.28 kg CO2e/ft2/yr. Similarly, the Visitors Center exhibited reductions from 6.5 kg CO2e/ft2/yr to 5.04 kg CO2e/ft2/yr after upgrading, with a potential decrease of 1.46 kg CO2e/ft2/yr. The Visitors Center achieved a more significant reduction than the Honors building.

Cost-effective upgrade opportunities were explored for both buildings, focusing on different aspects. Though the energy savings were deemed low, both facilities received the same upgrade suggestions for the building envelope. Lighting systems in both buildings were recommended to be upgraded to LED fixtures with occupancy sensors, but potential differences arose due to variations in existing fluorescent fixture types. The HVAC systems were classified as good in both buildings, with no upgrade opportunities identified. Including low-flow faucets was advised for both buildings to enhance water efficiency.

Structures and systems were evaluated and compared. While both buildings received an overall good ranking, distinctions were observed in specific categories. The Honors building was rated "Fair" for Roof U-Value, Non-Attic (Btu/ft2·h·°F), while the Visitors Center achieved a "Good" rating. In contrast, the Honors building received a "Superior" ranking for Walls + Windows U-Value (Btu/ft2·h·°F), while the Visitors Center received a "Good" rating. These differences could impact the final energy performance scores.

Factors beyond building attributes were considered, such as the HVAC system and building shape. Due to limited information about the HVAC system, assumptions were made, potentially impacting the final scores. The shape of the buildings also played a role; the Visitors Center's complex shape with more corners could lead to energy losses compared to the more straightforward shape of the Honors building. Lapisa (2019) emphasized the suitability of square building shapes to reduce energy consumption in various climates. He highlighted the potential for uncompacted shapes to result in significantly higher energy consumption.

Other factors contributing to energy use disparities included window distribution. The tool distributed windows evenly across surfaces for the rectangular Honors building, whereas the Visitors Center Building L-shaped plus a rectangular shape configuration posed challenges in determining window distribution. The presence of an elevator in the Visitors Center Building and its occasional use on weekends for events contrasts the absence of an elevator and weekend closure for the Honors building. These factors could contribute to the differences in energy usage patterns between the two buildings.

In conclusion, the discussion underscores the complex interplay of factors influencing energy performance in buildings, including geometric shape, building attributes, system specifics, and occupant behavior. The findings shed light on the potential for energy savings through building upgrades and the significance of understanding the nuanced relationship between building design and energy consumption.

## Conclusion

The research focused on developing a system to analyze and rate the energy efficiency of buildings at UD using the U.S. DOE's Asset Score Scale. Two pilot buildings, the Honors College, and the Visitors Center, were assessed based on their energy performance and potential for improvements. The findings indicated that both buildings have room for enhancement in terms of energy efficiency.

The research has laid the foundation for a future energy efficiency assessment system for the UD campus. Analyzing pilot buildings, proposing practical upgrades, and contributing to sustainable building practices. The tool aims to guide funding allocation for retrofits and improvements, offering the potential to enhance energy efficiency across the campus. Ranking buildings based on energy performance allows prioritizing projects with significant energy savings and environmental impact, proactively reducing energy consumption and carbon footprint, leading to a greener and more sustainable campus.

Despite the age difference between the buildings, both obtained similar scores, indicating comparable energy efficiency levels. This outcome suggests that various factors, such as design choices, retrofits, occupant behavior, and building features, significantly influence a building's overall energy performance. While the Visitors Center is a newer building, its energy efficiency may be affected by specific design choices or technologies that offset the benefits of modern construction. On the other hand, the Honors College, as an older building, could have undergone retrofits and upgrades over the years, contributing to its current energy efficiency level.

During the research journey, several challenges were encountered, such as understanding complex HVAC systems and the challenge of estimating gross floor area due to a lack of plans. Addressing these challenges improves the estimates. Collaborating with HVAC experts, gaining access to accurate building footprints, and utilizing advanced on-site data collection techniques will be essential for obtaining reliable energy efficiency scores and making informed decisions.

As the campus continues to evolve, the proposed system can play a pivotal role in shaping future retrofitting and energy-saving initiatives. By continuously evaluating and comparing building energy efficiency, the university can make data-driven decisions and channel resources toward projects with the highest potential for positive change. The commitment to energy efficiency initiatives reflects UD's dedication to sustainability and responsible resource management, driving the campus towards a more energy-conscious and environmentally friendly future.

## References


Green Building Practices. (n.d.). Complete Communities Delaware. Retrieved from https://www.completecommunitiesde.org/planning/sustainable/green-building-practices/.

Lapisa, R. (2019). The effect of building geometric shape and orientation on its energy performance in various climate regions. International Journal of GEOMATE, 16(53). DOI:10.21660/2019.53.94984. Retrieved from https://www.researchgate.net/publication/330515654_The_effect_of_building_geometric_shape_and_orientation_on_its_energy_performance_in_various_climate_regions.

NYC Department of Buildings. (n.d.). Buildings undergoing demolition or new construction. Retrieved from https://www.nyc.gov/assets/buildings/pdf/buildings_undergoing_demo_%20constr.pdf.

New York City Department of City Planning (DCP)[1]. (2023). Resiliency & Sustainability. Retrieved from: https://www.nyc.gov/site/planning/about/dcp-priorities/resiliency-sustainability.page#:~:text=The%20City%20has%20set%20an,the%20carbon%20footprint%20of%20buildings.

New York City Department of City Planning. (2023). Zone Green: Encouraging Energy-Efficient Construction and Retrofits. Retrieve from https://www.nyc.gov/assets/planning/download/pdf/plans/zone-green/zone_green.pdf.

New York City Mayor's Office of Sustainability. (2009) [1]. Local Law 85 of 2009: Energy Conservation Code. Retrieved from https://www.nyc.gov/html/gbee/html/plan/ll85.shtml.

NYC Mayor's Office of Sustainability. (2009) [2]. Local Law 88 of 2009: Lighting upgrades and submetering. Retrieved from https://www.nyc.gov/html/gbee/html/plan/ll88.shtml#:~:text=Local%20Law%2088%20of%202009,buildings%20achieve%20significant%20energy%20savings.

NYC Mayor's Office of Sustainability. (2016). NYC Capital Green Building Program, Local Laws 31 and 32 of 2016 Overview. Retrieved from https://www.nyc.gov/assets/oec/CGBP-Documents/MOEC_CGBP_Overview%20Deck.pdf.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, pp. 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

University of Delaware Honors College. (n.d.). A History of UDHC. Retrieved from https://sites.udel.edu/honors/a-history-of-udhc/.

The University of Delaware. (2009). New building to serve as a campus gateway. UDaily. Retrieved from https://www1.udel.edu/udaily/2009/aug/building082908.html.

The University of Delaware. (2019). 2018-2019 UD Greenhouse Gas Inventory Final Report [PDF]. Retrieved from https://bpb-us-w2.wpmucdn.com/sites.udel.edu/dist/e/763/files/2023/03/2018-2019-UD-Greenhouse-Gas-Inventory-Final-Report.pdf.

The University of Delaware. (2022). The UD Sustainability Plan 2022 [PDF]. Retrieved from https://bpb-us-w2.wpmucdn.com/sites.udel.edu/dist/e/763/files/2022/01/The-UD-Sustainability-Plan-2022. pdf.

The University of Delaware. (2023). Sustainability. Retrieved from https://sites.udel.edu/sustainability/.

Urban Green Council. (2023). Local Law 97. Retrieved from https://www.urbangreencouncil.org/what-we-do/driving-innovative-policy/ll97/.

U.S. Department of Energy. (2021) (EERE)1. Building Energy Asset Score. Office of ENERGY EFFICIENCY & RENEWABLE ENERGY. Retrieved from https://www.energy.gov/eere/buildings/building-energy-asset-score.

U.S. Department of Energy. (2021) (EERE)2. Tool Basics. Office of ENERGY EFFICIENCY & RENEWABLE ENERGY. Retrieved from https://www.energy.gov/eere/buildings/tool-basics.

USGBC. (2023)1 LEED. Retrieved from https://www.usgbc.org/leed.

USGBC. (2023)2. LEED - Scorecard tools. Retrieved from https://www.usgbc.org/leed-tools/scorecard.

# Appendices

## Appendix 01 - Building Information Gathering Checklist

**Building Information Gathering Checklist**

**1. Building Information**:

- Building name: _________________________ - Address/Location: _________________________________________________
- Year completed: ________
- Gross Floor Area ft² (*the total floor area within the building's perimeter, encompassing all floors*): __________

**2. Facility Description**:

- Number of floors: __________ - General building shape/type:

H Shape T shape L shape
Rectangular O Shape

**3. Use Types:**

- Primary building function/use (*residential, labs, offices, classroom, library*): ___________________________
- Number of occupants: _______________ Approximate operating hours per week: _____________________

**4. Construction:**

- **Roof Construction**:
  - Built-Up with Concrete Deck
  - Deck Built-Up with Wood Deck
  - Shingles and Shakes
  - Built-Up with Metal
  - Metal Surfacing

Roof Type:
- Cool Roof
- Blue Roof
- Green Roof

- **Wall Construction**:
  - Metal Panel/Curtain Wall
  - Brick/Stone on Steel Frame
  - Brick/Stone on Masonry- Below Grade Walls
  - Siding on Wood Frame
  - Brick/Stone on Masonry
  - Brick/Stone on Wood Frame
  - Siding on Steel Frame

- **Windows:** How many windows are on each side of the building by floor: _______Width: _______Height: _______

Framing Material
- Metal
- Wood/Vinyl/ Fiberglass
- Metal with Thermal Breaks
- Other

Glass type
- Single Pane
- Double Pane

**- Floor Type**:
- Concrete
- Steel Joist Floors
- Wood Framed floors.
- Slab on grade

5. **Lighting**: Area Served (*% or ft²*): _______________ Lighting type:
- Compact Fluorescent
- Fluorescent T12
- LED
- Fluorescent T5
- Fluorescent T12 - High Output
- Mercury Vapor
- Fluorescent T5 - High Output
- High-Pressure Sodium
- Metal Halide
- Fluorescent T8
- Incandescent
- Fluorescent T8 - Super T8
- Halogen

- Lighting controls
  - Manual
  - Timer
  - BAS
  - Photocell
  - Sensor
  - Other

**6. HVAC:**

- Principal HVAC Type *(or take a picture to identify after the visit)*:
  - Packaged Terminal Air Conditioner
  - Package Rooftop VAV with Electric Reheat
  - Water Loop Heat Pump
  - Four Pipe Fan Coil Unit
  - VAV with Hot Water Reheat
  - Ground Source Heat Pump
  - Packaged Terminal Heat Pump
  - VAV with Electric Reheat
  - VRF Terminal Unit
  - Package Rooftop Air Conditioner
  - Warm Air Furnace
  - Chilled Beam
  - Package Rooftop Heat Pump
  - Ventilation Only
  - Other
  - Package Rooftop VAV with Hot Water Reheat
  - Dedicated Outdoor Air System

Heating

Heating Equipment name:______________________Fuel type:________
- Hot Water Boiler
- District Hot Water
- Steam Boiler
- Utility District Steam

Cooling

Cooling Equipment name:______________________Fuel Type________
- Absorption Chiller - 1 Stage
- Gas Engine Chiller
- Steam Turbine Chiller
- Absorption Chiller - 2 Stage
- Electric Chiller
- District Chilled Water

Central Distribution
- Forced Air
- Two Pipe Steam
- Refrigerant (VRF)
- One Pipe Steam
- Hydronic
- None (unitized heating/cooling)

Ventilation System

Energy Recovery Ventilation
- Sensible and Latent
- Sensible Only
- None

Outdoor Air Control - Specifications of the equipment (*if possible, take a picture*): ________________________

- Central Fan
- Underfloor Air Distribution
- 4 Pipe Fan Coil Unit
- 2 Pipe Fan Coil Unit
- Split unit
- VRF Terminals
- Packaged Terminal Equipment
- Electric Baseboards
- Hot Water Baseboard
- Chilled Beam
- Radiant Floor or Ceiling
- Radiators or Convectors
- Window AC
- Other (Please Specify

**9. Operations:**

- Elevators (*elevator type and condition*): ___________________________ Number of elevators: ___________

## Appendix 02 - On-Site Visit Data

- Building name: Honors College University of Delaware - Address/Location: 186 S College Ave, Newark, DE
- Year completed: 1950 - Gross Floor Area ft²: 3100 sqft (with basement)
- Number of floors: 3 - General building shape/type: Rectangular
- Primary building function/use: Office - Number of occupants: 10
- Approximate operating hours per week: Weekdays:8 am - 5 pm
- Roof Construction: Shingles and Shakes
- Wall Construction: Brick/Stone on Wood Frame

Framing Material: Wood/Vinyl/ Fiberglass - Glass type: Double Pane

How many windows are by floor (preferentially even number): Floor 01: 14, Floor 02: 10, Floor 03: 08

Dimensions of the windows: Floors 01 and 02: Width: 2’35” ft Height: 4’; Floor 03: Width: 1’7” ft Height: 2’

- Floor Type: Wood Framed floors
- Area Served lightning: 100% - Lighting type: Fluorescent T8 - 32 watt - Lighting controls: Manual

- Principal HVAC Type: Window AC

Heating: Central Furnace

Heating System: Hot Water Boiler

Central Distribution: One-Pipe Steam

Outdoor Air Control: Radiators or Convectors and Window AC

- Building name: University of Delaware Visitors Center Address/Location: 210 S College Ave, Newark, DE
- Year completed: 2008 - Gross Floor Area ft²: 24000 (with basement)
- Number of floors: 2 (L shape) - General building shape/type: L shape + rectangular Shape
- Primary building function/use: Office - Number of occupants: 20
- Approximate operating hours per week: Weekdays: 08:30 am - 04:30 pm
- Roof Construction: Slate roof
- Wall Construction: Brick/Stone on Steel Frame
- Windows:

Framing Material: Wood/Vinyl/ Fiberglas

Glass type: Double Pane

How many windows are on the building: L shape: 62 windows (2 floors) , Rectangular shape (front) :16 windows

Dimensions of the windows: L shape: Width: 4’2” Height: 6’; Rectangular Shape: Width: 4’4” Height: 14’

- Floor Type: Steel Joist Floor

Area Served (% or ft²): 90 % Lighting type: Fluorescent T5

- Lighting controls: Manual; Sensor
- Principal HVAC Type: Four Pipe Fan Coil Unit**

***This system was deduced through research, and when selected in the tool, it automatically filled in the remaining HVAC fields.*

- Elevators: Hydraulic - Good condition - Number of elevators: 01