MEMORANDUM

Date:	**7/18/2024**		
To:	**City of Alexandria, Virginia; Office of Climate Action, City Manager Office**	Information Release #	**PNNL-SA-200796**
From:	**Kim Cheslak**		
Subject:	**Data and Analysis for Alexandria Target Setting**		

The City of Alexandria, Virginia (Alexandria) is in the process of updating their Green Building Policy to increase energy efficiency amongst other items. Currently Alexandria is enforcing the Virginia Commercial Energy Code, based on ASHRAE Standard 90.1-2019 and the International Energy Conservation Code (IECC) 2021. The Office of Climate Action in the City Manager's Office requested a review of existing building data to understand how to set more stringent energy use intensity (EUI) targets that would still be achievable, with a focus on commercial office and multifamily buildings. Because Alexandria has limited benchmarking data, Pacific Northwest National Laboratory (PNNL) pulled data from comparable sources to serve as a reasonable proxy for what would be achievable within Alexandria.

In coordination with the City, PNNL reviewed the following datasets to inform Alexandria staff in their decision making:

1. Existing building data for the Commonwealth of Virginia from EnergyStar Portfolio Manager Data Explorer.[1]
2. Local benchmarking data from Washington, DC and Montgomery County, MD.[2,3]
3. Simulation based building energy results for ASHRAE Standard 90.1-2022 that illustrate the range of EUIs that would be expected from buildings complying with the prescriptive path (variability study) and the EUI for the "standard prototype" for each building type. The "standard prototype" for each building prototype is a configuration, as selected by the ASHRAE 90.1 committee, intended to represent good, standard design options.
4. EUIs for the standard prototypes for the current and previous VA commercial energy codes based on 90.1-2019/IECC 2021 and 90.1-2016/IECC 2018 respectively.[4]

[1] Downloaded from EnergyStar Portfolio Data Explorer https://www.energystar.gov/buildings/resources-topic/portfolio-manager-data-explorer on May 15, 2024. Use of this dataset is not to be confused with EnergyStar Certification. An overview of the dataset and technical explanation for the tool can be found online. https://www.energystar.gov/sites/default/files/tools/Data%20Explorer%20Technical%20Reference%20Final%2010202023_508.pdf

[2] Data from Washington DC was downloaded from OpenData DC https://opendata.dc.gov/ on May 15, 2024.

[3] Data from Montgomery County, MD was received from MoCo DEP on May 8, 2024.

[4] Virginia updated to ASHRAE 90.1-2019/IECC 2021 with an effective date of Jan. 18, 2024.

This memo serves as a written record of the review of the energy data (presented as site EUI) and high-level estimated cost impacts.

Review of Data Sets

The Office of Climate Action in the City Manager's Office requested a focus on commercial office and multifamily buildings. As part of the U.S. Department of Energy established methodology, prototype buildings are established to simulate energy savings associated with changes in energy codes and standards. This methodology is used to evaluate published versions of the code, as well as in developing proposed code changes.[5,6] Three prototype buildings and their associated data and analysis are used in this analysis: Medium Office, Midrise Multifamily, and Highrise Multifamily building.

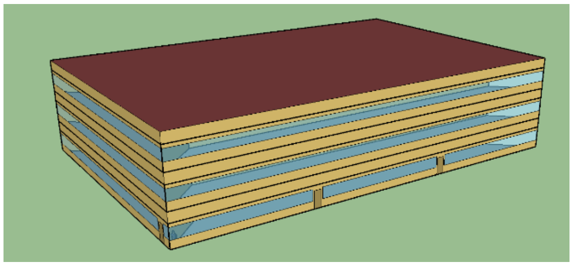

Figure 1. PNNL Medium Office Prototype

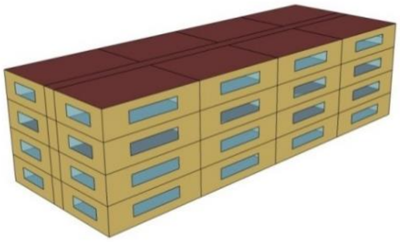

Figure 2. PNNL Midrise Multifamily Prototype

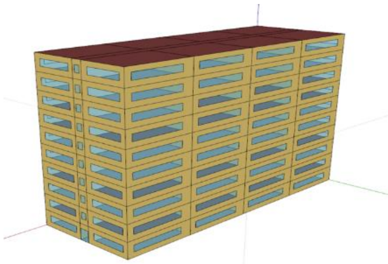

Figure 3. PNNL Highrise Multifamily Prototype

[5] https://www.energycodes.gov/prototype-building-models
[6] https://www.energycodes.gov/methodology

EnergyStar Data Explorer
The EnergyStar dataset is retrieved for data year 2022 to review buildings in the Commonwealth of Virginia using EnergyStar Portfolio Manager's Data Explorer tool. Data is reviewed by property type, year of construction and percentile of performance, focusing on the top 25% and median property performance values using Site EUI as the basis. The exact size of this dataset is unknown, as Data Explorer provides a range for the "Property Count". Where property counts in any category are less than five, Data Explorer does not provide EUIs.

To approximate a medium office building for comparison, the office building type is limited to gross floor area of 25,000 to 199,999 sq.ft. and are further limited to exclude veterinary offices (an EnergyStar defined sub-type in the office category). Office buildings are not limited by hours of operation. Table 1 presents the Data Explorer data for "medium office" as described.

Table 1. Medium Office Dataset (Site EUI)

Type	Year Built	25%	Median	Property Count
Office	All Years	46.8	57.6	250-500
Office	Before 1946	51.3	70.3	6-29
Office	1946-1959	-	-	<5
Office	1960-1979	49.4	62.9	30-49
Office	1980-1999	47.0	56.8	100-249
Office	2000-2009	46.9	56.8	50-99
Office	2010 and after	41.1	60.0	6-29

To approximate a midrise multifamily building for comparison, the multifamily buildings are pulled from the Lodging/residential property type by selecting the inclusion of only the multifamily subtype. Gross floor area is limited to 5,000 to 199,999 sq.ft. Table 2 presents the Data Explorer data for "midrise multifamily" as described.

Table 2. Midrise Multifamily Dataset (Site EUI)

Type	Year Built	25%	Median	Property Count
Multifamily MR	All Years	27.6	32.6	100-249
Multifamily MR	Before 1946	-	-	<5
Multifamily MR	1946-1959	-	-	<5
Multifamily MR	1960-1979	34.2	38.3	6-29
Multifamily MR	1980-1999	29.1	33.1	6-29
Multifamily MR	2000-2009	27.6	32.2	30-49
Multifamily MR	2010 and after	26.2	31.5	6-29

To approximate a highrise multifamily building for comparison highrise multifamily buildings are pulled from the lodging/residential property type by selecting the inclusion of only the multifamily subtype. Gross floor area is limited to >200,000 sqft. Table 3 presents the Data Explorer data for “highrise multifamily” as described.

Table 3. Highrise Multifamily Dataset (Site EUI)

Type	Year Built	25%	Median	Property Count
Multifamily HR	All Years	23.3	31.8	100-249
Multifamily HR	Before 1946	-	-	<5
Multifamily HR	1946-1959	-	-	<5
Multifamily HR	1960-1979	41.5	55.7	50-99
Multifamily HR	1980-1999	24.3	34.0	50-99
Multifamily HR	2000-2009	24.6	31.4	30-49
Multifamily HR	2010 and after	21.2	25.1	50-99

Local Benchmarking
Benchmarking data from Washington, DC and Montgomery County, MD are combined to review the metered energy performance of buildings in the Alexandria region. This data set is considered a reasonable proxy due to the geographic proximity to Alexandria, as well as a large overlap in construction practices and professionals. Data is sorted into categories by building type and year of construction, using the same parameters applied to the EnergyStar data set. Building type selection focuses on primary property type and does not account for additional property types in the buildings. Table 4 presents the local benchmarking data for “medium office,” “midrise multifamily,” and “highrise multifamily” as previously described.

Table 4. Local Benchmarking Dataset (Site EUI)

Type	Year Built	25%	Median	Property Count
Office	All Years	34.5	53.2	534
Office	Before 1946	27.3	48.2	91
Office	1946-1959	33.2	53.9	56
Office	1960-1979	38.6	56.4	152
Office	1980-1999	33.7	51.9	137
Office	2000-2009	35.4	61.3	47
Office	2010 and after	30.9	47.5	51
Multifamily MR	All Years	30.7	54.1	1,363
Multifamily MR	Before 1946	31.0	54.8	551
Multifamily MR	1946-1959	38.7	63.3	176
Multifamily MR	1960-1979	35.2	60.3	236
Multifamily MR	1980-1999	29.6	47.6	77

(Table continues on next page)

Type	Year Built	25%	Median	Property Count
Multifamily MR	2000-2009	32.8	47.2	141
Multifamily MR	2010 and after	29.4	42.8	169
Multifamily HR	All Years	33.9	52.8	428
Multifamily HR	Before 1946	40.3	56.9	49
Multifamily HR	1946-1959	40.3	56.3	46
Multifamily HR	1960-1979	36.7	61.5	97
Multifamily HR	1980-1999	32.2	42.8	17
Multifamily HR	2000-2009	35.5	51.0	64
Multifamily HR	2010 and after	30.9	46.7	153

Simulation Based Analysis
Alexandria, VA is located in ASHRAE climate zone (CZ) 4A. Simulation based building energy results for ASHRAE Standard 90.1-2022 (the most recent model commercial energy code) and 90.1-2019/IECC 2021 (the current code adopted in Virginia and Alexandria) for CZ 4A are used to understand the expected site energy use of new construction buildings built to code.

Results for both the medium office and midrise multifamily buildings are shown based on the following available simulation analyses:

1. ASHRAE Standard 90.1-2016/IECC 2018 standard prototype simulation result, specific to the previous adopted code in Virginia,
2. ASHRAE Standard 90.1-2019/IECC 2021 standard prototype simulation result, specific to the current adopted code in Virginia,
3. ASHRAE Standard 90.1-2022 standard prototype simulation result for CZ 4A,
4. ASHRAE Standard 90.1-2022 study of expected prescriptive variability for CZ 4A.

Results for highrise multifamily buildings are shown based on the following available simulation analyses:

1. ASHRAE Standard 90.1-2016/IECC 2018 standard prototype simulation result, specific to the previous adopted code in Virginia,
2. ASHRAE Standard 90.1-2019/IECC 2021 standard prototype simulation result, specific to the current adopted code in Virginia,
3. ASHRAE Standard 90.1-2022 standard prototype simulation result for CZ 4A.

Table 5. Simulation Based Analysis (Site EUI)

Type	VA 90.1-2016/ 2018 IECC	VA 90.1-2019/ 2021 IECC	90.1-2022	90.1-2022 Variability
Office	31.2	29.0	25.3	21.0 – 31.0
Multifamily MR	37.7	29.9	34.4	25.0 - 44.0
Multifamily HR	40.3	33.6	40.0[a]	Not Available

a. Current analysis for Multifamily HR is based on national data and is not available for CZ4A only.

The DOE methodology uses whole-building energy simulation to assess energy use impacts of code changes. The DOE methodology is based on 16 representative building types across all U.S. climate zones, as defined by Standard 90.1. Energy use intensities (EUIs) by fuel type and by end-use are developed for each building type and weighted by the relative square footage to estimate the difference between the aggregated national energy use under the previous code version, which serves as the baseline, and the new code or standard.

This methodology is also applied to the state level. The state level analysis uses six building types represented by six prototype building energy models. These models represent the energy impact of five of the eight commercial principal building activities that account for 74% of the new construction by floor area covered by the full suite of 16 prototypes. The prototypes represent common construction practice and include the primary conventional HVAC systems most used in commercial buildings. Each prototype building is analyzed for each climate zone found within a state. Using the U.S. DOE EnergyPlus software, the six building prototypes summarized are simulated with characteristics meeting the requirements of the current code and then modified to meet the requirements of the next edition of the code. The energy use and energy cost are then compared between the two sets of models.

Actual and Expected Performance of Office and Multifamily Buildings

The described datasets are combined to graphically present the data to inform city staff and decision makers in their effort to update the Alexandria Green Building Policy.

Medium office building site EUI data is shown in Figure 3 from these previously described data sources:

1. **EnergyStar Portfolio Manager Data Explorer**. For Data Explorer existing building data, the year groupings are limited by the way data is presented making the most recent group data including 2010-2022. This group is used as a proxy for new construction because it is the most recent year grouping that is provided in Data Explorer. The single value shown is the average EUI of the top 25% of performers in the Commonwealth of Virginia. Shown as a vertical dashed red line.
2. **Local benchmarking data:** For local benchmarking data (from Washington, DC and Montgomery County, MD), the single value shown is the average EUI of the top 25% of performers for buildings constructed after 2010. The year 2010 was used in order to align with the vintage of the Data Explorer data. Shown as a vertical dashed red line.
3. **90.1-2022 prescriptive variability data**: Simulation based building energy results for ASHRAE Standard 90.1-2022 that illustrate the range of EUIs that would be expected from buildings complying with the prescriptive path. This analysis limited to climate zone 4A, the only CZ in the Commonwealth of Virginia. Shown as a histogram (orange bars) illustrating model counts by site EUI bins from PNNL analysis of the Medium Office prototype in climate zone 4A for all model design variants. Each model design variant is minimally compliant with the prescriptive requirements of AHSHRAE Standard 90.1-2022.

4. **90.1-2022 CZ4A standard prototype**: This reference EUI value is the prototype building with typical HVAC systems. Shown as a vertical dashed red line.
5. **Analysis of the Virginia specific adoption of 90.1-2016/IECC 2018 and 90.1-2019/IECC 2021**: These reference EUI values represent the Virginia specific adoption of 90.1-2016/IECC 2018 and 90.1-2019/IECC 2021. This analysis is specific to Virginia only and only considers at the standard prototype application of the adopted code versions. Shown as a vertical dashed red line.

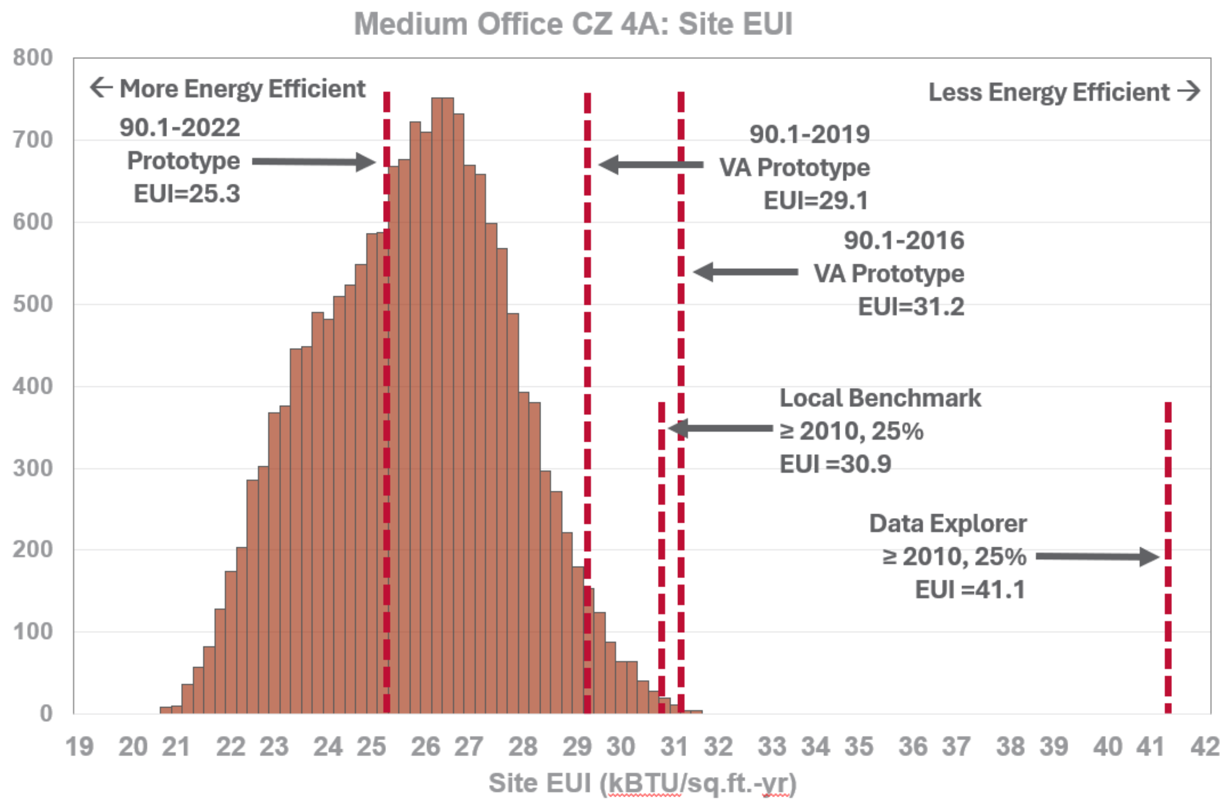

Figure 4. Medium Office Site EUI (kBtu/sq.ft.-yr) from Various Data Sources.

Comparing the local benchmarking data for recently constructed local office buildings with simulated performance data for the Standard 90.1-2022 Medium Office prototype:

- 7.8% of the benchmarked buildings report energy performance that is better than the 90.1-2022 standard prototype for Medium Office.
- 11.8% of the benchmarked buildings report energy performance that falls within the predicted range of energy performance for Medium Office buildings compliant with the prescriptive path of 90.1-2022.

The Midrise multifamily building site EUI data is shown in Figure 5 from the previously described data sets. The Virginia 90.1-2016/IECC 2018 Mid-rise Apartment standard prototype shows the highest site EUI at 37.7, stepping down to data from Data Explorer showing the lowest EUI at 27.3.

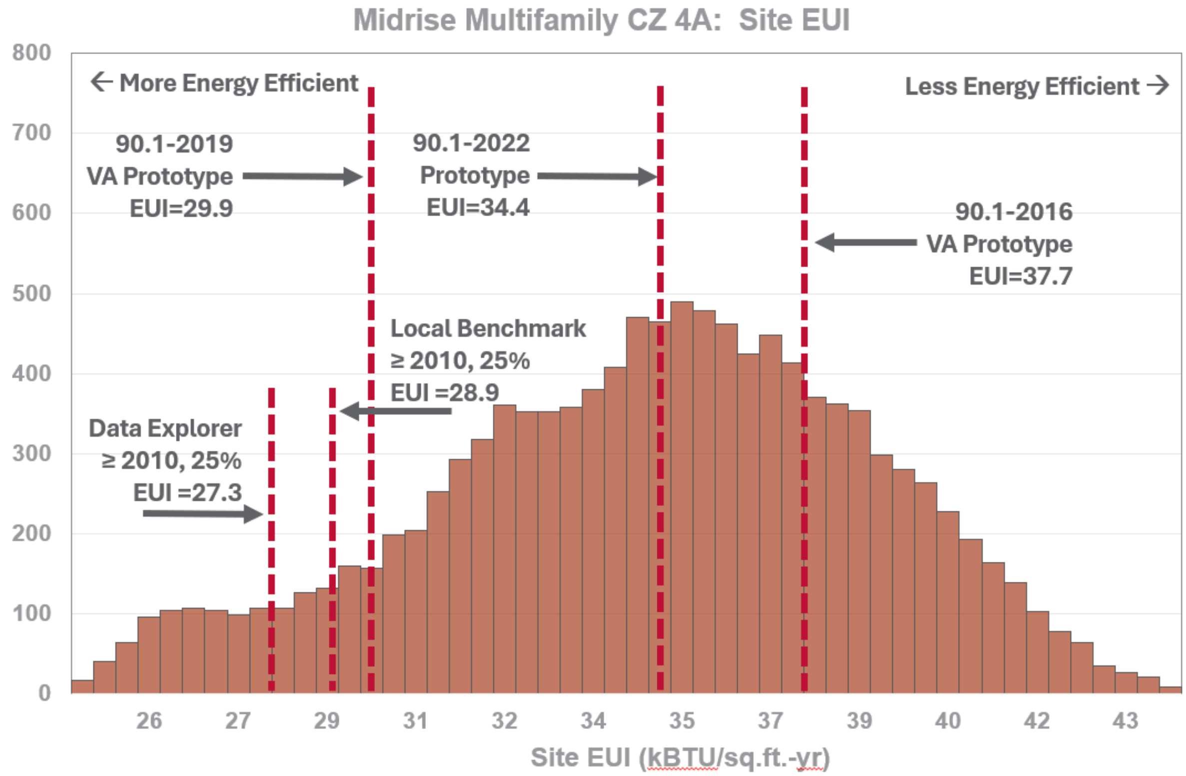

Figure 5. Midrise Multifamily Site EUI (kBtu/sq.ft.-yr) from Various Data Sources

Comparing the local benchmarking data for recently constructed local multifamily buildings with simulated performance data for the Standard 90.1-2022 midrise apartment prototype:

- 29.6% of the benchmarked buildings report energy performance that is better than the 90.1-2022 standard prototype for midrise apartment.
- 67.3% of the benchmarked buildings report energy performance that falls within the predicted range of energy performance for midrise apartment buildings compliant with the prescriptive path of 90.1-2022.

The highrise multifamily building site EUI data is shown in Figure 6, from the previously described data sources, excluding the prescriptive variability study data (which is not currently available for this building type). The Virginia 90.1-2016/IECC 2018 standard prototype shows the highest site EUI at 40.3, stepping down to data from Data Explorer showing the lowest site EUI at 21.2.

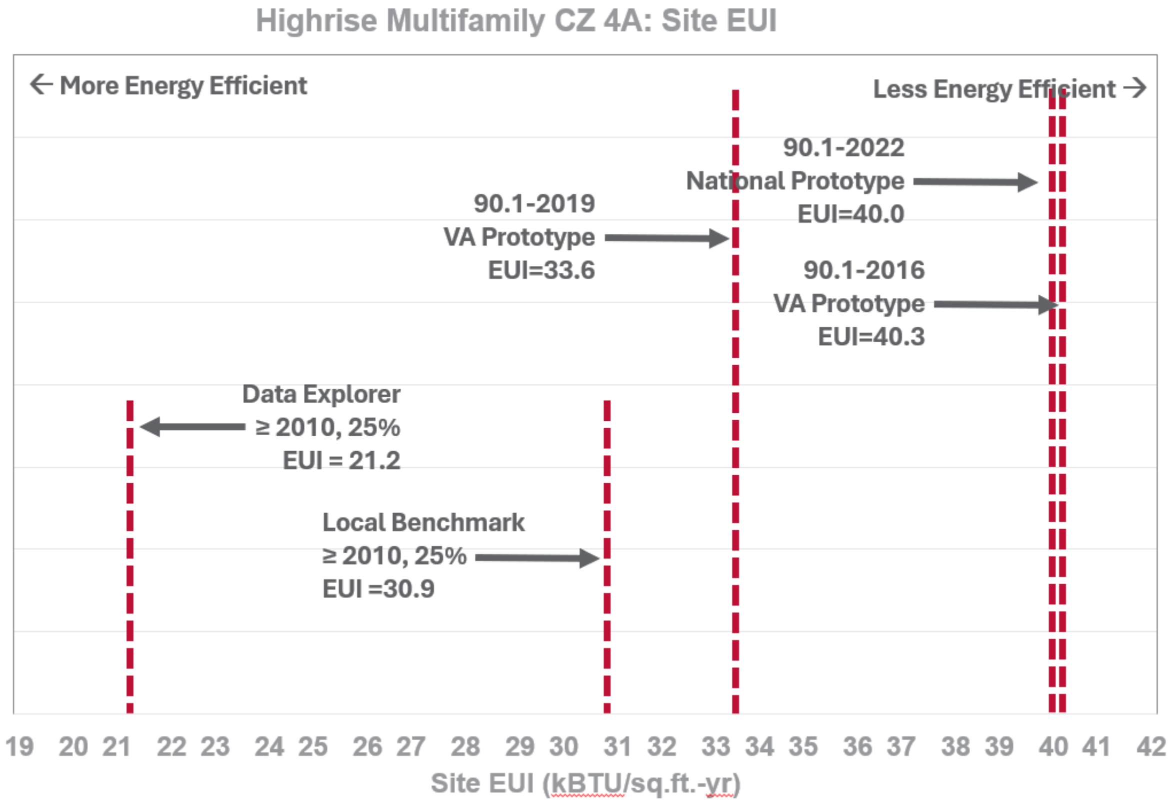

Figure 6. Highrise Multifamily Site EUI (kBtu/sq.ft.-yr) from Various Data Sources

Comparing the local benchmarking data for recently constructed local multifamily buildings with simulated performance data for the Standard 90.1-2022 highrise apartment prototype:

- 33.3% of the benchmarked buildings report energy performance that is better than the 90.1-2022 standard prototype for midrise apartment.

Cost Impacts

Analysis completed for the Commonwealth of Virginia shows that moving from ASHRAE Standard 90.1-2016 to ASHRAE Standard 90.1-2019 is not only cost-effective for Virginia, it also results in lower first costs for new commercial construction.[7] Construction completed in accordance with Standard 90.1-2019 will provide an annual energy cost savings of $0.037 per square foot and reduce first costs by $1.007 per square foot on average across the state.

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[7] Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for Virginia, PNNL-31535. https://www.energycodes.gov/sites/default/files/2021-07/Cost-effectiveness_of_ASHRAE_Standard_90-1-2019-Virginia.pdf

Tables 6 through 8 below show the expected impact of the recent update to Standard 90.1-2019 from a consumer perspective and statewide perspective. The methodology used for this analysis is consistent with the methodology used in the national cost effectiveness analysis.

Table 6. Consumer Impact of 90.1-2019, Commonwealth of Virginia, Statewide

Annual (first year) energy cost savings, $/ft2	$0.037
Added construction cost, $/ft2	-$1.007

Table 7 shows the economic impact of upgrading to Standard 90.1-2019 by building type in Virginia's CZ4A in terms of the annual energy cost savings in dollars per square foot. The annual energy cost savings across CZ4A.

Table 7. Annual Energy Cost Savings for Virginia CZ4A ($/ft^2)

Annual (first year) energy cost savings, $/ft2 (all types)	$0.034
Small Office	$0.032
Large Office	$0.042
Midrise Multifamily	$0.013

Table 8 shows incremental initial cost for individual building types in Virginia's CZ4A and weighted average costs by building type for moving to Standard 90.1- 2019 from Standard 90.1-2016. The incremental construction costs show a negative, or reduction, in first costs across key building types in CZ4A amounting to an immediate payback for building owners.

Table 8. Incremental Construction Cost for Virginia CZ4A ($/ft^2)

Added construction cost, $/ft2	-$1.021
Small Office	-$1.642
Large Office	-$1.926
Midrise Multifamily	-$0.338

Based on the results of the national technical analysis to quantify expected energy savings from Standard 90.1-2022[8], PNNL can estimate that moving from the current energy requirements to updated energy requirements for the Green Building Policy in line with ASHRAE Standard 90.1-2022 would result in an estimated savings of 10.4% for site energy and 9.8% for energy cost in the Commonwealth of Virginia, based on overall savings expected by climate zone.

[8] Details of the analysis, including specific details on amendments with energy impact can be found in the ANSI/ASHRAE/IES Standard 90.1- 2022: Energy Savings Analysis. https://www.energycodes.gov/sites/default/files/2024-02/Standard_90.1-2022_Final_Determination_TSD.pdf

Additionally, the estimated percent gross energy savings nationally between 2019 and 2022 editions of Standard 90.1 by building type (excluding the impact of on-site energy generation) for the building types presented in this memo are presented in Table 9.

Table 9. Estimated Percent Gross Energy Savings between 2019 and 2022 Editions of Standard 90.1 – for Medium Office, Midrise and Highrise Multifamily

		Savings	
Building Type	***Prototype Building***	***Site EUI***	***Energy Cost Index***
Office	Medium Office	10.7%	11.8%
Apartment	Midrise Multifamily	9.7%	9.0%
	Highrise Multifamily	11.7%	10.3%

PNNL expects that state specific analysis will be complete later in calendar year 2024 that will provide a Virginia specific analysis on the updated standard.

Disclaimer for DOE Technical Analysis

Technical assistance and support provided by DOE through a technical assistance request is separate and distinct from any application and programmatic requirements for any federal funding opportunity and does not constitute an endorsement of any application for federal funding. Results from this request, including any technical assistance findings, are bound within the scope of this specific request and should not be interpreted as a determination for eligibility in any funding program. Qualification for federal funding opportunities is determined solely through the established application process and review processes, including eligibility and review criteria therein, and within the established application period for a given opportunity. Any questions regarding DOE funding initiatives should be directed to the cognizant office: Building Technologies Office for inquiries regarding Section 40511 of the Bipartisan Infrastructure Law (BIL) and the Office of State and Community Energy Programs for inquiries regarding Section 50131 of the Inflation Reduction Act (IRA).

CADMUS

City of Alexandria Green Building Policy Analysis

March 14, 2025

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Tables

Executive Summary

The City of Alexandria asked Cadmus to evaluate the impacts of changing its Green Building Policy (GBP). Our analysis considers moving from prescriptive to performance-based building requirements. Our team created energy use baselines, energy targets, and the potential incentives to help spur new development. Cadmus also analyzed three strategies to incentivize development of efficient buildings in Alexandria.

1. Scope of Work

1.1. Task 1. Energy Modeling and Cost Analysis of Changing GBP to Site EUI Targets

Cadmus modeled and researched typical site energy use for each of the five building types, including single-family, hotel, restaurant, retail, and multifamily (all detailed in this section). We modeled each type based on typical new construction buildings in Alexandria to estimate its energy use baseline and target with the EnergyPlus engine. Cadmus used energy modeling tools developed by the Department of Energy (DOE) and National Renewable Energy Lab (NREL). OpenStudio is used by energy experts nationwide to create commercial building models, and BEopt is commonly used for modeling residential buildings.[1]

The target energy use intensities (EUIs) were set at 10% lower than the baseline model EUIs. The baseline models were developed to meet the current Virginia energy code. Table 1 summarizes the modeling results, which we rounded down for simplicity. The far-right column shows the modeled EUIs that were achieved with various energy conservation measures (ECMs). The Hotel and Restaurant models were not able to achieve the improved EUI target with conventional energy efficiency because of their high plug and hot water loads. These building types could achieve the improved EUI target by reducing internal loads or electrifying certain equipment.

Table 1. Summary of Modeled Site EUIs and Improved Targets

Building Type	Modeled EUI Baseline (kBtu/sq ft)	Improved EUI Target (kBtu/sq ft - 10% better)	Modeled EUI Achieved (kBtu/sq ft)
Single-Family[a]	35	31	31.8
Hotel	92	83	88.4
Restaurant	305	274	289
Retail	45	40	40.4
Multifamily	42	38	38.5
As-built Multifamily High-Rise	42.7	NA	39.5[b]

[a] Cadmus developed the single-family model in BEopt, which uses the EnergyPlus engine.
[b] Cadmus developed this model according to the design drawings for the building at 2250 Dock Lane, Alexandria, VA.

Developing Future Performance Targets

Cadmus also compared EUIs from the energy model output for each building type to locally benchmarked data on actual use (Table 2). These data come from local benchmarking programs in

[1] DOE. Accessed August 2024. "OpenStudio." https://www.energy.gov/eere/buildings/articles/openstudio
NREL. Accessed August 2024. "BEopt: Building Energy Optimization Tool." https://www2.nrel.gov/buildings/beopt

Maryland, the District of Columbia, and Virginia and can be accessed using the DOE's Building Performance Database (BPD).[2]

The BPD data was filtered for buildings built after 2010 and in Climate Zone 4A (similar to Baltimore), and each of the four categories had over 1,000 observations. We found that energy use data for multifamily buildings, hotels, retail facilities, and restaurants aligned fairly well between our models and the actual observed energy use data. However, reliable data were not available for single-family home energy use.

Table 2. Modeled and Baseline Building Type EUI's

Building Type	Modeled EUI Baseline (kBtu/sq ft)	Baseline Benchmarked EUI (kBtu/sq ft)
Single-Family	35	NA
Hotel	92	83
Restaurant	305	291
Retail	45	59
Multifamily	42	46

If target site EUIs are needed for additional building types in the future without modeling, we recommend using the following benchmarking approach. After identifying a new building type, use the Building Performance Database to access and filter benchmarking data for that type under the Building Classification tab. To tailor results for Alexandria, filter by location on Maryland, the District of Columbia, and Virginia. If more data points are needed, then expand the geography to Climate Zone 4A (Baltimore, Maryland). If a target for new construction is needed, then limit the Year Built filter to 2010 and later. The selected buildings will represent new construction that uses modern technology and is subject to energy codes.

Once the desired building type and observations are identified, then find the median site EUI for the buildings. Ideally, a collection of hundreds or thousands of observations (building EUIs) is best, and we recommend not drawing conclusions from any data set with fewer than 30 observations.

Estimating Baseline and Incremental Construction Costs

Cadmus also estimated incremental construction costs associated with energy efficiency and electrification upgrades for each building type, which we compared to a regional baseline cost. These findings are detailed below by building type.

To gather information on regional baseline costs, the City of Alexandria surveyed local real estate professionals about their experience with constructing various property types. Cadmus also researched local construction costs using RS Means and other market research. Table 3 summarizes the average costs per square foot (in 2024 U.S. dollars) based on survey responses and researched values. We calculated the incremental costs for each measure using the specific building type's total building area.

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[2] DOE. Accessed February 2025. "Building Performance Database." https://bpd.lbl.gov/.

Cadmus assumed all baseline estimates included the total cost of construction using standard union labor. We normalized each cost estimate to 2024 U.S. dollars and adjusted national estimates to the City of Alexandria's 2019 City Cost Index (CCI) per RS Means, which was 40% higher than the national average.[3] While the results were rough estimates (rounded to nearest 10 dollars per square foot) that included wide ranges of uncertainty, they helped to set the baseline for incremental cost comparisons.

Table 3. Summary of Construction Costs in Alexandria

Building Type	Average Cost ($/sq ft)	Survey Responses and Research Data Points
Single-Family	$420	3
Hotel	$280	3
Restaurant	$490	2
Retail	$360	5
Multifamily	$350	4
Commercial Office*	$250	4

*Cadmus did not model offices, but developers provided construction costs. Typical construction costs in Alexandria, Virginia, were provided by local developers. These typical costs were based on observations and building descriptions from six developers across Virginia. We determined cost values by taking the average of the costs provided by developers and found in our regional research.

Detailed explanations and results for each building type are summarized below. *Appendix A* includes additional information, such as the model inputs, model images, and references.

Single-Family Townhouse

The single-family townhouse modeled baseline adhered to the International Energy Conservation Code (IECC) 2021 and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1 2019 codes. The energy-efficient model achieved a 9% reduction, as shown in Table 4, by incorporating the three listed efficiency measures. It was also determined that this building could incorporate air-source heat pumps for space heating, without any of the efficiency measures included, to achieve a reduction of 24% to the EUI. If instead, they chose to install a heat pump water heater, the site would see a reduction of about 15%. The incremental costs, including electrification, for this building type were less than $4 per sq ft, which would be less than a 1% increase over the current construction cost baseline in Alexandria.

- Building size: 1,680 sq ft
- Number of rooms: 3 bedrooms, 2 bathrooms
- Modeled baseline site EUI: 35 kBtu/ sq ft
- EUI with efficiency measure package: 31.8 kBtu/sq ft

3 RSMeans data. 2019. "RSMeans City Cost Index." https://www.rsmeans.com/rsmeans-city-cost-index.

Table 4. Energy Efficiency and Electrification Measure Information

Measure Type	Measure	Energy Savings	Incremental Cost ($/sq ft)
Efficiency	Install 100% LED Lighting (3% reduction to the lighting power density)	9%	$0.09
Efficiency	Improve insulation in walls, including basement, adding 30% to the overall R-value		$2.53
Efficiency	Improve wall sheathing material, use R-12 Polyisocyanurate board instead of oriented strand board		$0.00
Electrification	Install air-source heat pumps (ASHP) for space heating	24%	-$1.03 to $1.00
Electrification	Install heat pump water heater (HPWH) for domestic hot water	15%	-$0.17

Hotel

The hotel modeled baseline adhered to IECC 2021 and ASHRAE 90.1 2019 codes, and the energy-efficient model did *not* achieve the 10% reduction with energy efficiency measures alone, as shown in Table 5. With the three efficiency measures listed, the site achieved a reduction of about 4%. This shortfall was due to the significant load coming from the water heating and electrical appliances in guest rooms, banquet rooms, kitchens, and laundry spaces.

However, when Cadmus paired the efficiency measures with the electrification of space heating or domestic hot water, the 10% target was achieved or exceeded. With electrification of the domestic hot water system we saw a reduction of about 21%, while electrification of the space heating resulted in about a 4% reduction, similar to the efficiency measure package. The incremental costs, including both efficiency and electrification measures, for this building type were less than $3 per sq ft, so that would be just over a 1% increase over the current new construction cost baseline in Alexandria.

- Building size: 122,120 sq ft
- Total number of units: 183
    - Typical room types: Guest rooms, retail space, dining space, and office
    - Major consumers: Faucets and shower heads (1.6 gallons per minute peak combined)
- Modeled baseline site EUI: 92 kBtu/sq ft
- EUI reduction with efficiency measure package: 88.4 kBtu/sq ft

Table 5. Energy Efficiency and Electrification Measure Information

Measure Type	Measure	Energy Savings	Incremental Cost ($/sq ft)
Efficiency	Improve insulation in walls and roof	4%	$2.09
Efficiency	Increase motor and belt efficiencies		$884.73/motor
Efficiency	Increase boiler and chiller efficiencies		$51/unit; >$0.01/sq ft
Electrification	Install ASHP for space heating	4%	-$0.49
Electrification	Install HPWH for domestic hot water	21%	$0.89 to $0.95

Restaurant

The restaurant modeled baseline adhered to IECC 2021 and ASHRAE 90.1 2019 codes, and the energy-efficient model did *not* achieve the 10% reduction with energy efficiency measures alone, as shown in Table 6. With the five efficiency measures listed, the site was able to achieve a reduction of about 5%. This was due to the site having significant load coming from the water heating and cooking equipment.

However, when Cadmus paired the efficiency measures with the electrification of domestic hot water, the 10% target was achieved or exceeded. With electrification of the domestic hot water system we saw a reduction of about 24%, while electrification of the space heating resulted in about an 8% reduction. The total incremental costs for this building type were less than $15 per sq ft, so that would be about a 3% increase over the current construction cost baseline in Alexandria.

- Building size: 5,502 sq ft
- Major consumers: Water systems and kitchen equipment
- Modeled baseline site EUI: 305 kBtu/sq ft
- EUI with efficiency measure package: 289 kBtu/sq ft

Table 6. Energy Efficiency and Electrification Measure Information

Measure Type	Measure	Energy Savings	Incremental Cost ($/sq ft)
Efficiency	Improve insulation in walls and roof	5%	$2.09
Efficiency	Increase motor and belt efficiencies		$884.73/motor
Efficiency	Increase heating and cooling efficiencies		$51/unit; $0.03/sq ft
Efficiency	Increase hot water boiler COP		$0.41
Efficiency	Daylight sensors in the dining area		$5.05
Electrification	Install ASHP for space heating	8%	$3.56 to $6.80
Electrification	Install HPWH for domestic hot water	24%	$0.89 to $0.95

Retail

The retail modeled baseline adhered to IECC 2021 and ASHRAE 90.1 2019 codes, and the energy-efficient model achieved a 10% reduction with efficiency measures shown Table 7. With the four efficiency measures listed, the site was able to achieve a 10% reduction. When looking into electrification, it was determined that a 15% reduction to the EUI can be achieved though electrification of the space heating, while using heat pumps for hot water would result in a reduction of about 7%. The total incremental costs for this building type were less than $3 per square foot, which would be less than a 1% increase over the current construction cost baseline in Alexandria.

- Building size: 24,692 sq ft
  - Water use: 0.25 gallon per minute peak
  - Major consumers: Natural gas equipment
- Modeled baseline site EUI: 45 kBtu/sq ft
- EUI with efficiency measure package: 40.4 kBtu/sq ft

Table 7. Energy Efficiency and Electrification Measure Information

Measure Type	Measure	Energy Savings	Incremental Cost ($/sq ft)
Efficiency	Improve insulation in walls and roof	10%	$2.09
Efficiency	Increase motor and belt efficiencies		$884.73/motor
Efficiency	Lighting controls (10 sensors)		$0.07
Efficiency	Increase gas burner efficiency		$51/unit
Electrification	Install ASHP for space heating	15%	-$0.49
Electrification	Install HPWH for domestic hot water	7%	$0.95

Multifamily Low Rise

The Multifamily modeled baseline adhered to IECC 2021 and ASHRAE 90.1 2019 codes, and the energy-efficient model achieved a 9% reduction with four efficiency measures, as shown Table 8. For this site, it was determined that using a heat pump water heater for domestic hot water would result in a reduction of about 24%, compared to the electrification of space heating, which would result in a reduction of about 7%. The total incremental costs for this building type were less than $10 per square foot, which would be less than a 3% increase over the current construction cost baseline in Alexandria.

- Building size: 33,740 sq ft
  - Total number of units: 39 residential units, 1 office
  - Typical room types: Residential apartments, office
- Cadmus modeled Baseline Site EUI: 42 (kBtu/ sq ft)
- EUI with efficiency measure package: 38.5 kBtu/ sq ft

Table 8. Energy Efficiency and Electrification Measure Information

Measure Type	Measure	Energy Savings	Incremental Cost ($/sq ft)
Efficiency	Improve insulation in walls and roof	9%	$0.70
Efficiency	Increase motor and belt efficiencies		$884.73/motor; $0.63/sq ft
Efficiency	Increase window U-Value and SHGC		$0.73
Efficiency	Increase cooling efficiency		$1.31
Electrification	Install ASHP for space heating	7%	$3.56 to $6.80
Electrification	Install HPWH for domestic hot water	24%	$0.89 to $0.95

Multifamily High Rise – Eisenhower Block 20

The Multifamily High-Rise model was developed to simulate energy use of the as-designed building at 2250 Dock Lane in Alexandria, Virginia. This building, known as Meridian 2250 at Eisenhower Station, is a 443-unit multifamily building with 26 above-ground stories. The team used ASHRAE 90.1 2019 to define the baseline energy model inputs based on requirements for Climate Zone 4A, which determined the envelope thermal characteristics and HVAC systems. The baseline used packaged terminal heat pumps (PTHPs) for heating and in-unit electric resistance water heaters for domestic hot water (DHW). Table 9 below shows the basic energy model inputs that were used for baseline and as-designed models. This baseline model was projected to use 42.7 kBtu/sq ft in annual energy use, and the design model was projected to use 39.5 kBtu/sq ft in annual energy use. The design showed a potential for 7.4% energy savings over the baseline.

Table 9. Basic Energy Model Inputs

Building Energy Model Input	Baseline	As-Designed
Model guideline	IECC 2021/ASHRAE 90.1 2019	Above Grade Permit Rev 3/21/22
Weather File (CZ4)	JB Anacostia Bolling, US-DC	JB Anacostia Bolling, US-DC
Above grade floors	26	26
Residential units	443	443
Wall construction (exterior)	Mass U-0.090 (11.1) and Steel-Framed: U-0.064 (R-15.56)	Brick and Steel-Framed: U-0.136 (R-7.4)
Roof construction	Metal Deck (R-30.86)	Metal Deck (R-26)
Foundation construction	Unconditioned garage	Unconditioned garage
Model window to wall ratio	40%	47%
Window (U-Factor/SHGC)	0.45 U/0.4 SHGC	0.4 U/0.35 SHGC
Interior Lighting Power Density (LPD)	0.5 W/sq ft	0.4 W/sq ft
Plug Load Density (PLD)	0.9 W/sq ft	0.9 W/sq ft
Hot water (DHW)	In-unit Electric heater, UEF=0.95	In-unit Electric heater, UEF=0.95
Heating System Efficiency (COP)	3	3.25
Cooling System Efficiency (COP)	3	3.55
HVAC	Packaged RTUs + PTHPs	Packaged RTUs + VRF and Split ASHP
Fan Efficiency/Control	0.35 W/CFM	0.35 W/CFM

1.2. Task 2. Costs for Buildings that Achieve a 20% to 30% Lower EUI: Multifamily Reductions

Multifamily building development is crucial for the City of Alexandria and offers significant potential for energy savings through electrification. Cadmus investigated measure packages that can reduce the baseline energy use by 20% to 30%. To achieve these energy savings, Cadmus determined a combination of efficiency and electrification measures suitable for new buildings through EnergyPlus modeling and state Technical Resource Manual (TRM) calculations**.**

Table 10. Phase 2. GBP Analysis - Multifamily Measure Packages

Multifamily Measure Package	Measures included	Energy Use Intensity (EUI in kBtu/sq ft)	Percent Reduction from Baseline	Incremental Cost of Measure Package ($/sq ft)
Baseline	New Construction standard per local code	42.00	0%	N/A(average baseline cost of $350)-
Good	Increase roof insulation by 30%, Increase exterior wall insulation by 30%, Improve window's U-Value to 1.2 and Solar Heat Gain Coefficient (SHGC) to 0.25, Increase cooling COP to 4.5, and Increase motor efficiency to 96%	38.50	8%	$3.37 (1%)
Better	All improvements in the Good Package, plus Reduce elevator load by 10%, Install daylight sensors in corridors, Electrify Space Heating	35.70	15%	$9.31 (3.6)
Best	Increase roof insulation by 30%, Increase exterior wall insulation by 30%, Increase motor efficiency to 96%, Electrify Domestic Hot Water with Heat Pump Water Heater	30.98	26%	$2.28 (4.27)

Good: First 10% site energy use reduction target

Better: Second target with fully electrified space heat (includes all measures from “Good” package)

Best: Third target with fully electrified DHW (three efficiency measures + DHW electrification)

1.3. Task 3. Rooftop Photovoltaic Systems for 3% to 5% Building Energy Offset

The rooftops of all the building types will include areas dedicated to amenities, HVAC equipment, and possibly renewable power. Cadmus analyzed the potential sizes and costs of rooftop solar photovoltaic (PV) systems with an annual electricity production goal of 3% to 5% of the building’s total energy use. Since energy use in single-family homes is relatively low, we also estimated a larger PV system, which typically makes more financial sense for this building type.

Cadmus based the roof areas for each building type on the energy models for that type. We used NREL’s PVWatts calculator and System Advisor Model to model solar PV systems. We assumed building orientations accommodated south-facing PV modules pitched at a 35-degree angle**,** and premium modules were selected. We calculated system costs on a per-watt direct current (DC) basis, with the low estimate at $1.80 and the high estimate at $2.34. Cadmus based these estimates on recent trends for commercial PV system costs and historical information provided by NREL.[4] Table 10 summarizes the full results of our analysis by building type. As shown in the table, most of the building types would still have plenty of space available for mechanical HVAC equipment, amenities for occupants, or potentially a larger PV.

[4] NREL. Accessed February 2025. “Solar Market Research & Analysis.” https://www.nrel.gov/solar/market-research-analysis/solar-installed-system-cost.html

Table 11. Phase 2. GBP Analysis - Solar Analysis by Building Type

Building Type	Offset Target	System Size DC (kW)	System Area (sq ft)	Total Available Roof Space (sq ft)	Roof area available for HVAC (sq ft)	Annual Electricity Production (kWh)	Estimated Module Count	Estimated Install Cost (Low: $1.8/W)	Estimated Install Cost (High: $2.34/W)
Single-Family	3%	0.4	21	469	448	530	2	$720	$936
Single-Family	5%	0.7	34	469	435	862	2	$1,170	$1,521
Single-Family (full system*)	61%	8.0	411	469	58	10,576	24	$14,400	$18,720
Multifamily	3%	10.0	513	8,435	7,922	13,321	30	$18,000	$23,400
Multifamily	5%	17.0	872	8,435	7,563	22,646	50	$30,600	$39,780
Hotel	3%	75.0	3,845	13,790	9,945	99,911	218	$135,000	$175,500
Hotel	5%	125.0	6,408	13,790	7,382	166,518	365	$225,000	$292,500
Retail	3%	7.5	385	12,345	11,960	9,991	22	$13,500	$17,550
Retail	5%	12.0	616	12,345	11,729	15,986	35	$21,600	$28,080
Restaurant	3%	11.0	564	5,500	4,936	14,654	32	$19,800	$25,740
Restaurant	5%	19.0	974	5,500	4,526	25,311	56	$34,200	$44,460

* This "full system" maximizes the number of panels on the South-facing roof.
Please see "Cadmus Memo 3 – City of Alexandria GBP model_20250911.pdf" Table 2 for most up to date cost estimates.

1.4. Task 4. Comparison of Green Building Incentive Types

Cadmus estimated the impacts of green building tax abatement by first assessing the current value of recently built commercial properties using public records. Next, we applied the City of Alexandria's commercial tax rate to these properties and created scenarios for various building certification levels. We then forecasted the number of developments in the permit pipeline likely to pursue energy-efficient design. Finally, we assembled budget scenarios for the City of Alexandria to consider, showing the impact of the proposed tax abatements on the city budget over the given timeframes.

Scope and Methodology

To help the City of Alexandria evaluate updates to its green building policy, Cadmus investigated four possible developer-facing incentives:

- Tax abatement (special tax rate)
- Bonus density
- One-story increase in building height
- Reduced parking minimums

We investigated each of these incentive scenarios using six straw men developments with the following characteristics:

- Recently built (final occupancy in 2018 or after)
- Some form of green building certification (LEED, ENERGY STAR®)

- Locations in diverse Alexandria neighborhoods (Old Town North, Potomac Yard, Eisenhower East, West End)
- Diverse building types (mixed-use, multifamily mid- and high-rise, office), sizes, and heights
- Publicly available property values and information

Table 11 lists the six developments, with links to their City of Alexandria valuation records and basic data for each building. Note that square footage and number of units align with values in the official record.

Table 12. Straw Men Developments

Name and address of property	Public record	Sq ft (gross building area above grade)	Number of units (if multifamily) and stories	Assessed 2024 building value	Assessed 2024 total value (land + building)
APTA Centennial Center, 3030 Potomac Avenue	https://realestate.alexandriava.gov/detail.php?accountno=60032500	115,000	office; 7 stories	$21,207,800	$26,625,000
Gables Old Town North, 525 Montgomery Street	https://realestate.alexandriava.gov/detail.php?accountno=60035450	272,057	232 units, 8 stories	$90,489,435	$109,878,000
The Point at Eisenhower Square, 2827 Telek Place	https://realestate.alexandriava.gov/detail.php?accountno=60036930	516,508	336 units; 23 stories	$100,650,000	$119,130,000
The Dalton Apartments, 1225 First Street	https://realestate.alexandriava.gov/detail.php?accountno=10961500	258,963	270 units; 6 stories	$76,392,000	$93,942,000
Braddock Gateway, 1100 North Fayette Street	https://realestate.alexandriava.gov/detail.php?accountno=10971540	336,904	370 units; 7 stories	$184,270,000	$231,370,000
Park + Ford, 4401 Ford Avenue	https://realestate.alexandriava.gov/detail.php?accountno=50469920	474,000	222 units; 14 stories	$131,110,000	$159,495,000

Tax Abatement or Special Tax Rate

Background. Several local jurisdictions in the Commonwealth of Virginia offer a 50% tax abatement or a special tax rate incentive for one year for energy-efficient buildings, as defined by municipal code. The abatement is typically applied to the *building* value, not the land and building value of the development, and occurs in the first year after proof of performance. In the case of example jurisdictions such as Charlottesville, this involves proof of green building certification, but this incentive could equally apply to demonstrably low energy use intensity or low carbon construction. Because the abatement depends on documentation of an outcome, it may appear as a risk for some developers. However, if the outcomes are successful, the financial reward is significant, although delayed. An advantage in terms of ease of management (to both developers and the City of Alexandria) is that unlike bonus density or construction of an extra story, the special tax rate would not require that developers put up a financial surety as a guarantee of subsequent performance.

Table 12 lists the abatement amounts for each of the example projects, along with the total revenue that Alexandria would forgo if all six met the city's performance standards. Cadmus used the tax rate approved by the city in 2024 to calculate these values: $1.135 per $100 of assessed value (in this case, building value).

Table 13. Sample Development's Abatement Information

Name and address of property	Assessed 2024 building value	Tax (rate of $1.135 per $100 of assessed building value)	50% building value tax abatement for one year
APTA Centennial Center, 3030 Potomac Avenue	$21,207,800	$240,708.53	$120,354.27
Gables Old Town North, 525 Montgomery Street	$90,489,435	$1,027,055.09	$513,527.54
The Point at Eisenhower Square, 2827 Telek Place	$100,650,000	$1,142,377.50	$571,188.75
The Dalton Apartments, 1225 First Street	$76,392,000	$867,049.20	$433,524.60
Braddock Gateway, 1100 North Fayette Street	$184,270,000	$2,091,464.50	$1,045,732.25
Park + Ford, 4401 Ford Avenue	$131,110,000	$1,488,098.50	$744,049.25
TOTAL tax and tax abatement		**$6,856,753.32**	**$3,428,376.66**

Bonus Density

Background. For over 20 years, the City of Alexandria's neighbor, Arlington County, has made bonus density its primary green building incentive. Arlington County bases its award on proof of green building certification, against which developers must offer financial securities. While Table 13 illustrates the benefits to the City of Alexandria in terms of increased property taxes resulting from increased square footage, Arlington County's proof of concept demonstrates that the financial advantages to developers are an even stronger pull.

The following example project, Braddock Gateway, illustrates the strength of bonus density as an incentive for developers when given the opportunity to include additional square footage. Braddock Gateway's rental website advertises studios of 438 sq ft renting at $2,110 per month. If allowed to build an additional 23,055 sq ft (.25 FAR bonus density), this could translate into roughly 52 additional units at an additional $109,720 per month or $1,316,640 per year. At the .35 FAR bonus density level, with as many as 73 additional units, additional rent could be $154,030 per month or $1,848,360 per year.

Table 13 summarizes Cadmus' bonus density calculations for all of the example projects. Please note that because Gables Old Town North's lot size is listed as "0" in the public record (perhaps because it does not own the land it occupies), we did not include it in these calculations.

Table 14. Sample Development's Bonus Density Calculations

Name and address of property	Lot size, square feet	Added sq ft for .25 FAR	Added sq ft for .35 FAR	Building value	Building value per sq ft above grade	Added value at .25 FAR	Added value at .35 FAR	Assumed total assessed value (land+building) with added building value at .25 FAR	Additional annual tax collected based on increased sq ft at .25 FAR	Assumed total assessed value (land+building) with added building value at .35 FAR	Additional annual tax collected based on increased sq ft at .35 FAR
APTA Centennial Center, 3030 Potomac Avenue	19,890	**4,973**	**6,962**	$21,207,800	$184.42	$917,006.83	$1,283,809.56	$27,542,006.83	$10,408.03	$27,908,809.56	$14,571.24
Gables Old Town North,525 Montgo-mery Street	0	**0**	**0**	$90,489,435	$332.61	$0.00	$0.00	$109,878,000.00	$0.00	$109,878,000.00	$0.00
The Point at Eisenhower Square, 2827 Telek Place	145,873	**36,468**	**51,056**	$100,650,000	$194.87	$7,106,432.74	$9,949,005.84	$126,236,432.74	$80,658.01	$129,079,005.84	$112,921.22
The Dalton Apartments, 1225 First Street	43,462	**10,866**	**15,212**	$76,392,000	$294.99	$3,205,235.02	$4,487,329.03	$97,147,235.02	$36,379.42	$98,429,329.03	$50,931.18
Braddock Gateway, 1100 North Fayette Street	92,221	**23,055**	**32,277**	$184,270,000	$546.95	$12,610,093.43	$17,654,130.80	$243,980,093.43	$143,124.56	$249,024,130.80	$200,374.38
Park + Ford, 4401 Ford Avenue	160,099	**40,025**	**56,035**	$131,110,00	$276.60	$11,070,980.95	$15,499,373.34	$170,565,980.95	$125,655.63	$174,994,373.34	$175,917.89
Additional annual total tax collected									**$396,225.65**		**$554,715.91**

Construction of One Additional Story

Background. The advantages of adding one additional story to developers are similar to those of bonus density: added square footage and the ability to build and profit from an entire floor of additional units. However, the height increase may be controversial and even problematic for neighbors. Added height will also impact Alexandria's urban ecosystem in terms of sunlight, wind and ventilation, bird-friendly construction, and more.

Table 14 summarizes the results of Cadmus' analysis of adding one additional story for our example developments. In most cases, we determined the number of stories above grade by looking at visual images of the developments from Google Street View. We then divided the total above-ground square footage by the number of stories to calculate the square footage of each story.

Table 15. Sample Development's with an Additional Story

Name and address of property	Square footage (gross building area above grade)	Number of units (if multifamily) and stories	Assessed 2024 total value (land + building)	Added sq ft for extra story	Assessed 2024 building value	Building value per sq ft above grade	Added value for extra story	Assumed total assessed value (land+buidling) with added building value for extra story	Additional annual tax collected based on increased sq ft
APTA Centennial Center, 3030 Potomac Avenue	115,000	7 stories	$26,625,000	**16,429**	$21,207,800	$184.42	$3,029,685.71	$29,654,685.71	$34,386.93
Gables Old Town North, 525 Montgomery Street	272,057	232 units, 8 stories	$109,878,000	**34,007**	$90,489,435	$332.61	$11,311,179.38	$121,189,179.38	$128,381.89
The Point at Eisenhower Square, 2827 Telek Place	516,508	336 units; 23 stories	$119,130,000	**22,457**	$100,650,000	$194.87	$4,376,086.96	$123,506,086.96	$49,668.59
The Dalton Apartments, 1225 First Street	258,963	270 units; 6 stories	$93,942,000	**43,161**	$76,392,000	$294.99	$12,732,000.00	$106,674,000.00	$144,508.20
Braddock Gateway, 1100 North Fayette Street	336,904	370 units; 7 stories	$231,370,000	**48,129**	$184,270,000	$546.95	$26,324,285.71	$257,694,285.71	$298,780.64
Park + Ford, 4401 Ford Avenue	474,000	222 units; 14 stories	$159,495,000	**33,857**	$131,110,000	$276.60	$9,365,000.00	$168,860,000.00	$106,292.75
ADDITIONAL TAX PER YEAR									**$762,019.00**

Reduced Parking Minimums

Background. The push to reduce or eliminate parking minimums has become a full-fledged national "parking reform" movement, with advocates tying parking oversupply to traffic congestion, environmental harm, and housing unaffordability. Consider that the cost to build a single off-street, under-grade (not electric-vehicle-ready) parking space in New York City is now estimated at $150,00.[5] Developers pass these costs on to tenants in the form of increased rent. The extent to which local jurisdictions may be able to lift parking mandates depends on factors such as availability and proximity of local public transit, urban walkability, nearness of services such as grocery stores and schools, and the relationship of housing location to employment. It also depends on politics, wealth, status connected with car ownership, and the city's ability to manage street infrastructure and on-street parking rules.

Because construction of new surface parking in an increasingly dense and land-scarce urban region is rare, Cadmus assumed that new parking areas would be underground or garage parking, with an estimated cost of $85,000 per space. We based this regional cost figure on the median value in the range of $70,000 to $100,000, as cited in a 20204 Montgomery County press release summarizing public testimony in support of lifting parking minimums.[6] The savings of avoided parking space construction would accrue to developers; we did not monetize the environmental and social benefits to the City of Alexandria and its neighborhoods. For multifamily buildings, Alexandria parking minimums are tied to the number of bedrooms per dwelling unit. Since this information was not publicly available for the example projects, Cadmus assumed that 20% of the total number of units in a development were two bedrooms and 80% were one bedroom. (Alexandria defines studios and one-bedroom units as one-bedroom equivalents.) We also assumed that all example multifamily projects would be eligible for a 50% reduction of the parking minimum. Table 15 summarizes the results of our analysis.

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5 Openplans.org. March 2023. *Lifting Parking Mandates in New York City*. https://static1.squarespace.com/static/5e71380706dc865d40a6f93c/t/6414c8fb08a2bf368b41ca51/1679084194164/Parking+Mandates_whitepaper_OpenPlans.pdf

6 Montgomery County Council. March 5, 2024. Press Release. "Council Enacts Zoning Measure to Eliminate Parking Requirements and Promote Housing Near Transit Hubs." https://www2.montgomerycountymd.gov/mcgportalapps/Press_Detail.aspx?Item_ID=44870

Table 16. Sample Development’s with Reduced Parking Minimums

Name and address of property	Square footage (gross building area above grade)	Number of units (if multi-family)	Number of bed-rooms (see assump-tions in text)	Parking now required (.8 spaces per bedroom)	Reduced parking scenario (for MF, half [.4] of required minimum)	Number of avoided spaces	Savings to developers, in dollars ($85,000 per avoided space)	Office calculation of .25 spaces per 1000 sq ft of building area	Savings to developers, in dollars ($85,000 per avoided space)
APTA Centennial Center, 3030 Potomac Avenue	115,000						N/A	115 spaces required: 25% reduction = 29 avoided spaces	**$2,465,000**
Gables Old Town North, 525 Montgomery Street	272,057	232 units	271	217	108	109	**$9,265,000**		N/A
The Point at Eisenhower Square, 2827 Telek Place	516,508	336 units	403	322	161	161	**$13,685,000**		N/A
The Dalton Apartments, 1225 First Street	258,963	270 units	324	259	130	129	**$10,965,000**		N/A
Braddock Gateway, 1100 North Fayette Street	336,904	370 units	444	355	178	177	**$15,045,000**		N/A
Park + Ford, 4401 Ford Avenue	474,000	222 units	266	213	106	107	**$9,095,000**		N/A

Utility

Dominion Energy is the electricity utility serving the City of Alexandria. Dominion Energy actively provides various incentives related to green building, clean energy, and electrification policies, as summarized below.[7]

Technical Assistance/Assessments

Income and Age Qualifying Energy Efficiency Program. Qualifying customers receive a free site visit including a custom energy assessment report and installation of energy-saving products.

Home Energy Assessment Program. Residential customers receive a home energy assessment from qualified contractors who perform the assessment and recommend improvements. They receive a customized report containing cost-effective options and recommendations to help them reduce their energy usage. Recommended measures include installing lighting, hot water appliances, efficient faucets and aerators, and cool roofs; tuning up and upgrading heat pumps; and sealing and insulating ducts.

EnergyShare. In addition to energy bill payment assistance, qualifying customers can receive free weatherization services and educational tips to help reduce their energy usage by making lasting energy-saving improvements.

Small Business Improvement Enhanced Program. This program provides on-site energy assessment of customer's facilities. Qualifying customers can receive incentives for making energy efficiency improvements identified during the assessment.

Commercial Equipment Distributors: EE Midstream Program. Qualifying customers can upgrade their business with ENERGY STAR-rated products, like food service appliances and more efficient heating and air conditioning.

New Construction Program. Qualifying customers receive customized recommendations and incentives for installing energy-efficient measures in new construction projects. Eligible buildings include small and medium offices, stand-alone retail shops, and outpatient healthcare facilities.

Multifamily Program. Property owners and managers receive an on-site energy assessment of common areas and tenant units and a follow-up report identifying and quantifying savings opportunities, estimated project costs, and available incentives.

Rebates/Financial Incentives

Commercial Lighting Systems and Controls Program. Participating customers may receive a rebate from Dominion Energy Virginia by upgrading lighting or installing new energy-efficient lighting and controls.

Non-Residential Office Energy Management System Efficiency Program. Participating customers may receive a rebate from Dominion Energy Virginia by recommissioning improvements made to their

7 Virginia Energy Sense. Accessed February 2025. "Incentives and Rebates." https://www.virginiaenergysense.org/incentives-and-rebates/

office's energy management system. Program measures available include scheduling lighting, heating, and air conditioning equipment, setting a different temperature at night, and resetting the chiller condenser air temperature.

Distributed Generation Program. Participating customers receive an incentive to use their on-site backup generation to reduce the use of electricity when electrical demand is high. Customers operate their on-site backup generation to supply some or all of their electrical needs during load control events for up to 120 hours per year.

Appliance Rebates. Rebates are available for the following ENERGY STAR–certified appliances:

- Refrigerator ($50)
- Freezer ($50)
- Clothes washer ($50)
- Electric clothes dryer ($100)
- Dehumidifier ($25)
- Room air purifier ($50)
- Dishwasher ($50)

Appliance Recycling. Dominion Energy offers a $20 rebate for recycling an old refrigerator or freezer.

EnergyShare. In addition to energy bill payment assistance, qualifying customers receive free weatherization services and educational tips to help reduce their energy usage and lower their bills by making lasting energy-saving improvements.

Small Business Improvement Enhanced Program. This program provides customers with an energy assessment of their facility and incentives for making energy efficiency improvements identified during the assessment.

Agriculture Program. Eligible Dominion Energy customers receive rebates for high-efficiency agricultural equipment, lighting, etc. Participants also have access to Dominion Energy's network of equipment vendors and contractors associated with the agricultural industry.

Existing Building Automation and Controls Program. Eligible customers receive rebates for making recommissioning improvements to their facility's energy management system.

Data Server Room Program. This program is designed to conserve energy in data server rooms at dedicated data center buildings, offices, hospitals and health care buildings, private universities, manufacturing facilities, large industrial facilities, colocation data centers, cloud-based data centers, modular data centers, etc.. The program offers rebates to eligible Dominion Energy Virginia customers for installing high-efficiency computer room air conditioner or computer room air handler units, a high-efficiency power supply, space temperature set point adjustment, lighting occupancy sensors, etc.

Healthcare Energy Solutions Program. This program provides incentives for efficient technologies used in healthcare facilities, including indoor lighting, outdoor lighting, cooling, ventilation, refrigeration, vending machines, cooking equipment, and motors.

New Construction Program. Eligible customers receive customized recommendations and incentives for implementing energy-efficient measures in their new construction project. Eligible buildings include small and medium offices, stand-alone retail shops, and outpatient healthcare facilities.

Hotel and Lodging Energy Solutions Program. This program provides incentives for efficient technologies used in hotels, motels, and dormitories, including indoor lighting, outdoor lighting, cooling, ventilation, refrigeration, vending machines, cooking equipment, and motors.

Prescriptive Enhanced Program Bundle. Qualifying customers receive a rebate for improvements made to ductwork, HVAC system, kitchen appliances, and refrigeration systems.

Federal

Financial Incentives

Fannie Mae Green Financing Loan Program. This program offers mortgage financing to apartment buildings and cooperatives (with five or more units) to finance energy and water-efficiency improvements. Its green financing programs include Green Rewards and beneficial pricing for loans secured by a property with an eligible Green Building Certification.

Energy-Efficient Mortgages. Homeowners can receive energy-efficient mortgages to either fund energy efficiency improvements to existing homes, including renewable energy technologies or to increase their home buying power with the purchase of a new energy-efficient home. The U.S. federal government insures these loans through Federal Housing Authority or Veterans Affairs programs.

Weatherization Assistance Program (WAP). Through WAP, the U.S. DOE issues grants to states, territories, and some Indian tribes to increase the energy efficiency of low-income homes in their jurisdictions. The DOE and state governments do not issue grants directly to low-income families or perform the retrofits. States, territories, and Indian governments contract with local governments and nonprofit agencies that provide the weatherization services. Low-income homes that qualify for the program will receive free weatherization based on the needs of the home and the rules in the state.

Residential Energy Conservation Subsidy Exclusion. According to Section 136 of the U.S. Code, energy conservation subsidies provided to customers by public utilities are non-taxable. This exclusion does not apply to electricity-generating systems registered as "qualifying facilities" under the Public Utility Regulatory Policies Act of 1978. If a taxpayer claims federal tax credits or deductions for the energy conservation property, the investment basis for the purpose of claiming the deduction or tax credit must be reduced by the value of the energy conservation subsidy (i.e., a taxpayer cannot claim a tax credit for an expense that the taxpayer ultimately did not pay).

Residential Renewable Energy Tax Credit. A taxpayer may claim a credit for a renewable energy system that serves a dwelling unit that is owned and used as a residence by the taxpayer. Expenditures with respect to the equipment are treated as made when the installation is completed. If the installation is at a new home, the "placed in service" date is the date of occupancy by the homeowner. Expenditures include labor costs for on-site preparation, assembly or original system installation, and piping or wiring to interconnect a system to the home.

U.S. Department of Energy Loan Guarantee Program. Under Section 1703, DOE is authorized to issue loan guarantees for projects with high technology risks that "avoid, reduce or sequester air pollutants or anthropogenic emissions of greenhouse gases; and employ new or significantly improved technologies as compared to commercial technologies in service in the United States at the time the guarantee is issued."

Low Income Home Energy Assistance Program (LIHEAP). The LIHEAP provides resources to aid families with energy costs. This assistance helps in managing costs associated with home energy bills, energy crises, weatherization, and energy-related minor home repairs.

Business Energy Investment Tax Credit (ITC). The ITC offers a 6% to 30% tax credit depending on status of the project and labor factors and other bonus tax credits depending on domestic content percentage and communities served by renewable energy development.

Renewable Electricity Production Tax Credit. – This tax credit is a per kilowatt-hour tax credit for electricity generated by qualified energy resources and sold by the taxpayer to an unrelated person during the taxable year. The length of the credit is 10 years after the date the facility is placed in service.

Energy-Efficient Commercial Buildings Tax Deduction. This tax deduction is available to owners of qualified commercial buildings and designers of buildings that achieve at least 25% overall energy savings compared to an ASHRAE Reference Standard 90.1 model.

Residential Energy Efficiency Tax Credit. Property owners may receive tax credits for energy efficiency improvements. Tax credits vary depending on when the building was built (before or after January 1, 2023).

Energy-Efficient New Homes Tax Credit for Home Builders. Homes builders can receive tax credits for energy efficiency upgrades. Tax credits vary depending on when the building was built (homes constructed or acquired before or after January 1, 2023).[8]

[8] NC Clean Energy Technology Center. Accessed February 2025. “Programs.” https://programs.dsireusa.org/system/program?zipcode=20598

State

Regulation

Virginia Solar Rights. According to state law, community associations in Virginia generally may not prohibit a homeowner from installing or using a solar energy collection device on their property.

Virginia Solar Easements. The Virginia Solar Easements Act of 1978 allows property owners to create binding solar easements for the purpose of protecting and maintaining proper access to sunlight.

Net Metering. Net metering in Virginia is available on a first-come, first-served basis until the rated generating capacity owned and operated by customer-generators reaches 1% of an electric distribution company's adjusted Virginia peak-load forecast for the previous year. Net metering is available to customers of investor-owned utilities.

Shared Solar Program. In April 2021, the General Assembly enacted Chapter 532 (HB 1855) during special session I. The chapters authorize the shared solar program in the service territory of Dominion Energy Virginia with an aggregate capacity maximum of 150 MW.

Multi-Family Shared Solar Program. In April 2020, the Virginia General Assembly enacted Chapters 1187 (SB 710), 1188 (HB 572), 1188 (HB 1184), 1239 (HB 1647) of the 2020 Virginia Acts of Assembly. The chapters authorize a Multi-Family Shared Solar program in the service territories of Dominion Energy Virginia and Old Dominion Power. System size is limited to 3 MW, up to 5 MW cumulative for systems on contiguous locations owned by the same entity.

Commercial Solar Property Tax Exemption. The following property tax exemptions for solar facilities are available in Virginia: (1) 100% property tax exemption for the assessed value of equipment and facilities used in projects equaling 20 MW or less that serve a public institution of higher education or private college or projects equaling 5 MW or less, (2) 80% property tax exemption for the assessed value of equipment and facilities used in other projects over 5 MW and less than 150 MW. The exemption for projects greater than 20 MW shall not apply to projects upon which the construction begins after January 1, 2024.

Rebates/Financial Incentives

Income Tax Deduction for Energy-Efficient Products. Virginia taxpayers may deduct from their taxable personal income an amount equal to 20% of the sales taxes paid for certain energy-efficient equipment. The maximum incentive is $500.

Sales Tax Exemption for Energy-Efficient Products. Virginia allows sales tax exemption for dishwashers, clothes washers, air conditioners, ceiling fans, light bulbs, dehumidifiers, programmable thermostats, and refrigerators that reach federal ENERGY STAR standards. To qualify for the incentive, the products must meet or go beyond the federal ENERGY STAR or the Environmental Protection Agency's WaterSense standard, be $2,500 or less per product, and be purchased for noncommercial or personal use.

Small Business and Nonprofit Loan Program. In April 2014, H.B. 864 mandated that the Virginia Small Business Financing Authority provide funding for wind and solar projects to small businesses and nonprofits.

Energy Project and Equipment Financing. In March 2011, H.B. 2389 added renewable energy to the list of eligible projects which the Virginia Resources Authority can provide funding assistance to local governments in Virginia.

VirginiaSAVES Green Community Loan Program. This program provides low-cost financing to private commercial and industrial, nonprofits, and local governments for a wide range of energy efficiency and renewable energy projects in the state. The program works with third-party funding sources to provide funding for projects. The program is administered by CleanSource Capital, LLC.[9]

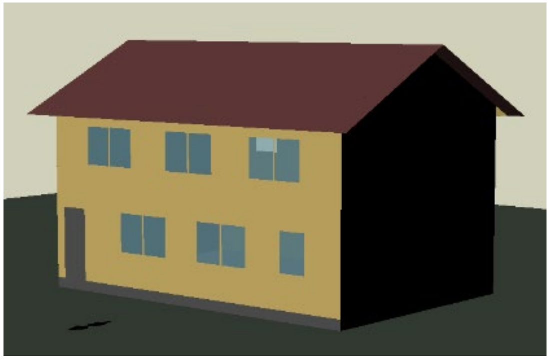
[9] NC Clean Energy Technology Center. Accessed February 2025. "Programs." https://programs.dsireusa.org/system/program?zipcode=20598

Appendix – modeling and cost estimate details

This appendix gives further detail and information on the energy modeling and cost estimation process. Calculations and references are organization by building type. A table at the end of this section shows all the EnergyPlus modeling inputs.

Overall, electrification incremental costs have a wide range depending on technology and property type. For simplicity, $5.50/sf was used as an estimate for the air source heat pump (ASHP) upgrade, and $0.95/sf was used for the heat pump water heater (HPWH) upgrades

1. Single Family
    a. Lighting Fixtures – RS Means
        i. 10" diameter, 36W LED = 503.09
        ii. Fluorescent, interior, 32W and 40W = 242.11
        iii. Baseline is 40% LED
            1. 503.09(0.4) + 242.11(0.6) = 346.50
            2. 503.09-346.5 = $156.59 / 1680 = $0.09/sf
    b. Insulation and Heat pumps - NREL Energy Efficiency Tool - https://remdb.nrel.gov/
        i. Insulation – Cost per square foot of wall area = $1.20 with 3,500 sq ft of wall and 1680 sq ft of floor area.
        ii. Heat pumps – basic heat pump cost is $3,400 per installation compared to $1,800 for basic furnace, so that is approximately $1.00 per square foot in incremental cost
    c. Wall sheathing – costs for OSB and R-12 polyiso board vary by less than $0.02
    d. Heat pumps for heating and domestica hot water – BuildingDecarbCostStudy.pdf
        i. "Cost Study of the Building Decarbonization Code." *New Buildings Institute*, Apr. 2022, newbuildings.org/wp-content/uploads/2022/04/BuildingDecarbCostStudy.pdf.

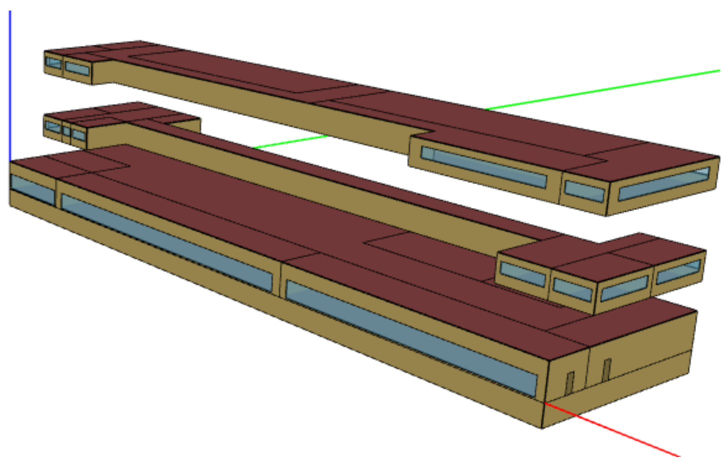


2. Hotel
    a. Incremental Costs
        i. Assume (1) chiller, (1) boiler, and (2) fan motors are upgraded
        ii. $884.73 * 2 = 1769.46 (/ 122120 = $0.01 / sq ft)
        iii. 51 * 2 = 102 (/ 122120 = $0.00 / sq ft)
    b. Heat pump for space heat - BuildingDecarbCostStudy.pdf

i. "Cost Study of the Building Decarbonization Code." *New Buildings Institute*, Apr. 2022, newbuildings.org/wp-content/uploads/2022/04/BuildingDecarbCostStudy.pdf.

c. Insulation – RS Means
   i. Blanket insulation for walls R13, 11" wide
      1. (2.5" thick R10.9 fiberglass = 4.30/sf)
   ii. Motor and Belt Efficiencies
      1. Baseline 5 HP motor = $368.64
      2. Drip proof, premium efficiency 5 HP motor = $1,253.37
         a. 1253-368= $884.73 / 122120 = $0.007244/sf
   iii. Heating and Cooling Efficiencies
      1. 3 T air cooled = $6,007.38
      2. 3 T water cooled = $6,057.88
         a. $50.50 per unit

d. NYSERDA's Building of Excellence program data: https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence/Winners/Resources
   i. Incremental costs before incentives for all-electric DHW systems range from even to $7.76 per sq ft, the median was $0.00 and the average was $0.95



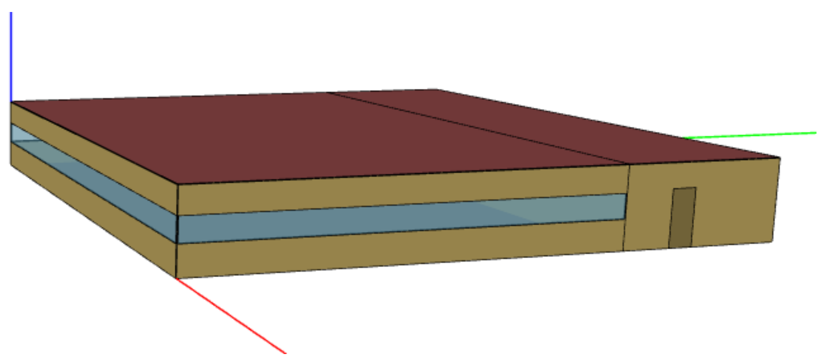
3. Restaurant
   a. Incremental Costs
      i. Assume upgrades are made in both the Kitchen and Dining Zones
         1. 884.73 * 2 = 1769.46 (/ 5502 = $0.32 / sq ft)
         2. 51 * 2 = 102 (/ 5502 = $0.02 / sq ft)
   b. RS Means
      i. Blanket insulation for walls R13, 11" wide
         1. (2.5" thick R10.9 fiberglass = 4.30/sf)
      ii. Daylight sensors, manual control = $278 per sensor
      iii. Motor and Belt Efficiencies
         1. Baseline 5 HP motor = $368.64

2. Drip proof, premium efficiency 5 HP motor = $1,253.37
   a. 1253-368= $884.73 / 5502 = $0.16/sf

iv. Hot water boiler
   1. 85 MBH (84%) = 3814.63
   2. 94 MBH (95%) = 6052.78
      a. 2238.15 / 5502 = $0.4067

v. Heating and Cooling Efficiencies
   1. 3 T air cooled = $6,007.38
   2. 3 T water cooled = $6,057.88
      a. $50.50 per unit

c. NYSERDA's Building of Excellence program data: https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence/Winners/Resources
   i. Incremental costs before incentives for all-electric HVAC range from $0.03 to $17.19 per sq ft, the median was $1.05 and the average was $3.56
   ii. Incremental costs before incentives for all-electric DHW systems range from even to $7.76 per sq ft, the median was $0.00 and the average was $0.95

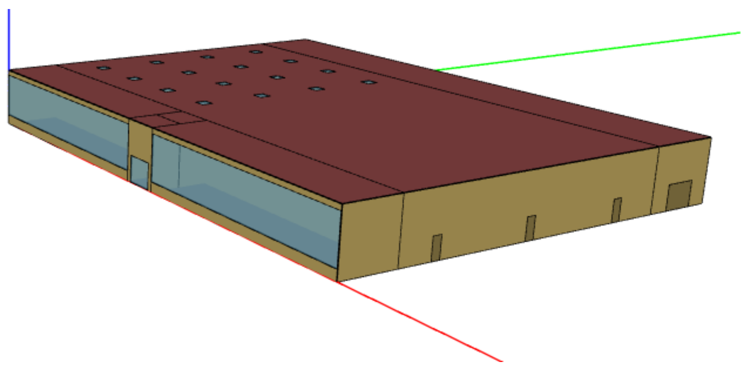


4. Retail
   a. Incremental Costs
      i. Assume upgrades are made in all 4 Zones
         1. 884.73 * 4 = 3538.92 (/ 24692 = $0.14 / sq ft)
         2. 51 * 4 = 204 (/ 24692 = $0.01 / sq ft)
   b. Heat pump for space heat - BuildingDecarbCostStudy.pdf
      i. "Cost Study of the Building Decarbonization Code." *New Buildings Institute*, Apr. 2022, newbuildings.org/wp-content/uploads/2022/04/BuildingDecarbCostStudy.pdf.
   c. RS Means
      i. Blanket insulation for walls R13, 11" wide
         1. (2.5" thick R10.9 fiberglass = 4.30/sq ft)
      ii. Occupancy sensor, passive infrared = 177.62 ea
      iii. Motor and Belt Efficiencies
         1. Baseline 5 HP motor = $368.64
         2. Drip proof, premium efficiency 5 HP motor = $1,253.37

a. 1253-368= $884.73 / 24692 = $0.358/sf

iv. Heating and Cooling Efficiencies
1. 3 T air cooled = $6,007.38
2. 3 T water cooled = $6,057.88
a. $50.50 per unit

d. DHW Electrification NYSERDA's Building of Excellence program data: https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence/Winners/Resources
i. Incremental costs before incentives for all-electric DHW systems range from even to $7.76 per sq ft, the median was $0.00 and the average was $0.95

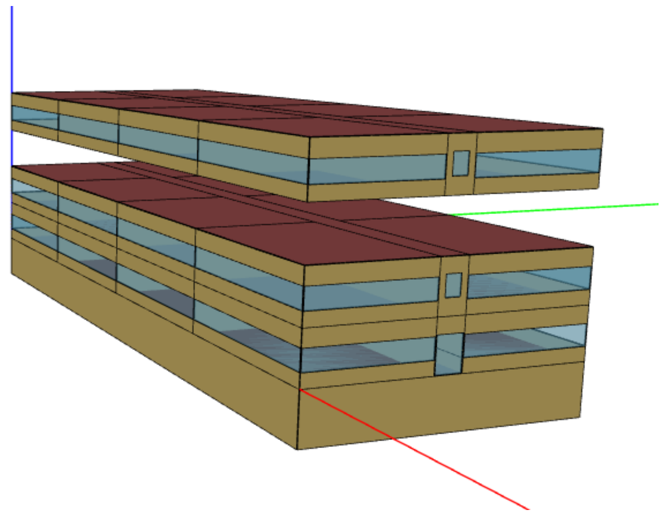


5. Multifamily
a. Incremental Costs
i. Assume upgrades are made in all 24 Zones, representing each space type
1. 884.73 * 24 = 21233.52 (/ 33740 = $0.63 / sq ft)
b. Microsoft PowerPoint - NEEA_Partner_Webinar-20170720
i. "Building Innovation - Multifamily." *New Buildings Institute*, 16 Mar. 2016, newbuildings.org/wp-content/uploads/2017/08/NEEA_Partner_Webinar-20170720.pdf.
ii. Incremental cost of installing cold climate heat pump in Boston was $6.80
c. Guide to Energy-Efficient Windows
i. "Guide to Energy-Efficient Windows." *U.S. Department of Energy*, Oct. 2010, www.energy.gov/sites/prod/files/guide_to_energy_efficient_windows.pdf.
d. NREL Energy Efficiency - EE Measures Database: https://remdb.nrel.gov/
e. NYSERDA's Building of Excellence program data: https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence/Winners/Resources
i. Incremental costs before incentives for all-electric HVAC range from $0.03 to $17.19 per sq ft, the median was $1.05 and the average was $3.56
ii. Incremental costs before incentives for all-electric DHW systems range from even to $7.76 per sq ft, the median was $0.00 and the average was $0.95
f. Motor and Belt Efficiencies
i. Baseline 5 HP motor = $368.64
ii. Drip proof, premium efficiency 5 heat pump motor = $1,253.37

1. 1253-368= $884.73 / motor

g. Elevator Improvement
   i. Average cost for standard elevator = $97,500
   ii. Average cost of efficient elevator = $110,500
      1. Difference of $13,000 = Incremental cost of $0.39/sf

h. Daylight Sensors
   i. 16 sensors, 4 per corridor on 4 floors @ ~$100 each
   ii. $1,600 total gives and incremental cost of $0.05/sf



Building Simulation Model Inputs					
Type Index	1	2	3	4	5
Building Type	Single Family Homes (townhome)	Multifamily Low Rise (1-4 Stories)	Hotel	Retail	Restaurants
Baseline Code	IECC 2021/ASHRAE 90.1 2019				
Vintage	New Construction				
Weather File (CZ4)	Washington-DC-Reagan-AP VA USA TMY3				
Number of floors (Above Grade)	2	4	4	1	1
Spaces	3 Bedrooms, 2 Bathrooms	39 Units, 1 Office	183 Guest rooms, Retail, Dinning, Office	Retail Space, Point of Sale	Kitchen, Dinning
Total Building Sq. Ft.	1,680	33,740	122,120	24,692	5,502
HVAC	Central AC and Gas-fired furnace	Split AC (with gas heating)	VAV with Reheat plus DOAS with ERV in guest rooms (Includes Economizer)	Unitary AC with gas heating coil	Unitary AC with gas heating coil
Hot water (DHW)	Storage Water Heater, Gas	Electric Water Heater	Storage Water Heater, Gas	Storage Water Heater, Gas	Storage Water Heater, Gas
Heating Efficiency (AFUE)	0.8	0.8	0.8	0.8	0.8
Cooling System Efficiency (SEER/EER/COP)	SEER 14	SEER 14	SEER 14	SEER 14	SEER 14
Heating Set Point (F)	70	70	70	70	70
Cooling Set Point (F)	73	73	73	73	73
Wall Construction (exterior)	Insulated Wood Framed(R-20)	Insulated Wood Framed(R-20)	Insulated Metal Building Wall (R-13.89)	Insulated Exterior Mass Wall (R-9.62)	Insulated Steel Framed (R-15.63)
Roof Construction	Insulated Attic (R-60)	IEAD Roof (R-31.25)	IEAD Roof (R-31.25)	IEAD Roof (R-31.25)	IEAD Roof (R-31.25)
Foundation Construction	Unconditioned Basement (Whole Wall- R10)	Unconditioned Basement (Whole Wall-R10)	Unconditioned Basement	Slab on Grade (F-Factor 0.52 Btu/hr.ft.R)	Slab on Grade (F-Factor 0.52 Btu/hr.ft.R)
Model Window to wall ratio	20%	40%	27%	20%	18%
Window (U-Factor / SHGC)	0.3U / 0.4 SHGC	0.36U / 0.36 SHGC	0.36U / 0.36 SHGC	0.36U / 0.36 SHGC	0.36U / 0.36 SHGC

CADMUS

Memorandum

To: Dustin Smith and Ryan Freed; City of Alexandria Office of Climate Action

From: Sean Brennan and Matthew Hill; Cadmus

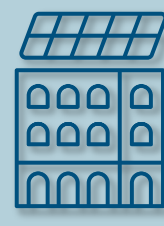
Subject: Additional Modeling Scope

Date: September 12, 2025

Introduction

The City of Alexandria asked Cadmus to evaluate the impacts of the City changing its Green Building Policy (GBP). Our analysis considers moving from prescriptive to performance-based building requirements, and we considered the requirements and impacts of various rooftop solar photovoltaic (PV) systems. Our team created energy use baselines, energy targets, and potential incentives to help spur new energy-efficient development in Alexandria. Cadmus modeled and researched typical site energy use for each of the five building types: single-family, hotel, restaurant, retail, and multifamily (all detailed in a previous report).

> To evaluate the impacts of the City of Alexandria changing its Green Building Policy, Cadmus modeled various rooftop solar PV systems and researched typical site energy use.



We initially created a generic prototype model with inputs from typical new construction buildings in Alexandria to create an energy use baseline and target with the Department of Energy's (DOE) EnergyPlus engine. The City requested more-detailed modeling on the multifamily building based on inputs from a project that was actually constructed in Alexandria. This memo details the latest high-rise multifamily energy models and solar system estimates.

High-Rise Multifamily Detailed Energy Model

Cadmus created a new energy model in July 2025 to simulate energy use of the as-designed building at 2250 Dock Lane in Alexandria, Virginia. This building, known as Meridian 2250 at Eisenhower Station, is a 443-unit multifamily building with 26 above-ground stories. It consists primarily of residential apartments, amenity spaces, and garage parking. The model groups offices and amenities together and defines the garage spaces as ventilated but unconditioned.

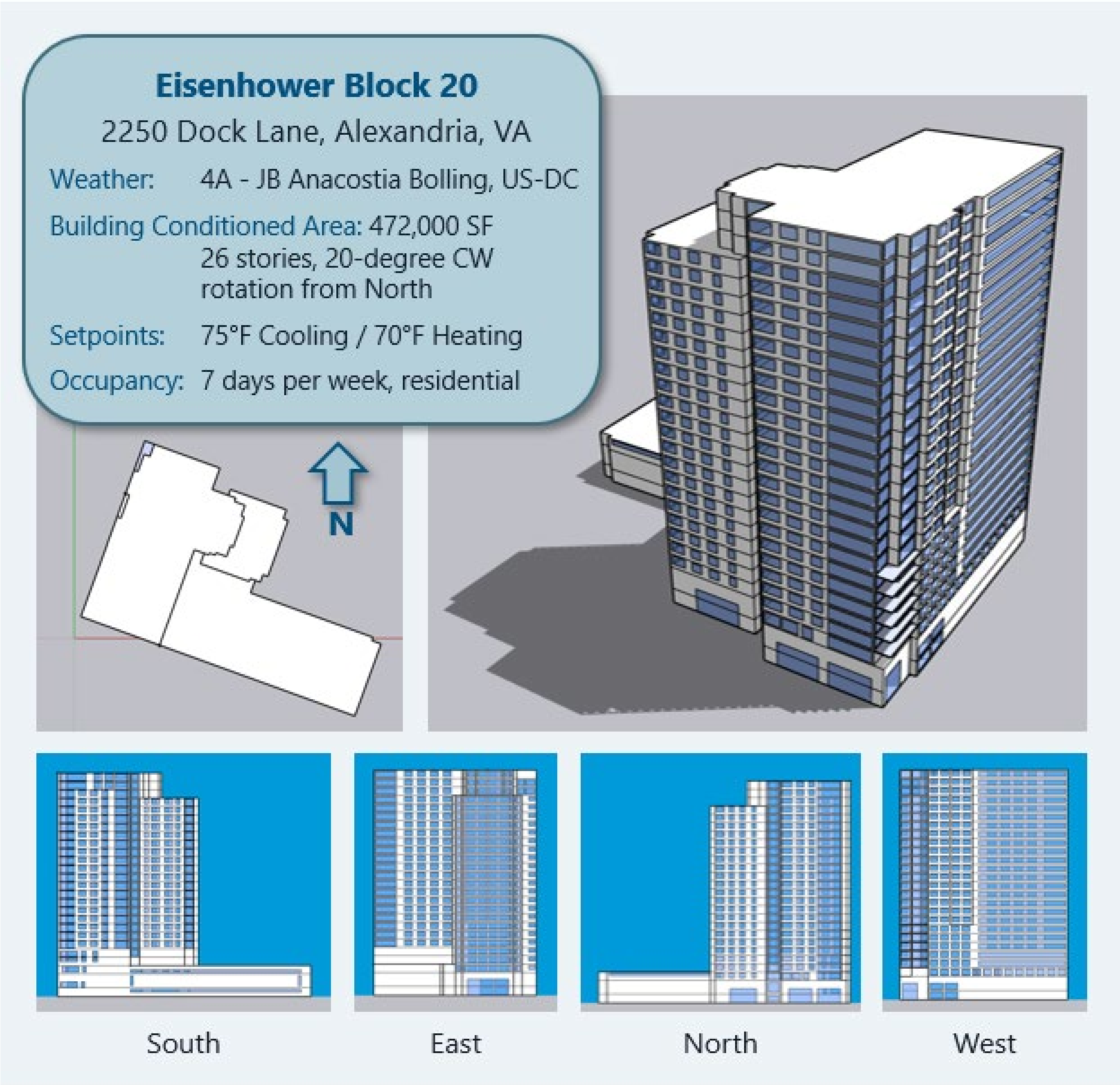


Figure 1, Model Views and Information

Based on the Above Grade Permit Review drawing set from March 21, 2022, Cadmus recreated the building geometry in Sketchup to accurately reflect windows, exterior walls, roofs, and floors. Figure 1 shows the model along with details, elevations, and site plan. The 1.5th floor was not explicitly modeled because it is either mostly open to the first floor or used for unoccupied spaces.

The team used ASHRAE 90.1 2019 to define the baseline energy model inputs based on requirements for Climate Zone 4A, which determined the envelope thermal characteristics and HVAC systems. The baseline used packaged terminal heat pumps (PTHPs) for heating and in-unit electric resistance water heaters for domestic hot water (DHW). Baseline inputs and details will be further defined in the final report's appendix. Table 1 shows the basic energy model inputs that were used for baseline and as-designed models.

Table 1. Basic Energy Model Inputs

Building Energy Model Input	Baseline	As-Designed
Model guideline	IECC 2021/ASHRAE 90.1 2019	Above Grade Permit Rev 3/21/22
Weather File (CZ4)	JB Anacostia Bolling, US-DC	JB Anacostia Bolling, US-DC
Above grade floors	26	26
Residential units	443	443
Wall construction (exterior)	Mass U-0.090 (11.1) and Steel-Framed: U-0.064 (R-15.56)	Brick and Steel-Framed: U-0.136 (R-7.4)
Roof construction	Metal Deck (R-30.86)	Metal Deck (R-26)
Foundation construction	Unconditioned garage	Unconditioned garage
Model window to wall ratio	40%	47%
Window (U-Factor/SHGC)	0.45 U/0.4 SHGC	0.4 U/0.35 SHGC
Interior Lighting Power Density (LPD)	0.5 W/sq ft	0.4 W/sq ft
Plug Load Density (PLD)	0.9 W/sq ft	0.9 W/sq ft
Hot water (DHW)	In-unit Electric heater, UEF=0.95	In-unit Electric heater, UEF=0.95
Heating System Efficiency (COP)	3	3.25
Cooling System Efficiency (COP)	3	3.55
HVAC	Packaged RTUs + PTHPs	Packaged RTUs + VRF and Split ASHP
Fan Efficiency/Control	0.35 W/CFM	0.35 W/CFM

The team used permit drawings from March 2022 to establish the as-designed energy model inputs for the building in Climate Zone 4A. Various building characteristics were updated including wall R-values, window performance, lighting power density, and HVAC systems. The design used a variable refrigerant flow (VRF) system for heating and cooling and in-unit electric resistance water heaters for domestic hot water (DHW). Design inputs will be defined in detail in the final report's appendix. As shown in Figure 2, the baseline model was projected to use 42.7 kBtu/sq ft in annual energy use, and the design model was projected to use 39.5 kBtu/sq ft in annual energy use. The design showed a potential for 7.4% energy savings over the baseline.

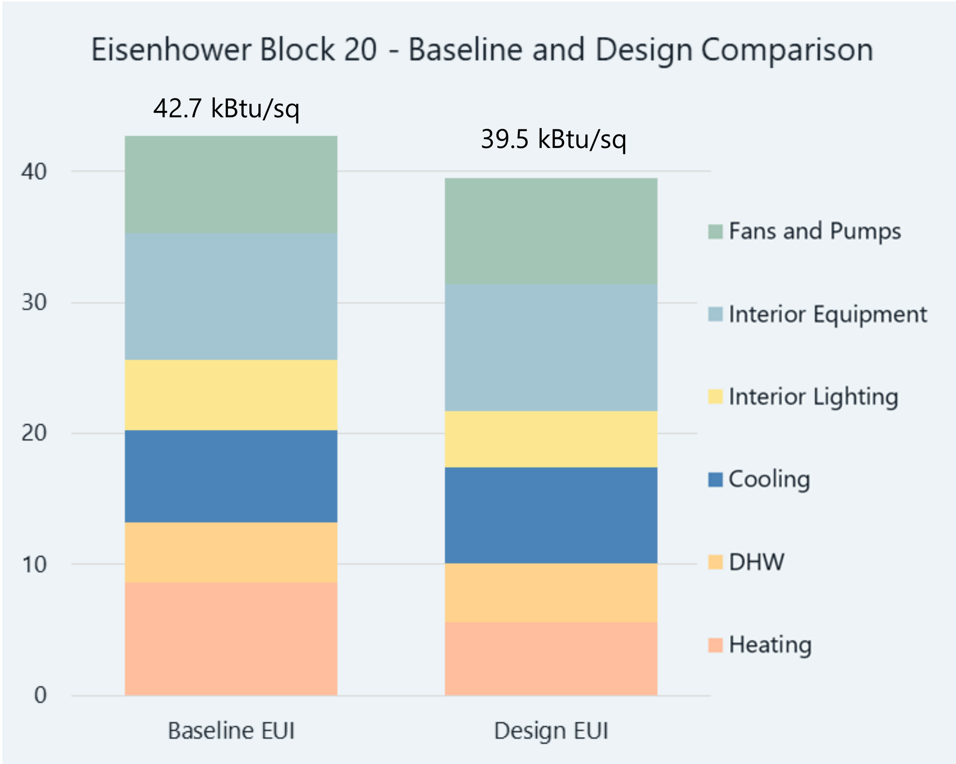
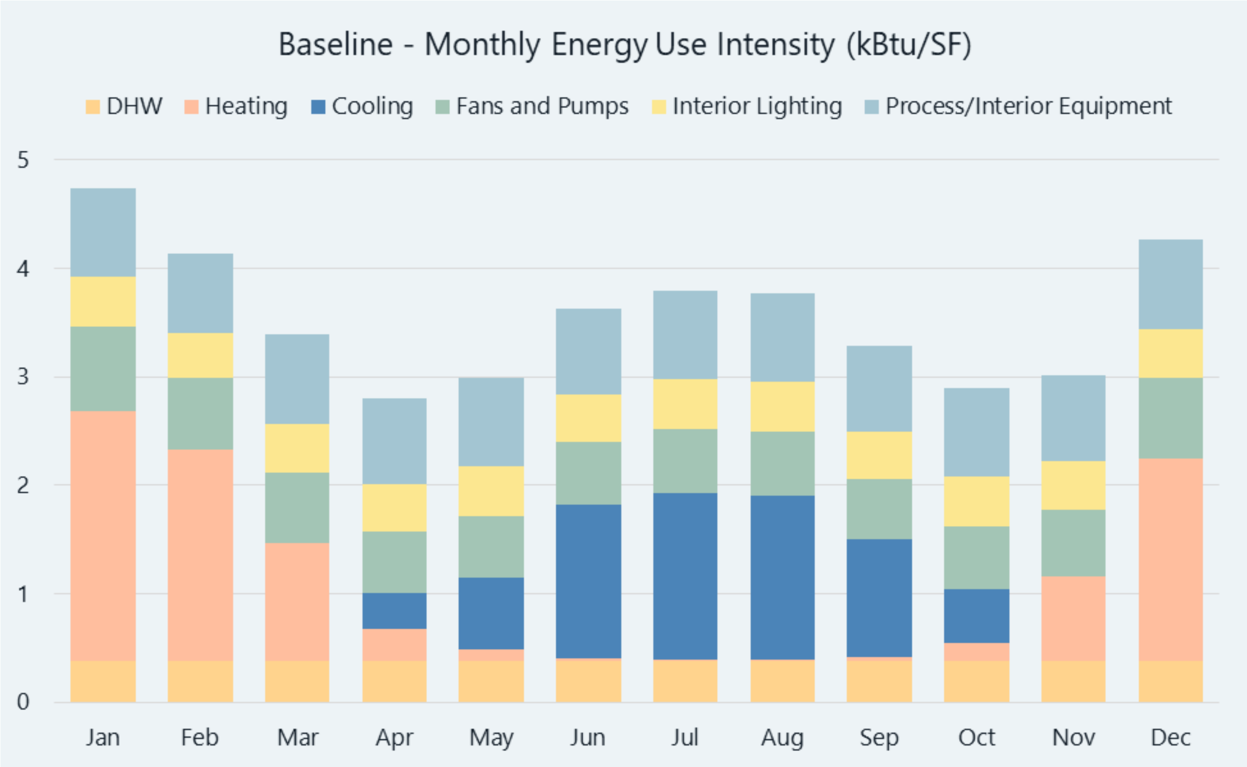


Figure 2. Baseline and Design EUI Comparison

Figure 3 shows the monthly energy use for each end use by model. Space heating saw the biggest energy savings between baseline and design at 36% because of envelope improvements, the switch from gas-fired to electric air handling units and more efficient in-unit heating. Space cooling increased slightly (4%) because of the increased outdoor air ventilation and increased glazing area. Interior lighting electricity use decreased by 20%, and fan energy use increased by 11%.



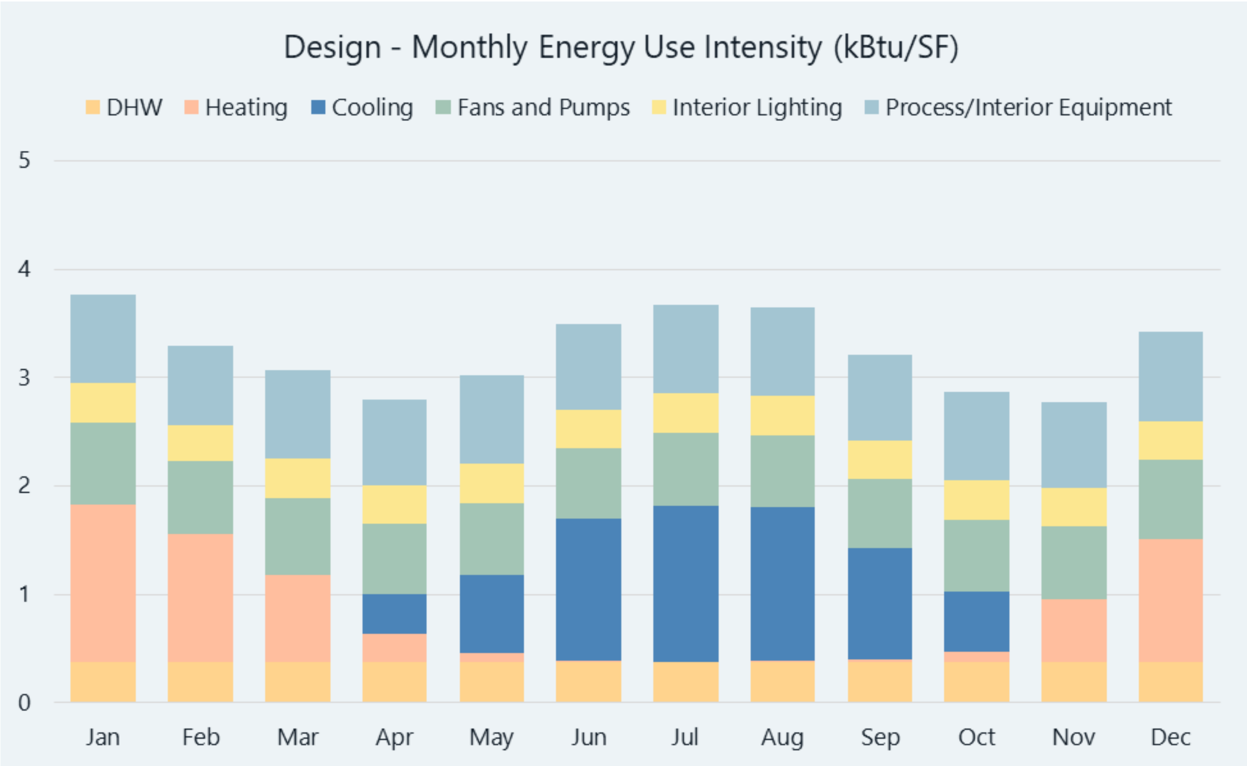


Figure 3. Monthly Energy Use Comparison

Photovoltaic System Details

Table 2 below compares potential solar PV systems for rooftop mounting at the various building types. Cadmus developed these estimates using the National Renewable Energy Laboratory's (NREL's) PVWatts tool in its System Advisor Model (SAM). The estimates assume that modules are arranged facing due south and pitched at an angle of about 35 degrees toward the sun to optimize electricity production on PV modules. The team created two system design options for each building type: one sized to cover about 3% of the building's annual electricity use and the second sized to cover about 5% of the annual use. PVWatts uses a production-size ratio of 1,326 kWh per kilowatt for single-family residential systems and 1,332 kWh per kilowatt for all other building types.

The single-family systems have the lowest value because they have the fewest modules of the five systems. With only a couple of modules, shading from passing clouds and surrounding trees will be more influential than with larger systems in which other modules are able to continue producing energy when some are shaded. It is also worth noting that there are various types and sizes of PV modules available and that system area and module count values are most heavily influenced by specific module choice, as well as system cost.

> The specific module choice and system cost have a strong influence on PV system area and module count values.

Cadmus estimated solar PV system costs on a dollar per watt basis. The estimated low cost ($2.34/W), was calculated based on a historical average of solar installed costs (including soft costs, labor, hardware, inverters, and modules) for commercial rooftops from 2013 to 2023 compiled by NREL.[1] The estimated high cost ($5.2/W) was calculated based on information gathered by New York's Buildings of Excellence program which included costs of solar installations.[2]

Table 2. Rooftop Solar System Sizes and Cost Estimates

Annual Electric Production (kWh)	System Size (kW)	System Area (sq ft)	Total Available Roof Space (sq ft)	Approximate Module Count	Estimated Low Cost ($2.34/W)	Estimated High Cost ($5.2/W)	Estimated Cost with Steel Dunnage ($11.5/W)
Single Family							
530	0.4	21	469	2	$936	$2,080	$4,600
862	0.7	34	469	2	$1,521	$3,380	$7,475
10,576	8.0	411	469	24	$18,720	$41,600	$92,000
Mid-Rise Multifamily							
11,323	8.5	436	8,435	25	$19,890	$44,200	$97,750
19,982	15.0	769	8,435	44	$35,100	$78,000	$172,500
High-Rise Multifamily							
33,304	25.0	1,281	8,435	73	$58,500	$130,000	$805,000
59,947	45.0	2,307	8,435	132	$105,300	$234,000	1,322,500
Hotel							
93,250	70.0	3,588	13,790	205	$163,800	$364,000	$74,750
153,197	115.0	5,895	13,790	350	$269,100	$598,000	$126,500
Retail							
8,659	6.5	334	12,345	20	$15,210	$33,800	$115,000
14,654	11.0	564	12,345	32	$25,740	$57,200	$207,000
Restaurant							
13,321	10.0	513	5,500	30	$23,400	$52,000	$287,500
23,979	18.0	923	5,500	53	$42,120	$93,600	$517,500

References

1. NREL. (n.d.). *Solar installed system cost analysis*. Solar Market Research and Analysis. https://www.nrel.gov/solar/market-research-analysis/solar-installed-system-cost.html

2. *Multifamily Buildings of Excellence Resources and Project Information - NYSERDA*. NYSERDA. (n.d.). https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence/Winners/Resources

Appendix

Zoning was model as a simple perimeter (15 foot depth) and core configuration, which reduced model development time. This simplification does not model each residential unit, but it captures the external and internal loads appropriately. Loads are met by the appropriate system by floor as Figure 4 shows below for the fourth floor.

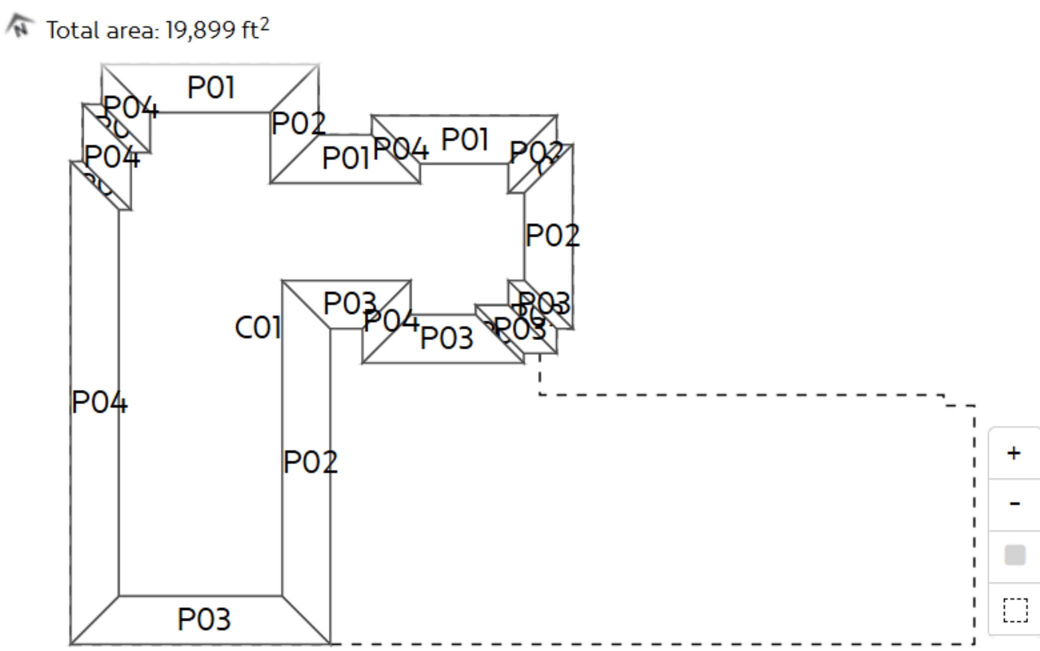


Figure 4: Zoning on Floor 4

Table 3 below shows an expanded list of inputs for the Baseline and As-Designed energy models. The in-unit equipment (PTHPs for the baseline, VRF for the design) were assumed to the primary source of heating and cooling. Heating loads, cooling loads, and ventilation rates were automatically sized by zone and floor. Ventilation, internal loads, and hot water use was based on 868 full-time residents, which was calculated based on 66 studios, 245 one-bedroom units, and 132 two-bedroom units.

Table 3: Full Model Inputs

Building Energy Model Input	Baseline	As-Designed
Model guideline	IECC 2021/ASHRAE 90.1 2019	Above Grade Permit Rev 3/21/22
Weather File (CZ4)	JB Anacostia Bolling, US-DC	JB Anacostia Bolling, US-DC
Above grade floors	26	26
Residential units	443	443
Zoning	Perimeter / Core with 15 ft offset	Perimeter / Core with 15 ft offset
Orientation	20 degrees clockwise	20 degrees clockwise
Wall construction (exterior)	Mass U-0.090 (11.1) and Steel-Framed: U-0.064 (R-15.56)	Brick and Steel-Framed: U-0.136 (R-7.4)
Roof construction	Metal Deck (R-30.86)	Metal Deck (R-26)
Foundation construction	Unconditioned garage	Unconditioned garage
Model window to wall ratio	40%	47%
Window (U-Factor/SHGC)	0.45 U/0.4 SHGC	0.4 U/0.35 SHGC
Window specification	Fixed Metal Framed	Double pane, Low-E, with aluminum frames
Shading	No internal shades, modeled external shading as designed	No internal shades, modeled external shading as designed
Interior Lighting Power Density (LPD)	0.5 W/sq ft, weighted average	0.4 W/sq ft, weighted average
Exterior Lighting	None	None
Lighting Controls	Time controlled to match diversity factor	Time controlled to match diversity factor
Plug Load Density (PLD)	0.9 W/sq ft	0.9 W/sq ft
Hot water (DHW)	In-unit Electric heater, UEF=0.95	In-unit Electric heater, UEF=0.95
Heating System Efficiency (COP)	3	3.25
Cooling System Efficiency (COP)	3	3.55
HVAC	Packaged RTUs + PTHPs	Packaged RTUs + VRF and Split ASHP
AHU Heat / Cool Source	Two 15,000 CFM DOAS: Gas-fired / Air cooled DX coil	Two 15,000 CFM DOAS: Gas-fired / Air cooled DX coil
Design Airflow Basis	Zone ventilation rate	Zone ventilation rate
Outdoor air intake rate (CFM/sq ft)	0.16	0.18
Outdoor air per person (CFM/per)	20.8	21.2
Fan Efficiency/Control	0.35 W/CFM	0.35 W/CFM
Fan Efficiency in unit	0.35 W/CFM	0.30 W/CFM

Table 4 and Table 5 below detail the model outputs for both the baseline and as-designed models across the different end uses for building consumption.

Table 4: Baseline Model Outputs

End Uses	Electricity [kWh]	Natural Gas [kWh]	Water [m3]
Heating	764,548.00	602,084.00	-
Cooling	1,111,967.00	-	-
Interior Lighting	846,460.00	-	-
Exterior Lighting	-	-	-
Interior Equipment	1,533,628.00	-	-
Exterior Equipment	-	-	-
Fans	1,155,789.00	-	-
Pumps	11,584.00	-	-
Heat Rejection	-	-	-
Humidification	3,720.00	-	5.19
Heat Recovery	-	-	-
Water Systems	718,799.00	-	21,422.29
Refrigeration	-	-	-
Generators	-	-	-
Total End Uses:	6,146,493.10	602,084.00	21,427.48

Table 5: As-Designed Model Outputs

End Uses	Electricity [kWh]	Natural Gas [kWh]	Water [m3]
Heating	877,390.89	-	-
Cooling	1,159,192.59	-	-
Interior Lighting	677,167.79	-	-
Exterior Lighting	-	-	-
Interior Equipment	1,523,627.53	-	-
Exterior Equipment	-	-	-
Fans	1,290,191.58	-	-
Pumps	-	-	-
Heat Rejection	-	-	-
Humidification	4,095.59	-	5.69
Heat Recovery	-	-	-
Water Systems	718,799.20	-	21,422.29
Refrigeration	-	-	-
Generators	-	-	-
Total End Uses:	6,250,465.20	-	21,427.98

City of Alexandria

Washington, D.C. Building Energy Performance Standard (BEPS) Sample Data

Oct 2025

1

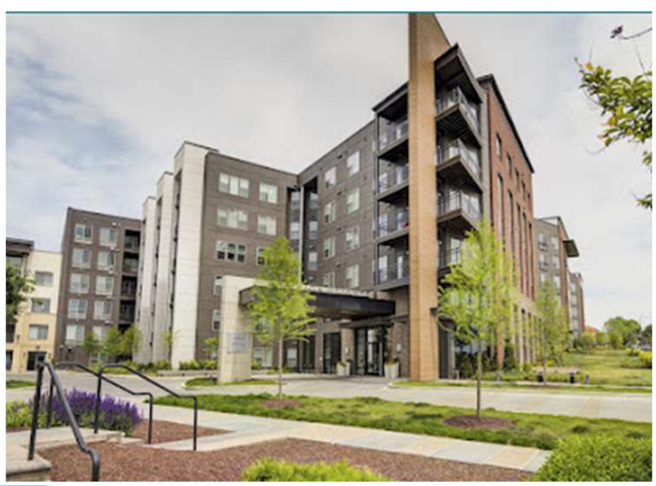
Union Heights East

Address: **1676 MARYLAND AVE NE**

Gross floor area: **325,215 sq.ft.**

Site EUI: **23.5**

Other Building Use? **No**



2

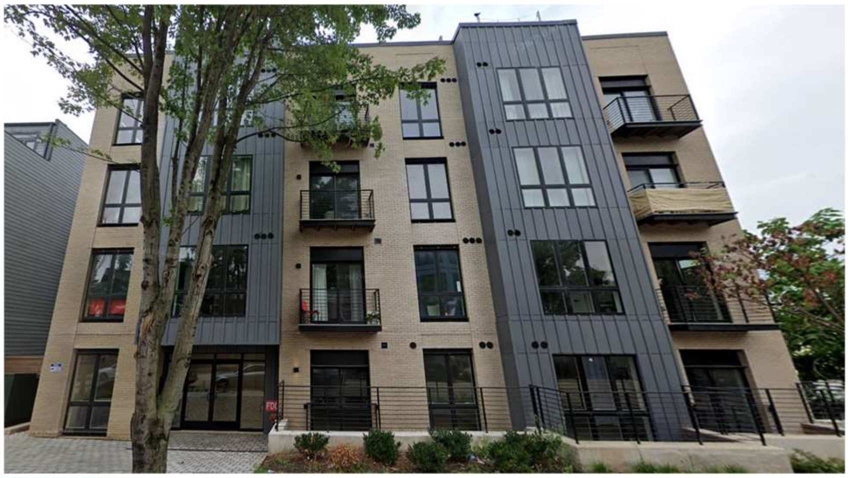
The View Condominium

Address: **1016 17TH PL NE**

Gross floor area: **37,049 sq.ft.**

Site EUI: **24.1**

Other Building Use? **No**



3

The Lockwood

Address: **1339 E ST SE**

Gross floor area: **142,538 sq.ft.**

Site EUI: **24.7**

Other Building Use? **No**

4

Judd

Address: **1625 ECKINGTON PL NE**

Gross floor area: **255,560 sq.ft.**

Site EUI: **27.3**

Other Building Use? **Yes – ground level retail, restaurant uses.**

5

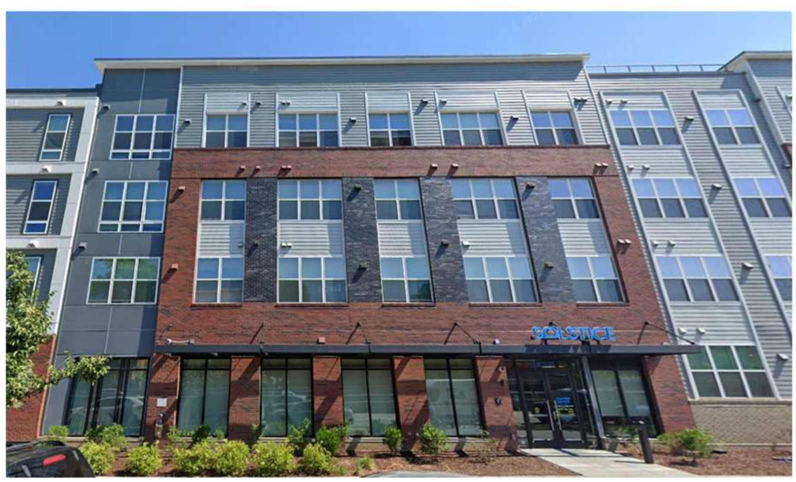
Solstice I & II

Address: **3500 EAST CAPITOL ST NE**

Gross floor area: **259,781 sq.ft.**

Site EUI: **28.9**

Other Building Use? **No**



6

Monroe Street Market

Address: **701 MONROE ST NE**

Gross floor area: **183,980 sq.ft.**

Site EUI: **30.1**

Other Building Use? **Yes – ground level retail space.**

7

Diane's House

Address: **2619 BLADENSBURG RD NE**

Gross floor area: **30,271 sq.ft.**

Site EUI: **30.5**

Other Building Use? **No**

8

Europa / Sonder

Address: **819 L St SE**

Gross floor area: **41,455 sq.ft.**

Site EUI: **30.5**

Other Building Use? **No**

9

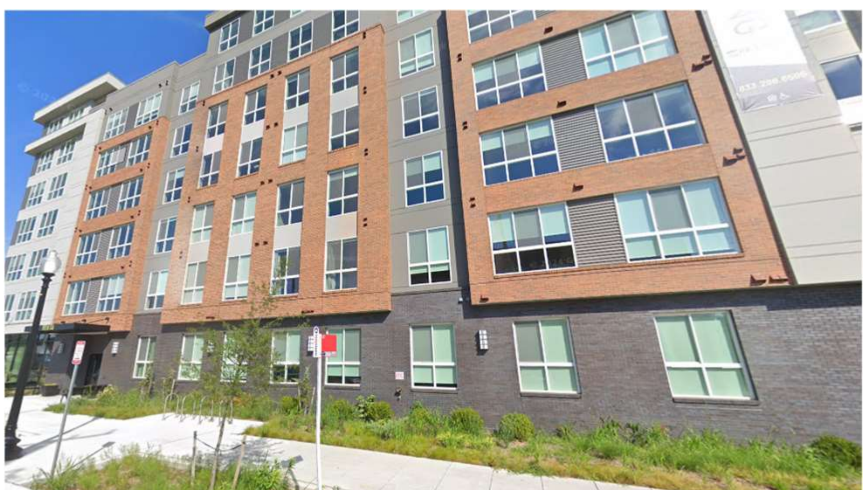
Vesta Parkside

Address: **800 KENILWORTH TER NE**

Gross floor area: **163,394 sq.ft.**

Site EUI: **32.1**

Other Building Use?



10

Ore 82

Address: **82 I ST SE**

Gross floor area: **227,371 sq.ft.**

Site EUI: **33.9**

Other Building Use? **Yes – ground floor restaurant and retail.**

11

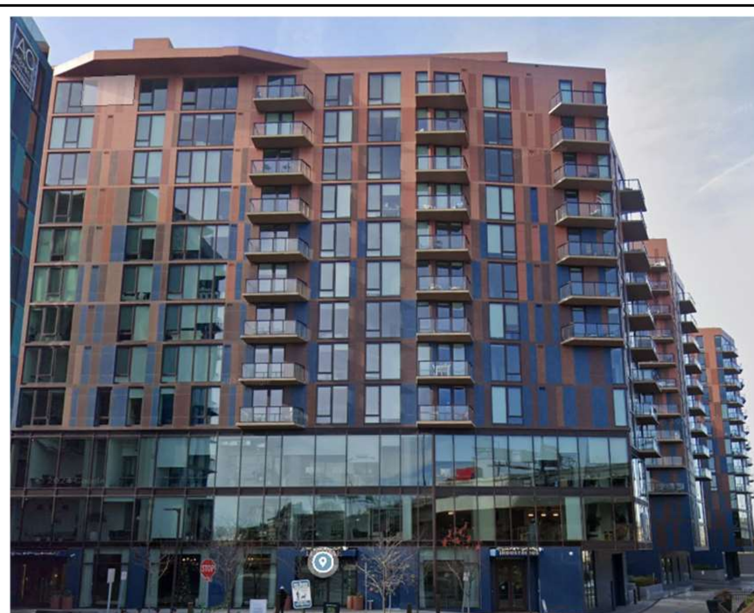
Illume

Address: **853 NEW JERSEY AVE SE**

Gross floor area: **749,058 sq.ft.**

Site EUI: **35**

Other Building Use? **No**



12

Lexicon Condominiums

Address: **50 FLORIDA AVE NE**

Gross floor area: **204,797 sq.ft.**

Site EUI: **35.5**

Other Building Use? **Yes – ground level retail**

13

Weiler

Address: **1500 HARRY THOMAS WAY NE**

Gross floor area: **163,127 sq.ft.**

Site EUI: **36.7**

Other Building Use? **No**

14