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Building Energy Performance Standards Development – Technical Analysis

Montgomery County, MD

BUILDING COST – BENEFIT CASE STUDY OVERVIEW

To test the viability of the targets, the analysis team chose nine building examples in Montgomery County and developed multiple retrofit packages. Each building was assigned a target using the proposed methodology, and a package of energy-reducing measures was created. The technical viability and economics of reaching the targets confirmed that, at least for the types of buildings exemplified in this technical analysis, the targets are reachable. High-level findings are contained in the “Building Cost-Benefit Case Study” section of this report.

The analysis team selected buildings from various occupancy types to show examples of target calculations and energy measure packages to meet a potential performance standard. These nine case study examples are meant to be representative of Montgomery County’s building stock that would have to meet a potential BEPS target and have current energy performance that would trigger the need to implement retrofits in order to achieve compliance with the proposed BEPS policy.

Each case study includes a brief description of the key building systems, a summary of the square footage of each property use type, whole building ENERGY STAR score for reference (if available), and calculated site energy use intensity (EUI) for 2019. EUI is a measure of the energy usage at a building per square foot where all fuels have been converted to a common unit of measure, typically thousand Btu per square foot (kBTU / SF). The case studies were anonymized by putting a range on the EUI, which in turn created a range of baselines and interim targets. The methodology describing the utility analysis process is described in the *Utility End Use Assessment* section.

The ***Methodology*** section in Appendix V describes several important aspects of this analysis.

Example Buildings and Pathways to Reach Energy Performance Targets

Each case study building was analyzed through a virtual desk audit to determine the applicable measures for three retrofit packages:

- A Zero Net Carbon-Compatible Target Package: what measures are needed to reach the building’s ZNC Target.
- An Energy Efficiency Target Package: what measures are needed to reach the building’s EE target.
- A Less-than-Five-Year Payback Package: what measures are identified in a typical energy audit.

The ZNC Target Package is intended to achieve the building’s hypothetical ZNC target established using the target-setting methodology in *Site Energy Use Intensity Performance Targets*. The EE Target Package is intended to achieve the building’s hypothetical EE target established using the target-setting methodology in *Site Energy Use Intensity Performance Targets*.

Each building has a Less-than-Five-Year Payback Package; in most cases, the EUI of this package is sufficient to get a building to the first interim ZNC target. However, further work is needed in most cases to meet the EE target, and in all cases to reach the ZNC Target. Note that in some building cases, there are no differences between the EE target EUI and the ZNC Target EUI.

The following table contains the baseline EUI for each case study building, the two chosen target EUIs, the projected EUI of the ZNC Target Package, and the projected EUI of the Less-than-Five-Year Payback Package. As seen in Table 6 and Figure 2, most buildings have substantial work to do in order to reach the ZNC target; however, this does not mean reaching the targets are impossible. Each building’s ZNC Target Package in this analysis either meets or exceeds the ZNC Target EUI.

Table 6. Basic overview of each building typology, potential EE and ZNC targets, ZNC Target Package, EE Target Package, and Less-than-Five-Year Payback Package.

#	**Typology** Sub-type	**Floor Area [SF]**	**Baseline Site EUI**	**ZNC Target EUI**	**ZNC Interim Target 1 EUI**	**ZNC Interim Target 2 EUI**	**EE Target EUI**	**EE Interim Target 1 EUI**	**EE Interim Target 2 EUI**	**ZNC Target Package EUI**	**EE Target Package EUI**	**Less-than-Five Year Payback Package EUI**
1	**Office** (p *79*) Class A	200,000 – 225,000	70 – 80	53.4	63 – 72	57 – 64	53.4	49 – 53	67 – 75	49 – 53	49 – 53	67 – 75
2	**Office** (p 89) Mixed-fuel HVAC	250,000 – 275,000	80 – 90	57.8	71 – 80	62 – 70	57.9	52 – 57	67 – 75	52 – 57	52 – 57	67 – 75
3	**Office** (p 95) Older All-Electric	225,000 – 250,000	80 – 90	53.4	71 – 80	62 – 70	53.4	47 – 53	57 – 64	47 – 53	47 – 53	57 – 64
4	**Multifamily** (p 109) New – Tall	125,000 – 150,000	50 – 60	38.7	46 – 53	42 – 47	59.1	35 – 38	50 – 60	35 – 38	N/A	50 – 60
5	**Multifamily** (p 119) Old – Tall	125,000 – 150,000	70 – 80	35.4	58 – 65	45 – 50	55.1	65 – 72	60 – 65	32 - 35	50 – 57	64 – 73
6	**Multifamily** (p 131) Short / Garden	50,000 – 75,000	115 – 125	35.4	90 – 95	60 – 65	55.1	95 – 102	75 – 80	31 – 34	51 – 55	107 – 116
7	**Lodging** (p 143) Full-service hotel	150,000 – 175,000	115 – 125	57.8	95 – 105	75 – 85	75.7	102 – 110	88 – 95	53 – 57	72 – 76	94 – 102
8	**Lodging** (p 156) Partial-service hotel	200,000 – 225,000	125 – 135	57.8	101 -110	77 – 85	75.7	108 – 115	90 – 96	53 – 57	72 – 76	99 – 107
9	**Worship** (p 168)	75,000 – 100,000	80 – 90	36.4	65 – 72	50 – 56	47.9	70 – 77	59 – 64	33 – 36	45 – 48	72 – 81

**the blue page numbers are links to the case studies in this report*

Figure 2 on the following page contains a subset of the information contained in Table 6 arranged in graphical format. An asterisk is noted to call out the all-electric building in the case studies.

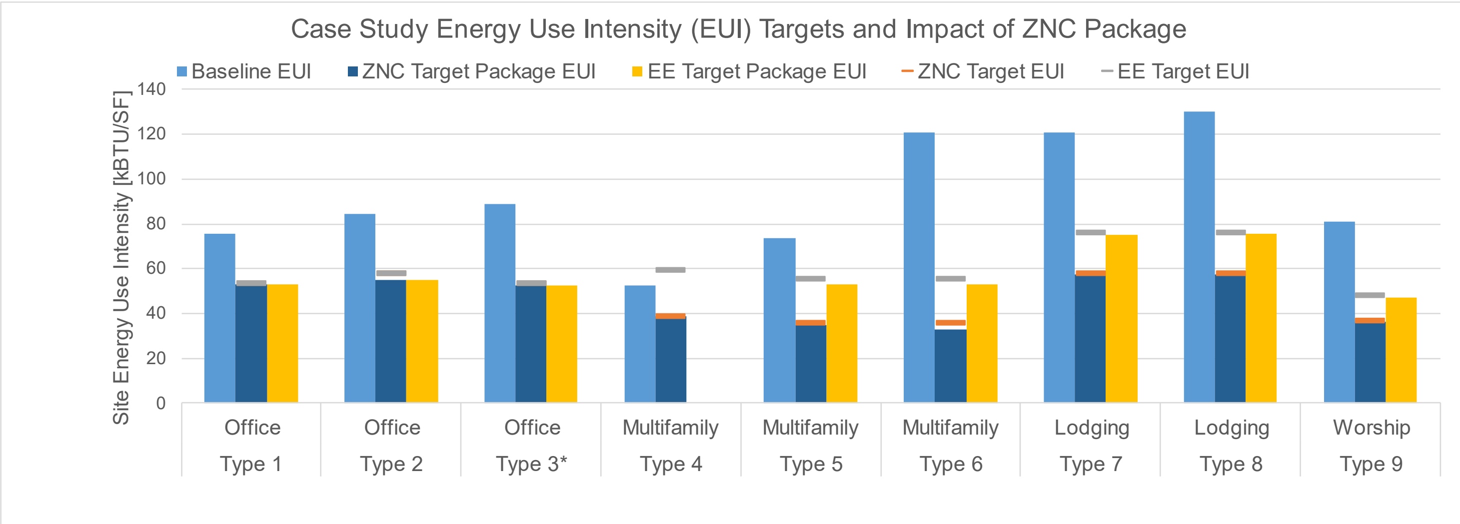

Figure 2. Comparisons of current energy usage of case study buildings to proposed targets and the end results of the ZNC Target Package and EE Target Package. The asterisk denotes an all-electric building.

Table 7 on the following page contains a financial overview of each of the packages. The costs associated with the Less-than-Five-Year Payback Package are often small (most buildings were less than $2 / SF) but generate moderate energy savings; the ZNC Target Package costs are often much higher than the Less-than-Five-Year Payback Package but generate deeper energy savings. The EE Target Package typically falls somewhere in the middle, with buildings further away from the EE target having higher costs.

Total costs were used, without incorporating potential cost reduction avenues such as:

1) avoided cost of business-as-usual equipment replacement,
2) financial assistance from myriad sources, including EmPOWER incentives and Green Bank financing,
3) incentives for efficiency work, or
4) cost pass-through to commercial and residential tenants.

Table 7. Basic overview of ZNC Target Package, EE Target Package, and Less-than-Five-Year Payback Package financials. Building 4's EUI is below the EE Target; no EE package is included.

#	**Primary Occupancy Type** Sub-type	**ZNC Target Package Cost / sq. ft.**	**ZNC Target Package Annual Savings / sq. ft.**	**ZNC Target Package Simple Payback (years)**	**ZNC Target Package ROI (%)**	**EE Target Package Cost / sq. ft.**	**EE Target Package Annual Savings / sq. ft.**	**EE Target Package Simple Payback (years)**	**EE Target Package ROI (%)**	**Less-than-Five Year Payback Package Cost / sq. ft.**	**Less-than-Five Year Payback Package Annual Savings / sq. ft.**	**Less-than-Five-Year Package Simple Payback (years)**	**Less-than-Five Year Payback Package ROI (%)**
1	**Office** (p *79*) Class A	$23 - $26	$0.60 - $0.80	35.1	3%	$23 - $26	$0.60 - $0.80	35.1	3%	$0.80 - $1	$0.30 - $0.40	2.0	49%
2	**Office** (p 89) Mixed-fuel HVAC	$16 - $19	$0.60 - $0.80	26.4	4%	$16 - $19	$0.60 - $0.80	26.4	4%	$1.60 - $1.80	$0.40 - $0.50	4.0	25%
3	**Office** (p 95) Older All-Electric	$25 - $28	$1.30 - $1.50	19.2	5%	$25 - $28	$1.30 - $1.50	19.2	5%	$3.40 - $3.60	$0.90 - $1	3.6	28%
4	**Multifamily** (p 109) New - Tall	$7 - $10	$0.30 - $0.50	31.9	3%	N/A	N/A	N/A	N/A	$0 - $0.20	$0 - $0.10	3.5	28%
5	**Multifamily** (p 119) Old – Tall	$16 - $19	$0.30 - $0.50	57.1	2%	$9 - $12	$0.90 - $1.10	28.3	4%	$0.60 - $0.80	$0.20 - $0.30	3.1	32%
6	**Multifamily** (p 131) Short / Garden	$25 - $28	$0.90 - $1.10	26.8	4%	$20 - $23	$0.70 - $0.90	21.5	5%	$0.60 - $0.80	$0.10 - $0.20	2.9	35%
7	**Lodging** (p 143) Full service hotel	$33 - $36	$0.70 - $0.90	48.9	2%	$10 - $13	$0.70 - $0.90	33.1	7%	$1.90 - $2.10	$0.50 - $0.60	3.5	28%
8	**Lodging** (p 156) Partial-service hotel	$31 - $34	$0.90 - $1.10	34.2	3%	$8 - $11	$0.90 - $1.10	17.3	10%	$3.30 - $3.50	$0.80 - $1.00	3.5	29%
9	**Worship** (p 168)	$33 - $36	$0.90 - $1.10	37.9	3%	$14 - $17	$1.10 - $1.30	13.3	8%	$0.50 - $0.70	$0.20 - $0.30	2.8	35%

**the blue page numbers are links to the case studies in this report*

Figure 3 on the following page contains a subset of the information contained in Table 7 arranged in graphical format. An asterisk is noted to call out the all-electric building in the case studies.

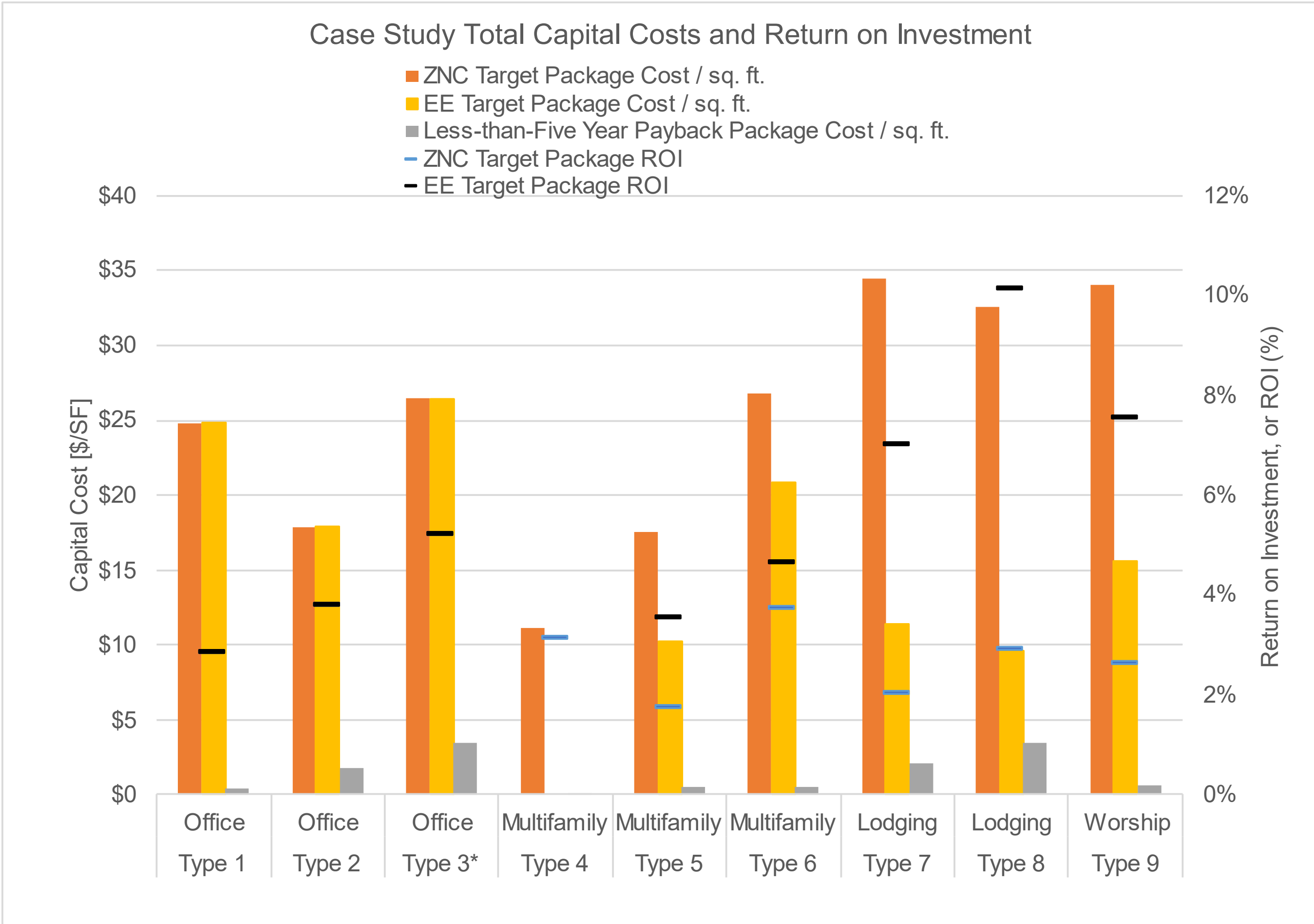

Figure 3. Costs to implement the ZNC Target Package identified for each case study building compared to the EE Target Package and Less-than-Five-Year Payback Package. ROI for the ZNC Target Package is included as a blue line and ROI for the EE Target Package is included as a black line. The ROI for the Less-than-Five Year target is higher than 20% in all cases, thus omitted from this figure. The asterisk denotes an all-electric building.

As seen in Table 6, Table 7, Figure 2, and Figure 3, each building is able to reach the ZNC Target, indicating these targets are technically achievable using today's technology. While the costs for implementing these packages vary significantly by building, the following general conclusions apply:

- Most major in-building equipment (i.e., mechanical equipment) is likely to be replaced prior to 2035. This capital cost can be redirected toward deeper retrofit projects. This creates a lower "effective" cost of compliance, but it should be noted these baseline capital costs are highly building dependent. Financial incentives and financing can fluctuate and are building-specific at a level outside the scope of this report. Baseline capital cost outlay, financial incentives, and financing are not included in this report.
- Utility cost savings from the EE Target Packages are generally similar to the ZNC Target Package for a specific site. Savings do not account for labor cost savings from new equipment (e.g., from reduced equipment maintenance or facility maintenance requests due to improved tenant comfort).
- ZNC Target Packages sometimes have measures that replace existing systems that would otherwise be optimized in EE Target Packages and Less-than-Five-Year Payback Packages. This presents potential risk for future replacement of fossil-fuel-fired equipment with new fossil-fuel-fired equipment.

- Some EE Target Packages—namely, the ones for offices—are the same as the ZNC Target Packages, as their targets are identical.
- The Less-than-Five-Year Payback Package is not sufficient to meet either the EE or ZNC targets in the vast majority of cases, indicating that deeper retrofits are necessary to meet Montgomery County's emissions goals for 2035.
- Building typologies with substantial costs associated with the Less-than-Five-Year Payback Package also have significant savings associated with implementing these measures. In all cases, the return on investment makes financial sense for these projects even with the upfront cost.
- Utility cost savings from the Less-than-Five-Year Payback Package are on average 50% (range: 3%-90%) of the utility cost savings for the ZNC Target Package for a specific site. Savings do not account for labor cost savings from new equipment (e.g., from reduced equipment maintenance or facility maintenance requests due to improved tenant comfort).

Summarizing the case studies into broad building types, the average capital cost intensity for offices, multifamily, and hotels/lodging under the ZNC and EE targets is shown in Figure 4. The chosen building typologies have a relatively consistent ZNC Target Package capital cost intensity in the range of $20 - $30 / SF (with an average $/SF across all case study buildings of approximately $22.85/SF) to reach the final target year, where multiple electrification measures drive up the capital cost intensity. Similarly, the EE Target Package capital cost intensity is between $9.50 - $26.50 / SF. This implies a significant investment will be required across building typologies.

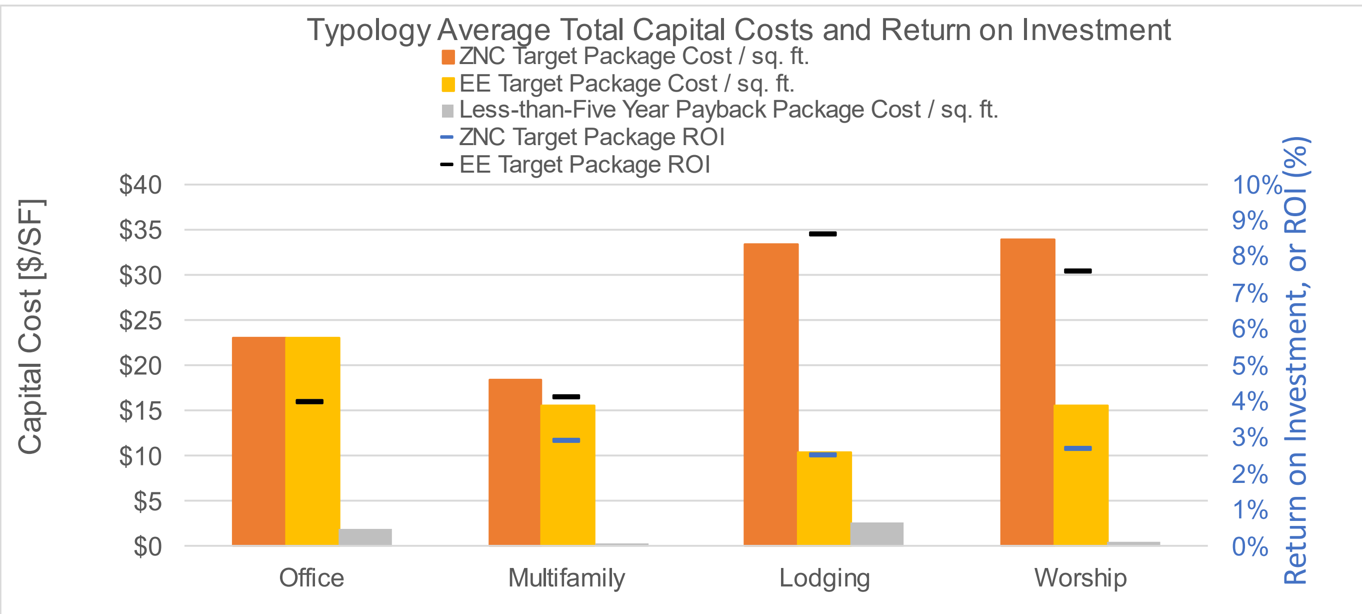

Figure 4. Costs to implement the ZNC Target Package identified for each building typology compared to the EE Target Package and Less-than-Five-Year Payback Package. ROI for the ZNC Target Package is also included as a blue line and ROI for the EE Target Package is included as a black line. The ROI for the Less-than-Five Year target is higher than 20% in all cases, thus omitted from this figure.

Figure 5 compares total capital costs and percent site energy savings for the ZNC target, EE target, and Less-than-Five-Year Payback Package for each building typology. The data in Figure 5 shows that, in general, higher capital cost expense yields larger energy savings towards the target. The highest savings numbers correspond to incredibly deep energy savings, but at a relatively high cost, mainly driven by electrification measures in fuel-heated buildings.

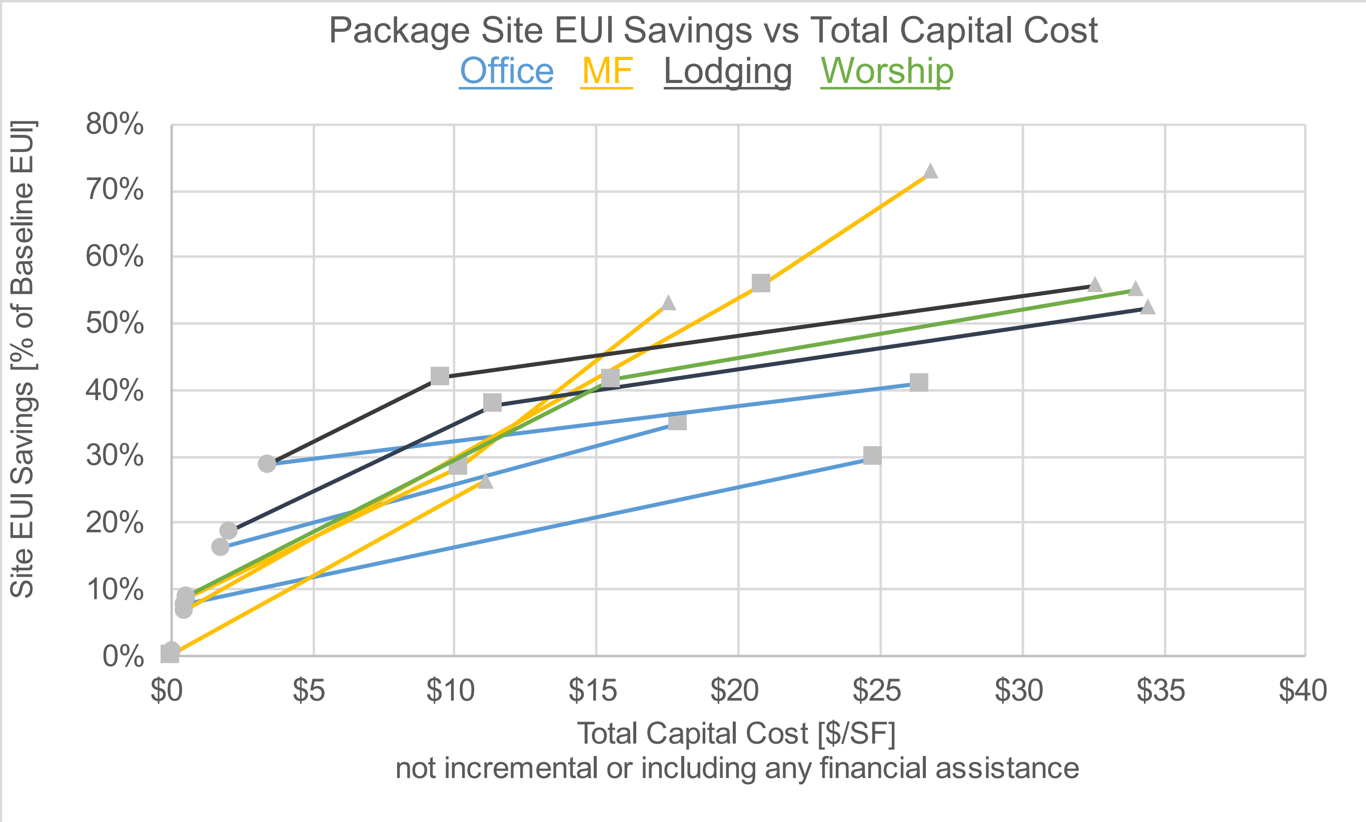

Figure 5. Comparison of capital cost to energy reduction trends, showing that generally more money is needed for deeper savings. This is partly driven by the fossil fuel dominated buildings having high starting EUIs. With electrification being one of the more expensive measures, those buildings spend the most and have the highest site EUI savings from electrification. In this figure, circles represent the Less-than-Five-Year Payback Package, squares represent the EE Target Package, and triangles represent the ZNC Target Package. Building typologies are color-coded.

Greenhouse Gas Impact

The energy reductions that could be achieved under different BEPS targets are converted to greenhouse gas emissions to estimate the change in energy-based emissions of the buildings in their current state, and if the EE or ZNC Package is adopted. Two grid forecasting scenarios are modeled to account for possible changes in the electric grid emissions intensity – in units of $kgCO_2e$ / kBTU:

Table 8. Electricity and natural gas emissions intensities used in this technical analysis.

	Gas $kgCO_2e/kBTU$	Elec $kgCO_2e/kBTU$
Today's Electricity Supply[5]	0.05472	0.0957
50% Renewable Electricity Supply[6]	0.05472	0.0492
100% Renewable Electricity Supply[7]	0.05472	0.0027

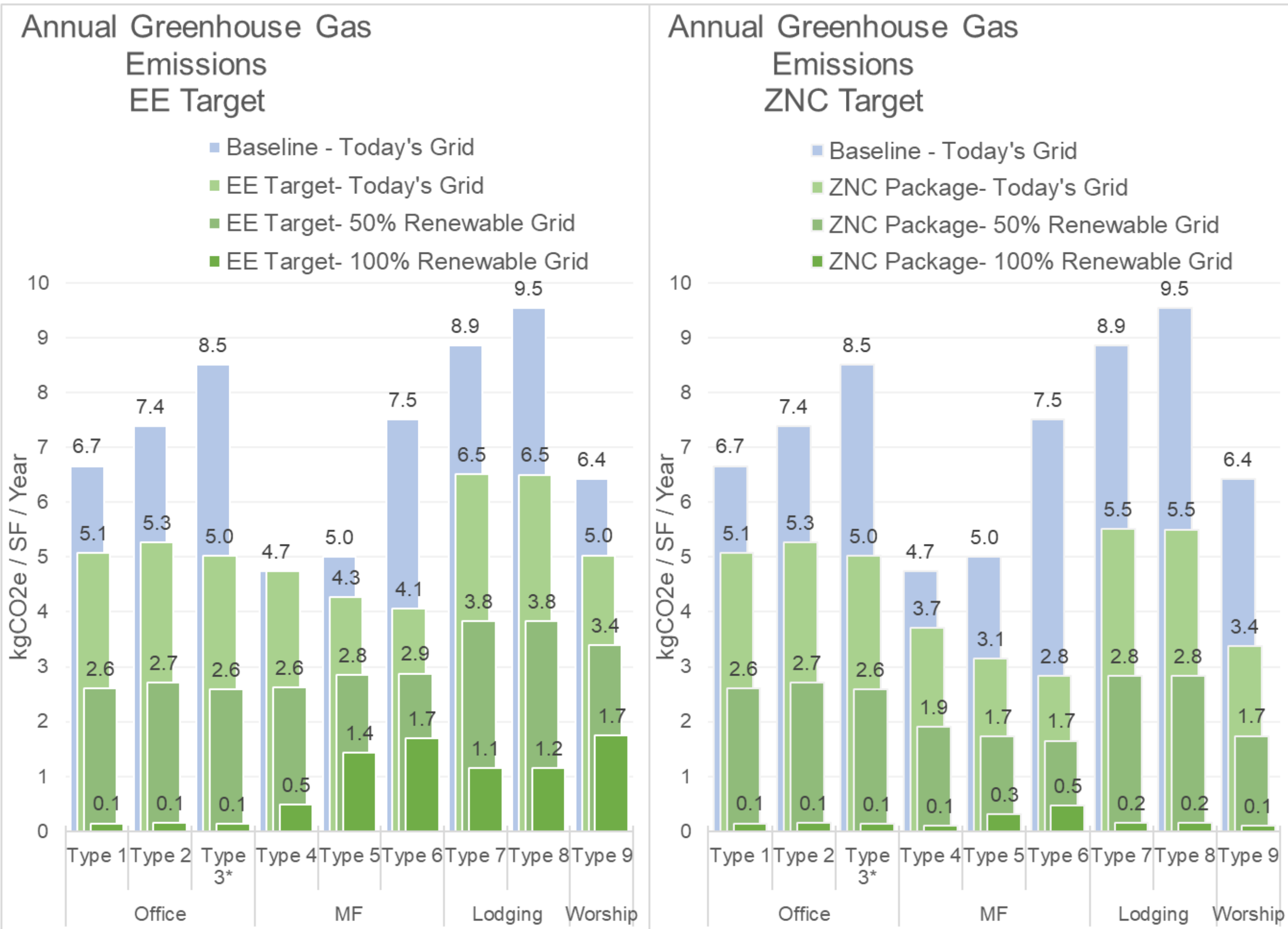

Figure 6. Greenhouse gas emissions impact of implementing the ZNC Target packages (right) under different potential electricity scenarios. At left, an estimate of the emissions reductions if the EE Targets were used, allowing fewer high-cost measures such as electrification, to be used to meet the targets. The asterisk denotes an all-electric building.

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[5] See Appendix VIII for GHG emissions factors data sources from the MC GHG Inventory, used for gas and electricity.

[6] This value corresponds roughly with the Renewable Portfolio Standard (RPS), which requires 50% of the electricity supply to come from renewable sources. The electricity value is half of today's emissions intensity, which is roughly 94% non-renewable. The assumption is that non-renewable sources (gas, oil, coal, and nuclear) will be ramped down evenly to meet the RPS. See page 2 of Pepco "Environmental Fuel Source Information" for June 2020, corresponding to calendar year 2019. https://www.pepco.com/MyAccount/MyBillUsage/Pages/ViewBillInserts.aspx

[7] Assumes ~3% of electricity consumption is from emitting sources, but these are offset through renewable purchases or other offset methods.

The emissions reductions achieved by implementing the ZNC Target packages are substantial. Assuming today's electricity supply, the packages reduce GHG emissions by 36% on average (range: 22% - 62%). With a completely emissions-free grid, emissions are reduced by 97% on average (range: 94% - 98%) with the ZNC Target-reaching packages.

For comparison, the emissions reductions achieved by setting the standards using the EE Target method would allow less decarbonization. Assuming today's electricity supply, the EE Target would reduce the case study buildings emissions by 26% on average (range: 0% - 46%). With a completely emissions-free grid, emissions are reduced by 87% (range: 71% - 98%).

Two observations when comparing the impact of the targets for these case study buildings:

1) Type 4, the newer multifamily building, has an EUI today that is lower than the EE Target, so that building would not need to take any action.
2) For many offices, the EE Target and the ZNC Target are the same because most offices in the county are all-electric already, and the assumption of electrification is the only difference between the two targets.

There are two reasons why a small amount of emissions remains after achieving the ZNC Target. One is that the electricity supply is estimated to still have a small amount of emissions associated with it, which can be offset through renewable energy purchases [8] This is reflected in a non-zero emissions factor for the "100% Renewable Electricity Supply" scenario above.

The second reason is that with a whole building site EUI target, some buildings are capable of meeting the ZNC Target without fully electrifying all fossil fuel end uses. For some buildings, the remaining fossil fuel use could be offset with deeper electricity efficiency to meet the site EUI target.

Disclaimer on Retrofit Capital Costs

While best estimates are used to develop total retrofit costs for measures, each measure is subject to a wide variety of factors within and outside the building. Each cost estimate should be interpreted as a rough estimate that is the result of a high-level review of building conditions and applicable measures. Costs are total equipment and labor costs, not including avoided costs of existing equipment replacements, incentives, or financing agreements which may reduce initial capital costs, all of which are components of developing a net cost of each measure for each building.

[8] Estimate of 3% remaining electricity emissions intensity from conversations with other cities in climate action planning using the CNCA EBPS tool.

APPENDIX V – BUILDING COST – BENEFIT CASE STUDY DETAILS

To test the viability of the targets, the analysis team chose nine building examples in Montgomery County and developed multiple retrofit packages. Each building was assigned a target using the proposed methodology, and a package of energy-reducing measures was created. The technical viability and economics of reaching the targets confirmed that, at least for the types of buildings exemplified in this technical analysis, the targets are reachable. High-level findings are contained in the "Building Cost-Benefit Case Study" section of this report.

Methodology

Selection of Case Study Buildings

The analysis team reviewed proposed covered building types in *Appendix I - Recommendations for Building Groups* and *Appendix II - Montgomery County Energy Use Distributions Overview* to identify typologies with common characteristics and a variety of starting points (mechanical systems, space use type and building layout). Common building types include:

- Commercial offices
- Multifamily buildings
- Lodging: hotels and other hospitality
- Mixed use spaces
- Retail

Because of the prevalence and diversity of office, multifamily, and hospitality buildings, the team evaluated multiple buildings within each typology. Offices were further divided into newer, class-A type offices, older mixed-fuel offices (i.e., office spaces that use both electricity and natural gas), and older all-electric offices. Multifamily buildings were further divided into newer, high-rise mixed-use buildings, older high-rise affordable housing buildings, and garden-style multifamily buildings.

Other spaces considered include different types of lodging with or without a significant amount of amenities, and a multi-function building that serves multiple end uses—for example, a building with both worship and school space.

The team reached out to many building owners seeking participants for this technical analysis and to conduct interviews. Only respondent buildings are included in the technical analysis, which limits building inclusion and eliminated the retail group, which had no respondents able to participate in the case study exercise.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Building Descriptions

Square Footage Calculations

Square footage figures are presented to comply with ENERGY STAR Portfolio Manager guidance. In some cases, the square footage breakdown or totals may differ from 2019 benchmarking data reported to the County. In these cases, the reported figures were adjusted in conjunction with the building representatives to follow Portfolio Manager guidance on benchmarking space use types.

Portfolio Manager Property Type Breakdowns / Guidance

To determine the appropriate site EUI target for each building, individual space use types and square footages needed to be identified. Targets for a total site use a blended site EUI target for each primary space type as a weighted average based on the square footage of each space. The methodology used in this technical analysis follows the Montgomery County benchmarking methodology which in turn relies on Portfolio Manager guidance. See *Appendix XI – Space Type Definition Guidance from EPA Portfolio Manager* for detail on how occupancy types were defined in this technical analysis.

Building System Information

Key building mechanical systems and envelope information were inventoried for each building. Equipment age from interviews, nameplate data, or building drawings is included where available.

End of Useful Life Assumptions

End of Useful Life (EUL) assumptions are included for major equipment. Estimates are derived from the *ASHRAE Equipment Life Expectancy Chart* and the *BOMA Preventative Maintenance Guidebook.*

EUL is the point at which it is no longer economically or physically feasible to continue the use of a piece of equipment or a system. Equipment upgrades are most cost effective at the EUL. Replacement of equipment prior to the end of its useful life will mean incurring replacement costs when existing equipment can still serve the building.

Since system replacement is part of the cost of operating a building, only the difference between in-kind-replacement equipment and an energy efficient upgrade (known as the incremental cost) should be weighed at EUL. Paybacks and returns on investment are more attractive when considering incremental cost rather than full project costs, so building owners should plan around EUL when a required replacement cost is already assumed.

For the purposes of this technical analysis, incremental costs were not calculated. Full project costs that include both soft costs (i.e., design) and hard costs (i.e., installation) were used in this report.

Utility End Use Assessment

Utility data for the case study buildings is sourced from the Montgomery County benchmarking compliance data for each of the case study buildings. Energy use information may differ from the benchmarking submission if any needed corrections were identified through this review. For example, if some energy use data was not included in a benchmarking submission (e.g., tenant or retail use), it was added in for this analysis in conjunction with the building representatives since the BEPS law would consider whole building energy data.

This utility data includes all house/primary utility accounts, tenant, and secondary space usage. Electricity kilowatt hours (kWh) and gas therms are converted into thousands of British Thermal Units (kBTU). Other fuel types such as fuel oil (e.g., propane, diesel) were not included in this analysis. The case study buildings did not use these fuel types in day-to-day operation, although they may use these loads in emergency conditions (e.g., generators).

Using this utility data, an end-use breakdown assessment is conducted for each building using 2019 monthly data. This breakdown assessment is done for each fuel type in order to identify major end uses such as heating load, cooling load, or domestic hot water (DHW) load. These end uses were estimated as described below, then organized by fuel type. Each end use is represented as a portion of site EUI.

Weather-Dependent End Uses

Weather-dependent (heating and cooling) end uses were first estimated by a regression analysis. Daily average temperature data was gathered from the US National Oceanic and Atmospheric Administration public data set. Changes in energy usage were compared in relation to changes in heating degree days (HDD) and cooling degree days (CDD), calculated from Ronald Reagan National Airport (DCA) weather data. Weather data from DCA is reliable, complete, and regularly used for analysis in Montgomery County as the ambient conditions are similar enough to represent a reasonable estimate of Montgomery County weather usage.

HDD and CDD were based on a base temperature of 65ºF. Average kilowatt hour (kWh) or therm usage per HDD or CDD was then applied to a ten-year average of temperatures to estimate an average, hypothetical year of energy usage, rather than just a single year of data. The following totals were used:

Table 23. 2019 Total Heating Degree Days (HDD) and Cooling Degree Days (CDD)

Month Start	Month End	Days	HDD	CDD
1/1/2019	2/1/2019	31	893	-
2/1/2019	3/1/2019	28	651	-
3/1/2019	4/1/2019	31	574	3
4/1/2019	5/1/2019	30	123	28
5/1/2019	6/1/2019	31	29	191
6/1/2019	7/1/2019	30	-	327
7/1/2019	8/1/2019	31	-	510
8/1/2019	9/1/2019	31	-	437
9/1/2019	10/1/2019	30	-	319
10/1/2019	11/1/2019	31	114	59
11/1/2019	12/1/2019	30	581	-
12/1/2019	1/1/2020	31	723	-
Totals		**365**	**3,688**	**1,874**

For example, in a building known to use gas for both heating and domestic hot water (DHW), increases in gas usage accompanying increases in HDD is associated with heating. In a building known to use gas for only DHW, all gas consumption regardless of changes in outdoor temperature is associated with water heating.

The calculated heating and cooling use for each building was compared to national building end use averages taken from the 2012 dataset (the most recent year available) of the United States Energy Information Administration Commercial Buildings Energy Consumption Survey (CBECS) as a reference dataset used by Portfolio Manager for typical building energy uses. The comparison can provide insight where calculated heating and cooling use is very different from CBECS averages, indicating the need to look deeper at the building's weather dependent versus independent energy use profile.

The analysis team also compared the calculated heating and cooling use to assumptions on Montgomery County building end uses compiled from methodology in the CNCA EBPS tool[51]. The CNCA calculations adjust national building end use averages taken from CBECS to Montgomery County's climate and building energy data, giving typical heating and cooling energy use intensity by typology. These values were used in some cases where actual building data was unreliable, incomplete, or lacked granularity.

Non-Weather-Dependent End Uses

The values in the CBECS data were used as a check against the regression analysis and to better estimate non-weather-dependent end uses such as cooking and DHW. Non-weather-dependent end uses are difficult to separate via weather-based regression methods, making supplemental resources such as CBECS useful for estimating these end loads. CBECS data was also used to estimate some weather-dependent end uses where the regression analysis results were not able to clearly separate end uses.

End Use Descriptions

Building energy usage is organized into energy use intensity (EUI) defined as total building energy usage divided by total building square footage (kBTU/SF). These data are inclusive of all house/ master accounts, tenant, and secondary space usage. Electricity kWh and gas therms are converted into kBTU.

Gas

- Heating: Gas used for heating boilers or furnaces. Also includes usage attributed to heating air for central conditioned air supply systems.
- Cooling: Gas used for fossil-fuel fired chillers. No reviewed buildings contained these systems.
- Domestic Hot Water (DHW): Gas attributed to heating boilers which also supply DHW, or for dedicated water heaters, whether centralized or individual units within tenant spaces.
- Baseload: Gas usage not assigned to the above categories; in most cases this takes the form of cooking.

Electricity

- Heating: Electricity used to generate space heating, associated with heat pump, split systems, and central ventilation units for conditioning supply air. Electricity assigned to heating will also appear in some buildings with central gas-fired equipment when electricity is used for distribution and other equipment. For example, buildings with baseboard heaters supplementing central gas-fired hot water boilers will see electrical use attributed to these baseboard heaters.
- Cooling: Electricity use for air conditioning, applies to all central systems such as electric chillers and cooling towers, as well as unitized air conditioners and heat pumps.
- DHW: Electricity used for DHW production, either through central or unitized DHW tanks.
- Baseload: Electricity usage not assigned to the above categories, includes lighting, ventilation fans, tenant plug loads, cooking where applicable, and other process loads such as elevators. This usage also includes baseload HVAC energy use like fans and pumps that run throughout the year, regardless of weather.
  - Commercial lighting estimates reflect primarily fluorescent lighting; lighting EUI for buildings with LED lighting are reduced by 5%-10% based on the amount of LEDs installed at the building as determined via interviews.
  - Estimates for lighting for multifamily buildings are included. Information is based on the 2015 dataset of the United States Energy Information Administration Residential Energy Consumption Survey (RECS); lighting EUI for buildings with LED lighting are reduced by 5%-10% based on the amount of LEDs installed at the building as determined via interviews.

[51] Supra 11.

Case Study Energy Efficiency Measure Calculations

Energy savings resulting from applying various energy efficiency measures (EEMs) are calculated for each of the case study buildings. An EEM is a building upgrade measure that generates energy savings. All energy savings calculations are shown in percent reduction of site EUI.

Measure savings are calculated to be interactive when organized into packages. For this technical analysis, load reduction measures were estimated first, followed by equipment upgrades that are intended to improve upon the reduced load. Except where noted, additional measures that achieve energy savings beyond targeted goals are excluded to minimize costs, even if applicable to the building.

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.[52]

Each measure's simple payback (SP) is developed based on the expected capital outlay associated with *just the cost of that measure*. Simple Payback is calculated by dividing the total project cost by the energy cost savings per year. In practice, other items may factor into an "effective" SP calculation but are outside the immediate scope of this report. These items include, but are not limited to:

- Replacement costs for aged, existing equipment. Where possible, the approximate equipment age of equipment being replaced was called out at the case study level.
- Potential capital outlay offsets, such as utility incentives
- Effective methods for deferring capital outlay, such as financing

Each measure's return on investment (ROI) is determined by taking the energy cost savings per year divided by the total cost and converting this number to a percentage. Calculating an "effective" ROI is outside the scope of this report for the same reasons as calculating an "effective" SP.

Separately, a table of EEM descriptions, relevant performance standards, cost/savings assumptions, and informational references to assist in creating the proposed EEM packages for each building are included in the *BEPS EEM Matrix* Excel document provided with this report. The document contains EEMs used in this technical analysis, as well as EEMs not recommended for these specific buildings. The data in the *BEPS EEM Matrix* informed the costs and savings for measures in the case studies except where site-specific recommendations are required.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

[52] Montgomery County, Maryland Division of Treasury – Excise Tax Unit. "Public Utility Fuel-Energy Tax Return." https://www.montgomerycountymd.gov/Finance/Resources/Files/FY2021Utility%20Return.pdf

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
    - Electrified end uses were typically large (i.e., all of a building's heating loads), and
    - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the Less-than-Five-Year Payback Package.
- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 24 below.

Table 24: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[53].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited

[53] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

- optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low-cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five-year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

Technical Considerations

Where applicable, the following guidelines for the case studies were applied:

- In buildings with tenant spaces, the level of intrusiveness and invasiveness was qualitatively weighed against energy savings benefits to determine if a measure was feasible to implement. In some cases, entry to tenant spaces is required to complete measures that save enough to get to the energy performance targets, but in others, the balance of other applicable measures can achieve the same goal without as much disruption to tenants.
- When building systems were fully replaced in the ZNC Target Package, the ZNC Target Package did not include measures that modify existing building systems.

- When building system types were changed in the ZNC Target Package, this was assumed to happen at the end of equipment life. Most equipment in the case study buildings would need to be replaced between now and 2035.
- Existing mechanical systems were not substantially modified for the Less-than-Five-Year Payback Package.
- Envelope measures including exterior wall insulation retrofits and window replacement are labor intensive, carry a high cost, can have long paybacks, and are often difficult to implement in an occupied building. These measures were generally excluded from the case studies unless determined to be absolutely necessary to meet the ZNC package. Depending on technology advancements between now and 2035, these measures may not be necessary in the future.

Baseline Assumptions

Standard baseline assumptions were used for existing building equipment for consistency in calculations, unless noted otherwise:

- Gas-fired boilers and hot water heaters: 82% efficient
- Gas-fired furnaces: 80% efficient
- Electric resistance heaters and hot water heaters: 100% efficient
- Heat Pump Water Heaters: Annual average 2.2 COP
- Space heating air source heat pumps: Annual average 2.5 COP

Retro-commissioning

Retro-commissioning (RCx) is the process of ensuring systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs. It is a crucial process for maintaining existing building performance and is generally recognized as the first stage in the building upgrade process. Starting a staged upgrade approach with RCx accounts for interaction among energy flows within a building and ensures a systematic method to target the greatest possible energy savings. This process is always site-specific but is an effective real-world intervention.

Because the RCx scope of work can vary widely depending on the needs of a building and available budget, industry research estimates whole building energy savings can range widely from 5% to 30%, making precise estimates difficult.

As noted above, retro-commissioning was typically one of the first applied measures in the Less-than-Five-Year Payback Package. The savings percentage applied varied somewhat by building type based upon results from occupant interviews. The following guidelines applied:

- Buildings where the existing building automation system (BAS) had more visibility into terminal equipment had a higher percentage savings.
- Buildings with older equipment had a higher percentage savings estimated than buildings with newer equipment.
- In buildings where *other* terminal upgrades occurred (for example, Guest Room Controls in lodging building types), retro-commissioning measures applied *only* to central equipment.
- For some buildings, RCx was not recommended because of equipment layout (decentralized systems) or because major equipment was being replaced and would not be subject to RCx.

Solar PV Estimates

Estimates for solar photovoltaic (PV) system installation were derived from the NREL PVWatts® Calculator (https://pvwatts.nrel.gov/). Solar PV systems use solar energy to generate electricity.

The following parameters were used in the tool:

- Module Type: Premium

- Array Type: Fixed (roof mount)
- Soiling: 0%
- Tilt:10 degrees

PVWatts makes basic assumptions on permissible roof area, however site-specific inspections are required to determine accurate capacity based on building code and regress requirements.

Solar PV cost savings calculations are based purely on generated energy savings. Other financial incentives such as tax benefits or the sale of solar renewable energy certificates (SRECs) were not included in solar PV financials. SRECs are certificates generated for each megawatt-hour of electricity generated from solar PV that can be sold on an open market to offset the capital cost of a PV system.

Financial & Cost Calculations

Cost information for case study EEMs was derived from SWA industry research, RSMeans data, and interviews with case study properties owners and managers.

Estimated costs were intended to be inclusive of the total cost to complete the project (e.g., engineering, design, equipment and materials, associated work related to equipment installation, and labor). Soft costs for engineering, design, and other considerations were not explicitly itemized as part of the cost estimates. These fees were assumed to be a relatively small percentage of the overall capital cost for whole-building upgrades and generally captured in the cost estimates referenced here from research studies and other case study examples.

These estimated costs are absolute figures. They do not consider other factors that may make financial performance more appealing, including the following:

- Sunk costs for equipment replacement at the EUL
- Utility incentives
- Tax credits or depreciation policies
- Financing through entities such as the Montgomery County Green Bank
- Fines resulting from non-compliance with BEPS, and future liability from approaches that may not comply with potential carbon reduction and electrification requirements.
- Labor cost savings from new equipment (e.g., reduced maintenance, value of tenant comfort)

Each EEM's simple payback – measured by simple payback (SP) – was determined after identifying measures applicable to the building. This was calculated by dividing total measure cost by the measure's annual dollar savings.

Each EEM's return on investment, or ROI, was determined by dividing the annual dollar savings by total measure cost and converting to a percentage.

Case Study 1: Class-A Office

Building Information

This Class A office building in Montgomery County has a restaurant on the first floor. An adjacent parking garage can be used by tenants and visitors to the restaurant. Most of the non-restaurant space is comprised of typical office space (e.g., offices, conference rooms, and ancillary support areas like pantries).

This building was approximately 40% unoccupied based on 2019 data. The impacts of vacancy on targets are discussed more within *Recommendations for Adjustments based on Occupancy*. This case study target is based upon the methodology currently available to Montgomery County.

Table 25. Building Characteristics – Case Study 1

Category	Building Information
Typology	Office
Square Footage	200,000 ft.^{2} – 225,000 ft.^{2} Office: 100% Parking: 150,000 ft.^{2} – 175,000 ft.^{2} (on premises but does not factor into conditioned square footage)
Year Built Range	2005 – 2010
2019 ENERGY STAR Score	60 – 65
2019 Site EUI (kBTU/SF) (calculated for this study)	70 – 80

Building System Information

The basic building system information specific to the case study building is described below.

Table 26. Building System Information – Case Study 1

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	Building automation system controls mechanical equipment	Electric	13	<5
Heating	Distributed electric VAV heaters	Electric	13	10-15
Cooling	2x chillers (in series) w/free cooling HX	Electric	13	10-15
Ventilation	Floor-by-floor AHUs with an ERV. VAV terminal units	Electric	13	10-15
DHW	Distributed electric water heaters	Electric	13	5-10
Lighting	Mostly converted to LED	Electric	5-10	5-10
Envelope	Original to the building	N/A	13	30-35
Metering	Two main electric meters plus a gas meter for the restaurant	Electric, Gas	N/A	N/A

Utility End Use Assessment

The building's energy usage type and estimated end use is displayed below.

- Gas: exclusively used in the restaurant space, totaling 18% of the building's energy use.
- Electricity: used for heating, cooling, ventilation, lighting, and electric plug loads. In total, electricity is 82% of the building's energy use.

Table 27. 2019 Site EUI by End Use – Case Study 1. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Lighting – Electric	Baseload – Electric	Total EUI
0%	0%	0%	18%	17%	10%	0%	43%	12%	**100%**

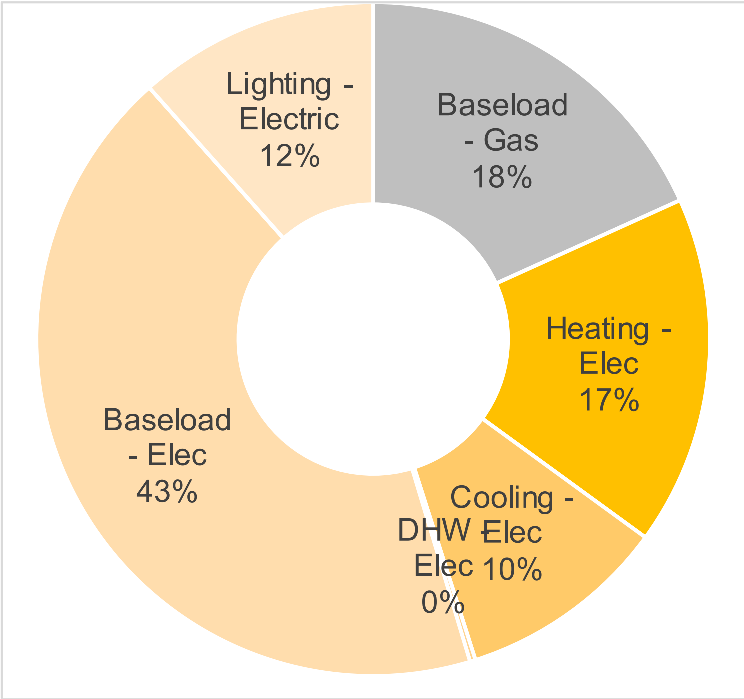

Figure 36. Site EUI Share (%) by End Use – Case Study 1

Target Determination

Total site EUI targets for the building are determined by a weighted average of applicable ZNC targets per space use type. Space use types are provided in Portfolio Manager and via reviews of available drawings. Table 28 contains a breakdown of the space use targets for purposes of calculating the ZNC target. Other building uses are discussed below this table.

A relatively small restaurant is located within the building (less than 5% of the overall floor area). Because this space does not make up more than 25% of the floor area, it does not factor into this building's target calculation. The floor area is instead added to the Office space per EPA ENERGY STAR guidance. The restaurant is the only space that uses gas.

Note that the floor areas shown in the table below are approximated based on Table 26.

All the following analysis uses the ZNC target. The table also has an alternate target ("EE Standard"), which is no different than the ZNC Target for this building. The building will need to take action in order to meet both the ZNC and EE Targets. All the following analysis uses the ZNC target.

Table 28. Space Use Target Methodology Summary – Case Study 1

Specific Space Type	Space Type Group	Area %	Floor Areas	ZNC Standard [Site EUI]	EE Standard [Site EUI]	Weighted ZNC EUI (ZNC * Area%)	Weighted EE EUI (EE * Area%)
Office	Office	100%	225,000	53.4	53.4	53.4	53.4
Total	**-**	**100%**	**225,000**	**-**	**-**	**53.4**	**53.4**

A significant portion of this building is listed as vacant office space based on Portfolio Manager data. While an eventual useful end goal of separating vacant space from occupied space should be pursued (see *Site EUI Target Adjustment Factors*), for case study purposes, the analysis team assumed the initial ZNC target would have to be set based upon information available to Montgomery County today.

The baseline site EUI is derived from whole building 2019 utility data over whole building square footage.

Table 29. ZNC and Interim Targets – Case Study 1

EUI Description	ZNC Target	EE Target
Baseline EUI	70 – 80	70 – 80
2026 – Interim Target 1	63 – 72	63 – 72
2030 – Interim Target 2	57 – 64	57 – 64
2035 – Target	53.4	53.4

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *Less-than-Five-Year Payback Package* is based on the results of a package that have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax breaks.

An EE Target Package was not developed for this building as the ZNC Target is identical to the EE Target.

All costs are total costs for the measures, not incremental costs. These costs do not include applicable incentives. The following table offers a financial overview of these packages.

Table 30. EEM Package Summary – Case Study 1

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
ZNC Target Package	49 – 53	30%	$150,400	$5,280,000	35.1	3%
Less-than-Five-Year Payback Package	67 – 75	8%	$47,300	$95,00	2.0	49%

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 31 that shows the estimated remaining life of the equivalent replacement system. An “N/A” indicates the existing system is not replaced, and a “DNE” means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 31. ZNC Target Package EEMs – Case Study 1. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Convert to VRF System	Convert the mechanical system to a VRF system	7.2%	$43,900	$4,682,000	106.6	1%	15	10
2	Electrify Cooking	Convert gas cooking to electric cooking	7.7%	$16,100	$24,000	1.5	66%	15	N/A
3	Retro-commissioning	Retro-commission and implement improvements on building systems	6.8%	$41,400	$74,000	1.8	56%	5	5-10
4	Plug Load Management	Install smart plug load management tools	1.6%	$9,700	$38,000	3.9	25%	10	DNE
5	Solar PV	Install roof-mounted solar PV	6.5%	$39,300	$462,000	11.7	9%	15	DNE
Total			**29.8%**	**$150,400**	**$5,280,000**	**35.1**	**3%**	**-**	

Table 32. Post Retrofit Percent Reductions from Baseline for ZNC Target Package – Case Study 1

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	0%	0%	0%	18%	17%	10%	0%	43%	12%	**100%**
End Use Difference	0%	0%	0%	-100%	-69%	51%	-8%	-10%	-8%	**70%**

EE Target Package

This typology has the same ZNC target as EE target; therefore, there is no separate EE target package for this building. The ZNC target package in Table 31 would also serve as an EE target package.

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback Package allows the building to reach its first interim target threshold.

Table 33. Less-than-Five-Year Payback Package EEMs – Case Study 1. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)
1	Retro-Commissioning	Retro-commission and implement improvements on building systems	6.5%	$39,800	$74,000	1.9	53%	5
2	Plug Load Management	Install smart plug load management tools	1.2%	$7,500	$21,000	2.8	35%	10
	Total		**7.8%**	**$47,300**	**$95,000**	**2.0**	**49%**	**-**

Table 34. Post Retrofit Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 1

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	0%	0%	0%	18%	17%	10%	0%	43%	12%	**100%**
End Use Difference	0%	0%	0%	0%	-8%	-8%	-8%	-11%	-8%	**92%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

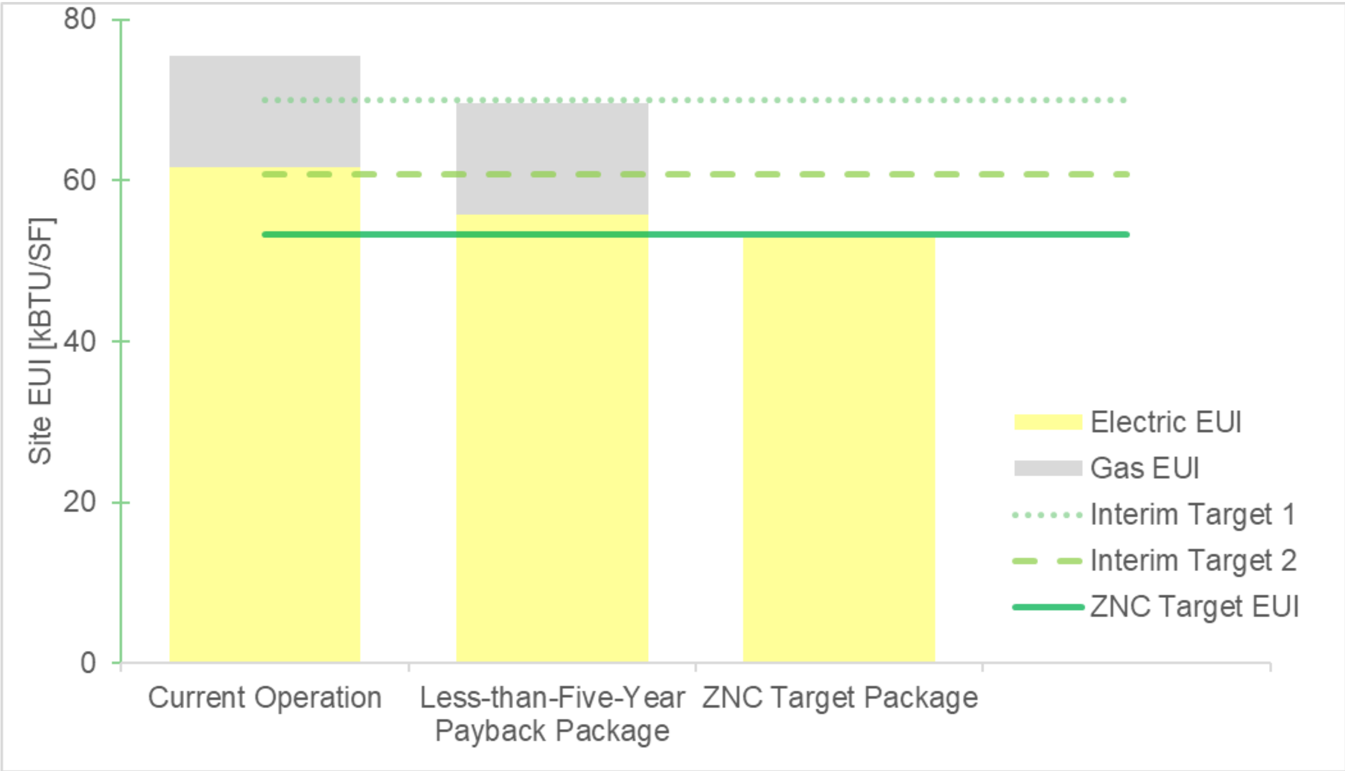

Figure 37. Target-to-Package Comparisons – Case Study 1

The Less-than-Five-Year Payback Package clears the first interim target but leaves the building well short of the ZNC Target.

Building-Specific Technology Assessment

Electric heating is rather inefficient compared to other heat pump technology (for example, either WSHP or VRF systems). Improving heating efficiency represented the best opportunity to reach the ZNC target.

A WSHP conversion would maintain some of the existing piping through the core of the office building; new water piping would need to be run throughout the building perimeter. In addition, the pumping system would be maintained. A VRF conversion would also be intrusive in terms of refrigerant piping; however, the pumping energy required for refrigerant is much less than the pumping energy required for water. This reduction in pumping energy made the energy savings of VRF more attractive than WSHP.

Gas is not used in office spaces at this building. As a result, electrification of the restaurant loads represents the only effective way to eliminate gas usage.

Following these system upgrades, other measures affecting building demand were chosen, such as plug load management. These measures do not have a large overall impact on savings and were generally non-interactive in nature meaning savings from these measures do not appreciably increase or decrease savings from other measures.

Lastly, solar PV is applied to the roof only. Other approaches to solar PV such as canopied PV over the adjacent parking garage or empty lot next door increase the amount of PV and may be a more attractive financial approach than the ZNC Target Package.

The Less-than-Five-Year Payback Package was constructed using nearly the same measures as the ZNC Target Package, with the exception of system conversion, restaurant electrification and solar PV.

This building has substantial unoccupied space which makes the ZNC target easier to reach. The section *Recommendations for Adjustments based on Occupancy* describes possible adjustments to this building (and similar building types with substantial vacancy) which may in turn impact the actual measures chosen.

Package Comparisons

The existing system can be optimized to meet the ZNC target. However, system conversion should be investigated when the existing chilled water system reaches the end of its life, as another type of system could provide greater efficiency.

There are some ways to reduce compliance retrofit costs:

- Some of the total capital cost may be effectively defrayed by subtracting avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment will likely be replaced before the 2035 target. This money can be effectively set aside to help cover part of the costs.
- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today. Funds are available on three-year cycles and the program offerings can change during the program cycle; based on this, incentive estimates are not included in this report.
- Advances in technology between now and the ZNC target date may result in viable alternative approaches, meaning reduction in the ZNC costs and payback ranges described.

The Less-than-Five-Year Payback Package largely utilizes retrofits to existing equipment. Applying a higher estimated savings for retro-commissioning may be possible.

Measures Not Recommended

Measures reviewed for the building but not included in the EEM package are described below.

- DHW: domestic hot water is a minimal load in office buildings and was not examined.
- Envelope: Re-roofing was considered but ultimately determined as non-cost effective and not necessary to meet the ZNC target. The remaining envelope items should still be functional and effective in 2035.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Two packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
  - Electrified end uses were typically large (i.e., all of a building's heating loads), and
  - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the Less-than-Five-Year Payback Package.
- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package (Not Applicable for this Case Study)

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 35 below.

Table 35: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[54].

[54] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Utility Rates

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.

Case Study 2: Older Mixed Fuel Office

Building Information

The building was constructed in the 1970s, and most mechanical equipment has been replaced once since original construction. The building is heated and cooled by water source heat pumps (WSHPs) connected to a condenser water loop, with a central boiler and cooling tower to provide heat and heat rejection, respectively, for this system. Onsite parking is available.

The ground floor of this building has retail and restaurants, which in total make up less than five percent of the overall floor area. These tenants generally have their own mechanical systems and meters.

Table 36. Building Characteristics – Case Study 2

Category	Building Information
Typology	Office
Floor Area	Total: 250,000 ft.^{2} – 275,000 ft.^{2} Office: 50% Medical Office: 50% Parking: 50,000 ft.^{2} -75,000 ft.^{2} (on premises but does not factor into conditioned square footage)
Year Built	1970-1975
2019 ENERGY STAR Score	40 – 45
2019 Site EUI (kBTU/SF) (calculated for this study)	80 – 90

Building System Information

The basic building system information specific to the case study building is described below.

Table 37. Building System Information – Case Study 2

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	Manages central plant/major equipment only. Perimeter heat pumps operated on stop/start only	Electric	Unknown (estimated 15 years)	Unknown (est. <5)
Heating	Distributed WSHPs with central boiler for heating	Gas	5	15-20
Cooling	Distributed WSHPs with cooling tower for heat rejection. Larger central WSHPs also provide fresh air.	Electric	9-14	5-10
Ventilation	No dedicated ventilation equipment. Outdoor air delivered via ventilation shaft to each mechanical room	Electric	N/A	N/A
DHW	Two electric DHW heaters	Electric	Unknown (estimated 10 years)	Unknown (est. 5-10)
Lighting	Mostly completed LED upgrades	Electric	0-2	5-10
Envelope	Brick with poured concrete exterior. Façade components are original, though the west side of the building has window tint.	N/A	50	5-10
Metering	Retail and restaurant spaces on separate meters	Electric, Gas	N/A	N/A

Utility Energy End Use Assessment

The building's energy usage type and estimated end use is displayed below.

- Gas: used in the office space for space heating via the central boiler. The retail spaces, including the restaurant, also use gas. Gas makes up 21% of the building's site energy use.
- Electricity: used for heating and cooling (through WSHPs), ventilation, lighting, and electric plug loads. Electricity makes up 79% of the building's site energy use.

Table 38. 2019 Site EUI by End Use – Case Study 2. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Elec	Cooling – Elec	DHW – Elec	Baseload – Elec	Lighting – Elec	Total EUI
16%	0%	0%	4%	13%	8%	0%	47%	10%	**100%**

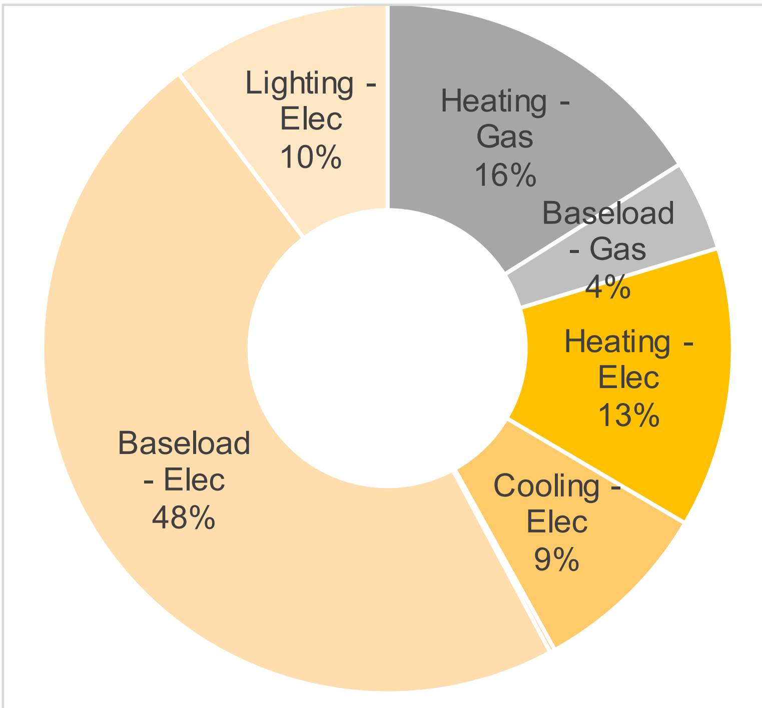

Figure 38. Site EUI Share (%) by End Use – Case Study 2

Target Determination

Site EUI targets are determined by a weighted average of applicable ZNC targets per space use type. Space use types are provided in Portfolio Manager and via reviews of available drawings. Table 39 contains a breakdown of the space use targets for purposes of calculating the ZNC target. Other building uses are discussed below this table. The table also has an alternate target ("EE Standard"), which is no different than the ZNC Target for this building. The building will need to take action in order to meet both the ZNC and EE Targets. All the following analysis uses the ZNC target.

Note that the floor areas shown in the table below are approximated based on Table 37.

Table 39. Space Use Target Methodology Summary – Case Study 2

Specific Space Type	**Space Type Group**	**Area %**	**Floor Areas (ft.^{2})**	**ZNC Standard [Site EUI]**	**EE Standard [Site EUI]**	**Weighted ZNC EUI (ZNC * Area%)**	**Weighted EE EUI (ZNC * Area%)**
Office	Office	50%	125,000	53	53	26.7	26.7
Medical Office	Health Care Outpatient	50%	125,000	62	62	31.1	31.1
Total	**-**	**100%**	**250,000**	**-**		**57.8**	**57.8**

This building has restaurant and other retail spaces. These spaces are relatively small (less than 5% of the overall floor area). Because the ground floor retail spaces do not make up more than 25% of the floor area, these spaces' individual targets do not factor into this building's target calculation. These retail floor areas are instead spread evenly across the Office and Health Care Outpatient spaces.

The baseline EUI is derived from whole building 2019 utility data over whole building square footage.

Table 40. ZNC and Interim Targets – Case Study 2

Target	**ZNC Target**	**EE Target**
Baseline EUI	80 – 90	80 – 90
2026 – Interim Target 1	71 – 80	71 – 80
2030 – Interim Target 2	62 – 70	62 – 70
2035 – ZNC Target	57.8	57.8

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *Less-than-Five-Year Payback Package* is based on the results of a package that would have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax credits.

An EE Target Package was not developed for this building as the ZNC Target is identical to the EE Target.

All costs are total costs for the measures, not incremental costs. These costs do not include applicable incentives. The following table offers a financial overview of these packages.

Table 41. EEM Package Summary – Case Study 2

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
ZNC Target Package	52 – 57	35%	$183,000	$4,832,000	26.4	4%
Less-than-Five-Year Payback Package	67 – 75	16%	$118,100	$476,000	4.0	25%

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 42 that shows the estimated remaining life of the equivalent replacement system. An “N/A” indicates the existing system is not replaced, and a “DNE” means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 42. ZNC Target Package EEMs – Case Study 2. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify Space Heating	Convert the central boiler to an air-to-water heat pump	11.8%	$8,000	$3,730,000	466	0%	18	15-20
2	Electrify Restaurant	Convert gas cooking to electric cooking	1.7%	($10,500)	$12,000	N/A	N/A	10	Unknown (estimated 10 years)
3	Retro-commissioning	Retro-commission and implement improvements on central building systems	6.9%	$59,600	$95,000	1.6	63%	5	N/A
4	HVAC Schedule Adjustments	Adjust existing HVAC schedules to align with occupancy	6.6%	$57,000	$3,000	0.0	2,281%	5	N/A
5	Electric Submetering	Install submeters to incentivize tenants to reduce their energy use	1.0%	$8,800	$149,000	16.9	6%	10	DNE
6	Lighting Occupancy Presence Sensors	Install lighting sensors to sense occupants in offices	0.1%	$1,300	$59,000	46.7	2%	10	DNE
7	Daylighting Controls	Install daylighting sensors to turn off lights in perimeter spaces	0.2%	$1,900	$95,000	51.0	2%	10	DNE
8	Garage LED upgrade	Complete ongoing LED conversion for the parking garage	0.3%	$2,200	$48,000	21.7	5%	10	0-5
9	Plug Load Management	Install smart plug load management tools	1.3%	$11,500	$27,000	2.4	42%	10	DNE
10	Solar PV	Install roof-mounted solar PV	5.0%	$43,200	$614,000	14.2	7%	15	DNE
Total			**34.9%**	**$183,000**	**$4,832,000**	**26.4**	**4%**	**-**	

Table 43. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 2

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI (%)
Baseline	16%	0%	0%	4%	13%	8%	0%	47%	10%	**100%**
End Use Difference	-100%	0%	0%	-100%	1%	-24%	0%	-23%	-15%	**65%**

EE Target Package

This typology has the same ZNC target as EE target; therefore, there is no separate EE target package for this building. The ZNC target package in Table 42 would also serve as an EE target package.

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback Package allows the building to reach its first interim target threshold.

Table 44. Less-than-Five-Year Payback Package EEMs – Case Study 2. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)
1	Retro-commissioning	Retro-commission and implement improvements on central building systems	7.6%	$58,500	$95,000	1.6	62%	5
2	HVAC Schedule Adjustments	Adjust existing HVAC schedules to align with occupancy	5.5%	$34,100	$3,000	0.1	1,365%	5
3	Electric Submetering	Install submeters to incentivize tenants to reduce their energy use	1.0%	$8,500	$149,000	17.6	6%	10
4	Lighting Occupancy Presence Sensors	Install lighting sensors to sense occupants in offices	0.1%	$1,300	$59,000	46.1	2%	10
5	Daylighting Controls	Install daylighting sensors to turn off lights in perimeter spaces	0.2%	$1,900	$95,000	50.5	2%	10
6	Garage LED upgrade	Complete ongoing LED conversion for the parking garage	0.3%	$2,200	$48,000	21.7	5%	10
7	Plug Load Management	Install smart plug load management tools	1.3%	$11,600	$27,000	2.3	43%	10
	Total		**16.1%**	**$118,100**	**$476,000**	**4.0**	**25%**	**-**

Table 45. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 2

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	16%	0%	0%	4%	13%	8%	0%	47%	10%	**100%**
End Use Difference	-23%	0%	0%	0%	-24%	-24%	0%	-12%	-15%	**84%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

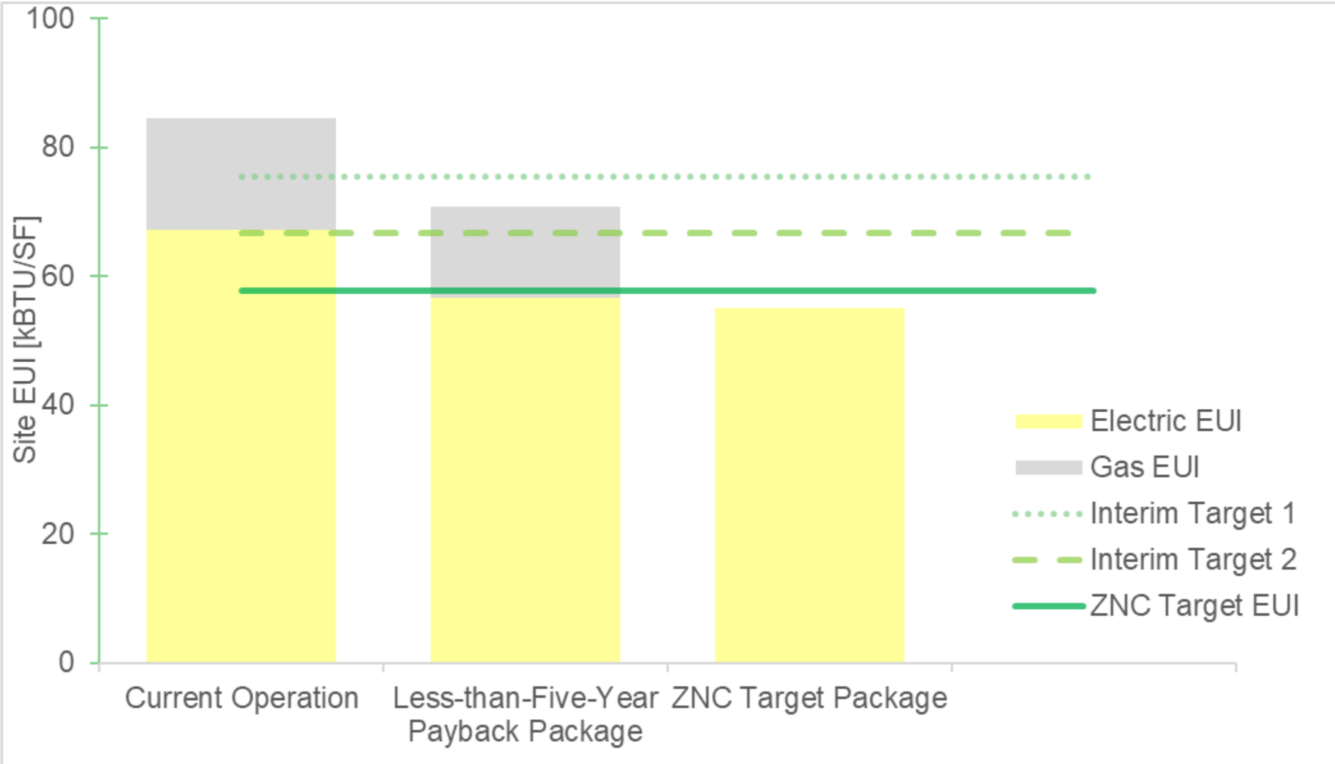

Figure 39. Target-to-Package Comparisons – Case Study 2

As seen in Figure 39, the Less-than-Five-Year Payback Package results in a savings amount below the first interim target. As discussed below, savings above and beyond the ZNC Target are certainly possible for this building.

Building-Specific Technology Assessment

When offices have a substantial gas load, it is typically for space heating. Given this, electrification for this building would consist of electrifying the boiler system by converting it to an air-to-water heat pump and then electrifying any of the smaller retail loads.

Once these improvements are completed, optimization of the remaining building systems can occur. These additional savings measures can be complicated to implement for a heat pump loop building, since most of the building efficiencies already lay within the system itself. The controls system can help somewhat, but the main benefit employed here is around scheduling. About 13 hours per week of run-time can be reasonably reduced, to a total of 65 hours per week based on information provided by building operators. Further run-time reductions may be possible, but in general 65 hours per week is a reasonable approximation of average run-time for offices of this building type.

Retro-commissioning is applied to the ZNC Target Package; since most of the mechanical equipment (except the central heating plant) will remain, retro-commissioning is viable for this building.

Other measures affecting building energy demand were reviewed such as LED lighting conversions and high-efficiency water aerators. These measures do not have a large overall impact on savings and are generally non-interactive in nature, meaning savings from these measures do not appreciably increase or decrease savings from other measures.

Plug Load Management is applied to both packages, and roof-mounted solar PV is applied to the ZNC Target Package. In practice, solar PV needs to be coordinated with other measures that require roof space.

The Less-than-Five-Year Payback Package is largely constructed using similar measures as the ZNC Target Package.

Package Comparisons

Although this building can reach its ZNC target with technology available today, doing so incurs a significant cost without factoring in incentives and grants. There are some ways to reduce compliance retrofit costs and spread the upfront capital costs over time with financing, which improves the cash flow of a building as well:

- Other detailed savings measures (i.e., applicability of sensors and more advanced control techniques) may result in larger savings amounts than estimated in Table 2-6. These types of improvements may be possible with a more detailed look at the building.
- Some of the total capital cost may be effectively defrayed by accounting for avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment will likely be replaced before the 2035 target. This money can be effectively set aside to help cover part of the costs.
- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today. Funds are available on three-year cycles and the program offerings can change during the program cycle; based on this, incentive estimates are not included in this report.

The Less-than-Five-Year Payback Package largely utilizes retrofits to existing equipment. Applying a higher estimated savings for retro-commissioning and lighting measures may be possible, depending on the deficiencies found during the retro-commissioning process.

Advances in technology between now and the ZNC target date may result in viable alternative approaches, meaning reduction in the ZNC costs and payback ranges described.

Measures Not Recommended

Measures reviewed for the building but not included in the EEM package are described below.

- HVAC: a full replacement to the heating and cooling system with a refrigerant-based distribution system may yield higher savings but costs substantially more and is far more intrusive to tenant spaces throughout the building. In addition, more aggressive schedule adjustments (i.e., operating HVAC only 10 hours a day instead of 12) are not included.
- Dedicated Outdoor Air Systems: A DOAS may be required by code if a substantial renovation of the building occurs prior to 2035; however, the ZNC Target pathway that included DOAS as an option is a less attractive financial package than the ZNC Target Package in Table 2-6. Installation of a DOAS will result in energy reductions, presenting a possible alternative pathway to reaching the ZNC Target that is not included in this report.
- Envelope: envelope measures were reviewed but not included in either package. Other measures such as electrification generate more energy savings at similar capital outlays and are a more effective way to reach the ZNC target.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
  - Electrified end uses were typically large (i.e., all of a building's heating loads), and
  - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the Less-than-Five-Year Payback Package.
- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package (Not Applicable for this Case Study)

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 46 below.

Table 46: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[55].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five-year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

[55] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Utility Rates

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.

Case Study 3: Older All-Electric Office

Building Information

This office building was constructed in the 1970s. Most of this office space is dedicated to various office-related functions such as meeting rooms, offices, and other similar uses. This building also has a dining facility. This building also has a large base load.

Table 47. Building Characteristics – Case Study 3

Category	Building Information
Typology	Office
Square Footage	225,000 – 250,000 ft.^{2} Office: 100%
Year Built	1970 – 1975
2019 ENERGY STAR Score	30 – 35
2019 Site EUI (kBTU/SF) (calculated for this study)	80 – 90

Building System Information

The basic building system information specific to the case study building is described below.

Table 48. Building System Information – Case Study 3

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	Building automation system for central equipment only (central plant, AHUs, duct heaters), but no control over chillers.	Electric	Unknown (estimated 10 years for central, 35 years terminal)	5-10 (central), <5 (terminal)
Heating	Central electric duct heaters, perimeter VAV reheat	Electric	~40	<5
Cooling	Two centrifugal chillers; condenser water via 2-cell axial-fan cooling tower; some self-contained units (SCUs) on first floor on separate condenser loop	Electric	25	5-10
Ventilation	2x large VAV AHUs; no energy recovery	Electric	~40	<5
DHW	Unitized DHW	Electric	10-30	<5-10 (depending on heater)
Lighting	Mostly T8; one floor retrofit to LED	Electric	Unknown (estimated 10 years)	<5
Envelope	Original to the building, except roof; windows double-pane but sealing issues abound	Electric	35 (most components)	5-10
Metering	Four electric meters	Electric	N/A	N/A

Utility End Use Assessment

The building's energy usage type and estimated end use is displayed below.

- Gas is not used at this building.
- Electricity is used for all functions of this building.

Table 49. 2019 Site EUI by End Use – Case Study 3. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
0%	0%	0%	0%	12%	9%	1%	68%	10%	**100%**

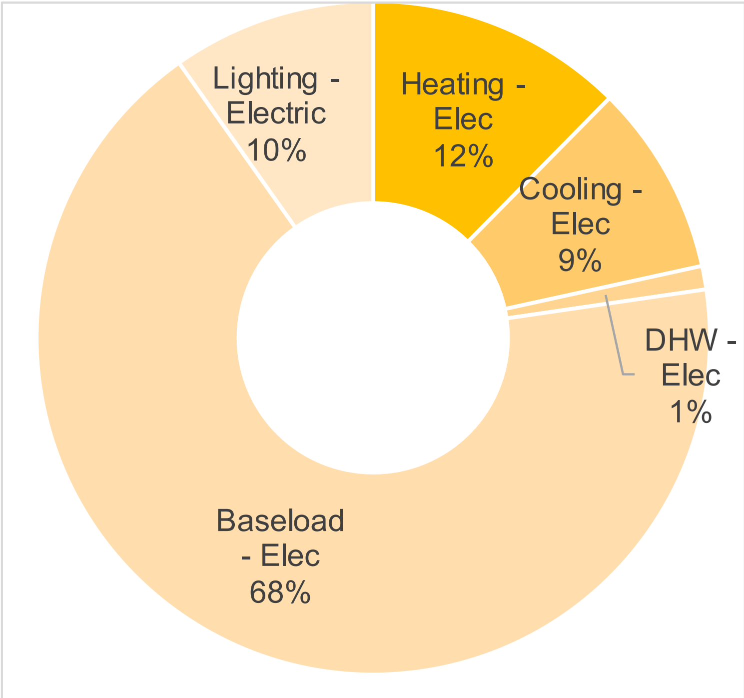

Figure 40. Site EUI Share (%) by End Use – Case Study 3

Target Determination

Site EUI targets are determined by a weighted average of applicable ZNC targets per space use type. Space use types are provided in Portfolio Manager and via reviews of available drawings. The table also has an alternate target ("EE Standard"), which is no different than the ZNC Target for this building. The building will need to take action in order to meet both the ZNC and EE Targets. All the following analysis uses the ZNC target.

Note that the floor areas shown in the table below are approximated based on Table 48.

Table 50. Space Use Target Methodology Summary – Case Study 3

Specific Space Type	Space Type Group	Area %	Floor Areas	ZNC Standard [Site EUI]	EE Standard [Site EUI]	Weighted ZNC EUI (ZNC * Area%)	Weighted EE EUI (EE * Area%)
Office	Office	100%	250,000	53.4	53.4	53.4	53.4
Total	**-**	**100%**	**250,000**	**-**	**-**	**53.4**	**53.4**

The baseline EUI is derived from whole building 2019 utility data over whole building square footage.

Table 51. ZNC and Interim Targets – Case Study 3

EUI Description	ZNC Target	EE Target
Baseline EUI	80 – 90	80 – 90
2026 – Interim Target 1	71 – 80	71 – 80
2030 – Interim Target 2	62 – 70	62 – 70
2035 – Target	53.4	53.4

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *Less-than-Five-Year Payback Package* is based on the results of a package that would have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax credits.

An EE Target Package was not developed for this building as the ZNC Target is identical to the EE Target.

All costs are total costs for the measures, not incremental costs. These costs do not include applicable incentives. The following table offers a financial overview of these packages.

Table 52. EEM Package Summary – Case Study 3

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
ZNC Target Package	47 – 53	41%	$323,900	$6,215,000	19.2	5%
Less-than-Five-Year Payback Package	57 – 64	29%	$226,600	$811,000	3.6	28%

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 53 that shows the estimated remaining life of the equivalent replacement system. An "N/A" indicates the existing system is not replaced, and a "DNE" means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 53. ZNC Target Package EEMs – Case Study 3. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

Measure #	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Convert to VRF	Convert the mechanical system to a VRF system	25.4%	$200,600	$5,169,000	25.8	4%	18	5-10
2	Install ERV	Install an exhaust recovery ventilation unit	7.0%	$55,100	$470,000	8.5	12%	15	DNE
3	HVAC Schedule Adjustments	Adjust existing HVAC schedules to align with occupancy	3.5%	$27,900	$3,000	0.1	1,116%	5	N/A
4	Finish LED Conversion	Convert the remaining lighting systems to LED	1.4%	$10,800	$207,000	19.1	5%	10	<5
5	Plug Load Management	Install smart plug load management tools	1.4%	$11,300	$23,000	2.1	48%	10	DNE
6	Solar PV	Install roof-mounted solar PV	2.3%	$18,200	$343,000	18.8	5%	15	DNE
Total			**41.0%**	**$323,900**	**$6,215,000**	**19.2**	**5%**	**-**	

Table 54. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 3

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	0%	0%	0%	0%	12%	9%	1%	68%	10%	**100%**
End Use Difference	0%	0%	0%	0%	-80%	-47%	0%	-37%	-14%	**59%**

EE Target Package

This typology has the same ZNC target as EE target; therefore, there is no separate EE target package for this building. The ZNC target package in Table 53 would also serve as an EE target package.

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback package allows the building to reach its second interim target threshold.

Table 55. Less-than-Five-Year Payback Package EEMs – Case Study 3. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

Measure #	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)
1	Install ERV	Install an exhaust recovery ventilation unit	9.6%	$75,900	$470,000	6.2	16%	15
2	HVAC Schedule Adjustments	Adjust existing HVAC schedules to align with occupancy	13.9%	$110,000	$3,000	0.0	4,400%	5
3	Retro-commissioning	Retro-commission and implement improvements on central building systems	1.6%	$12,700	$82,000	6.5	15%	5
4	Primary Chilled Water Pump VFDs	Install primary chilled water pump variable frequency drives	0.1%	$1,000	$7,000	7.3	14%	15
5	Condenser Water Pump VFDs	Install condenser water pump variable frequency drives	0.4%	$3,400	$19,000	5.5	18%	15
6	Finish LED Conversion	Convert the remaining lighting systems to LED	1.4%	$10,800	$207,000	19.1	5%	10
7	Plug Load Management	Install smart plug load management tools	1.6%	$12,800	$23,000	1.8	55%	10
	Total		**28.7%**	**$226,600**	**$811,000**	**3.6**	**28%**	**-**

Table 56. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 3

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	0%	0%	0%	0%	12%	9%	1%	68%	10%	**100%**
End Use Difference	0%	0%	0%	0%	-52%	-42%	0%	-25%	-14%	**71%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

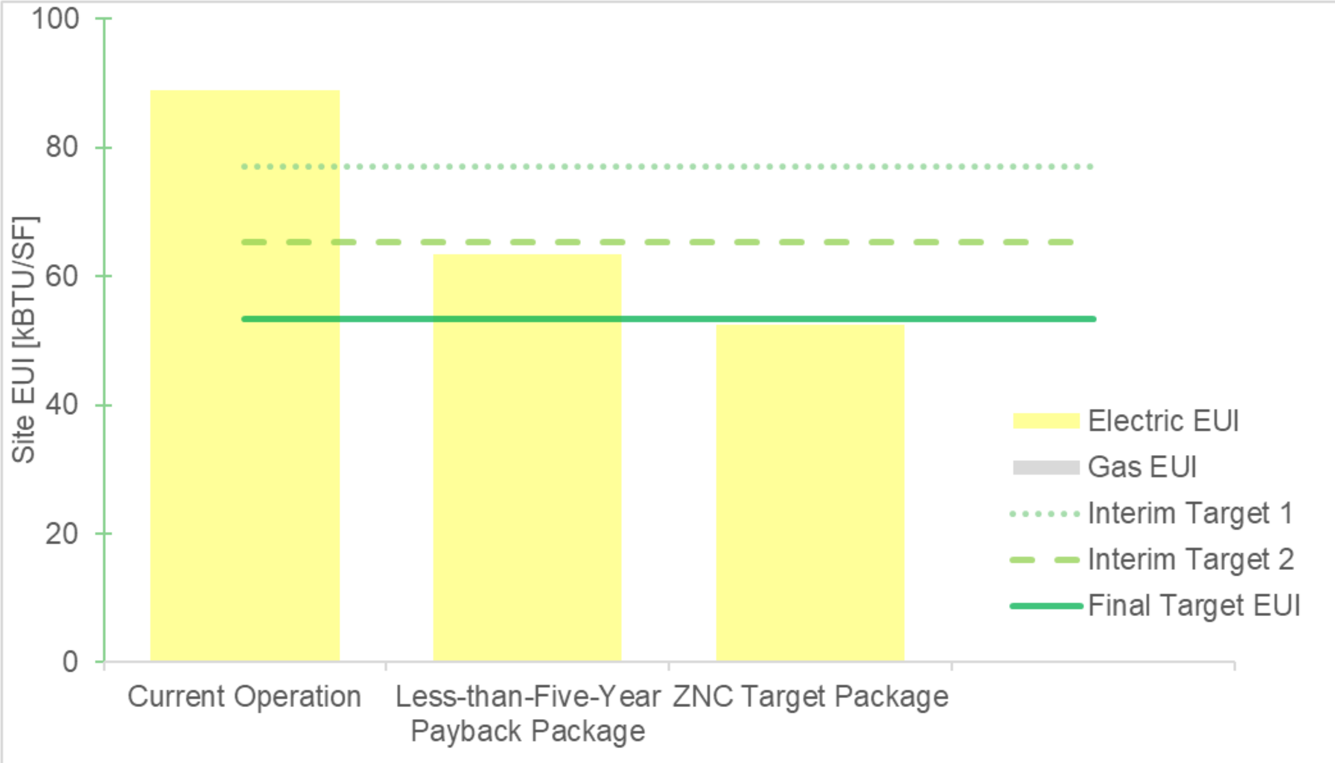

Figure 41. Target-to-Package Comparisons – Case Study 3

This building is unique among case study buildings: the Less-than-Five-Year Payback Package gets this building below the second interim target. The primary reason for this is the large reduction in energy usage from improvements in scheduling of HVAC equipment operation.

Building-Specific Technology Assessment

This office is all-electric. However, the electric heating system is relatively inefficient, and improvements are possible. This improvement can be achieved with a change to a VRF system.

VRF was determined to be a more effective measure than conversion to a heat pump loop for a handful of reasons:

- Water piping is only present in the central plant and mechanical rooms; terminal unit replacement for a WSHP loop would entail running water piping throughout the building. Refrigerant piping necessary for a VRF system is comparatively smaller.
- Removal of the existing pump loops also allows for claiming of pump and cooling tower energy savings, which is instrumental in reaching the ZNC target.

Installation of a exhaust recovery ventilation system (ERV) makes sense, as existing fresh air ductwork can be co-opted relatively easily. The combination of VRF and ERV measures consist of the major mechanical adjustments.

It should be noted that the schedule adjustments here are relatively unique. Based upon information from the building owner’s staff, in 2019 this building’s mechanical system was operating continually (i.e., during the technical analysis period, the building was operating continually). Since this time period, the building schedules were adjusted to run from 5:30 AM to 11 PM on each weekday, representing a 54% reduction in run-time. This type of run-time reduction is relatively uncommon across commercial typologies but was reasonable based upon information obtained at this site.

Since 2019 data was used as the baseline period, scheduling improvements were able to be claimed for both the Less-than-Five-Year and ZNC Target Packages. In the ZNC Target Package case, the schedule adjustments should be performed at the same time as the mechanical system conversions and not handled separately.

LED conversion is not needed to meet the ZNC target but can be included in the Less-than-Five-Year Target Package thanks to the large energy cost savings found from scheduling improvements. This measure is included in the ZNC Target Package since it is likely this work would occur prior to any system conversions. In addition, utility incentives are available that would help the financial performance of this measure.

Plug Load Management is applied to both packages, and solar PV is applied to the ZNC Target Package. In practice, solar PV needs to be coordinated with other measures that require roof space (e.g., VRF system installations, DOAS installation).

A handful of items appear in the Less-than-Five-Year Payback Package that are not included in the ZNC Target Package. Since the ZNC Target Package changes the type of mechanical system, the following measures are not physically possible to implement in ZNC Target Package:

- *Retro-commissioning:* similar to other building typologies with mechanical system changes, retro-commissioning for new building systems does not make practical sense. A slightly lower end use estimate for retro-commissioning is taken for conservative reasons; in practice, the schedule adjustments seen at this building are likely *not* typical for this typology. However, combined savings of scheduling plus retro-commissioning may be reasonable. SWA assumed that some of the savings that would typically be seen via retro-commissioning are instead realized via schedule adjustments.
- *Primary Chilled Water Pump VFDs and Condenser Water Pump VFDs:* these systems appear in the baseline building but not in the new mechanical systems, as the VRF system does not have these loops.

Package Comparisons

Although this building can reach its ZNC target with technology available today, doing so incurs a significant cost and substantial disruption. There are some ways to reduce compliance retrofit costs:

- Other detailed savings measures for the existing building mechanical systems *may* be enough to reach ZNC. These types of improvements may be possible with a more detailed look at the building, which is outside the scope of this technical analysis. With enough additional realized savings, this may render other upgrades such as air sealing or installing a DOAS unnecessary to reach ZNC.
- A substantial renovation occurring between now and 2035 may trigger some method of outdoor heat recovery due to code requirements (i.e, the DOAS installation). Although this work would have to take place and be paid for regardless, if a DOAS is installed for code compliance reasons, this would not be a cost associated with compliance with the ZNC target.
- Some of the total capital cost may be effectively defrayed by accounting for avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment would likely be replaced before the 2035 target. This money can be effectively set aside to help cover part of the costs.
- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today. Funds are available on three-year cycles and the program offerings can change during the program cycle; based on this, incentive estimates are not included in this report.

The Less-than-Five-Year Payback Package largely utilizes retrofits to existing equipment. Applying a higher estimated savings for retro-commissioning may be possible.

If the ZNC Target is unattainable or economically infeasible for this building, the owner may want to consider filing a Building Performance Improvement Plan.

Measures Not Recommended

Measures reviewed for the building but not included in the EEM package are described below.

- Building Controls: existing pneumatic controls located in individual spaces are a likely source of significant energy waste; however, developing costs for this measure is highly site-specific and beyond the scope of this case study. Based on generally accepted practices, this measure would likely have not applied for the Less-than-Five-Year Payback Package due to costs and would not be applicable to the ZNC Target Package as the pneumatic VAV controls would have been converted to a new mechanical system.
- DHW: domestic hot water is a minimal load in office buildings and was not examined.
- Envelope: envelope measures were not necessary to meet the ZNC Target.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
    - Electrified end uses were typically large (i.e., all of a building's heating loads), and
    - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the Less-than-Five-Year Payback Package.
- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package (Not Applicable for this Case Study)

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 57 below.

Table 57: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[56].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

[56] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Utility Rates

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.

Case Study 4: New High-Rise Mixed-Use Multifamily

Building Information

This is a newer multifamily complex of two buildings; since this complex has no shared building systems or physical connections between buildings, only one building in this complex was chosen for the case study. This building has first floor retail, which is a mix of restaurants and other general-purpose retail. The site contains both above ground and below grade parking. The building has in-unit electric heating and cooling systems and in-unit electric water heating that residents pay for, as well as shared common and amenity areas.

Table 58. Building Characteristics – Case Study 4

Category	Building Information
Typology	Multifamily
Square Footage	125,000 ft.^{2} – 150,000 ft.^{2} Multifamily: 92% Retail: 3% Restaurant: 2% Fitness Centers: 3%
Year Built	2000 – 2005
2019 ENERGY STAR Score	20 – 25
2019 Site EUI (kBTU/SF) (calculated for this study)	50 – 60

Building System Information

The basic building system information specific to the case study building is described below.

Table 59. Building System Information – Case Study 4

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	None	N/A	N/A	N/A
Heating	Each apartment has ducted heat pumps with electric resistance backup	Electric	Unknown (estimated 20 years)	<5
Cooling	Each apartment has ducted A/C with individual in-unit condenser equipment going through the wall	Electric	Unknown (estimated 20 years)	<5
Ventilation	DOAS units for hallways, fresh air delivered to apartments via undercuts on the door to each apartment	Electric/Gas	Unknown (estimated 20 years)	<5
DHW	Electric resistance water heaters in each apartment	Electric	Unknown (estimated 20 years)	<5
Lighting	Mostly converted to LED except for corridors and apartment fixtures	Electric	0-5	5-10
Envelope	Windows – double insulated window w/ thermal break. Wood frame construction and insulation	N/A	Windows: ~10 years, Frame: ~20 years	25-30
Metering	Apartments separately metered, retail separately metered	Electric/Gas	N/A	N/A
Other	Outdoor Pool, in-unit washer/dryer, dishwasher, disposal	Electric	Unknown (estimated 10 years)	Unknown (appliances likely 0-2 years; pool 5-10 years)

Utility End Use Assessment

The building's energy usage type and estimated end use is displayed below.

- Gas: used in the retail spaces including restaurant or retail cooking and possibly their respective domestic hot water or heating needs. Gas is also used to heat outdoor air for the corridors. Gas makes up 13% of the building's site energy use.
- Electricity: used for nearly all needs in the multifamily portion of the building, including cooking, heating, and domestic hot water for apartments. Electricity makes up 87% of the building's site energy use.

Table 60. 2019 Site EUI by End Use – Case Study 4. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Elec	Cooling – Elec	DHW – Elec	Baseload – Elec	Lighting – Electric	Total EUI
9%	0%	0%	4%	16%	10%	21%	34%	6%	**100%**

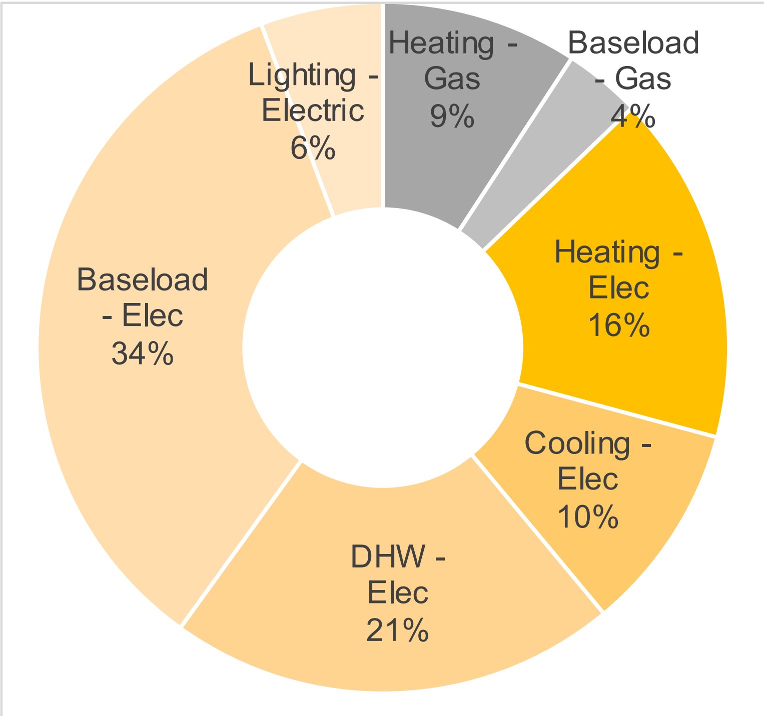

Figure 42. Site EUI Share (%) by End Use – Case Study 4

Target Determination

Site EUI targets are determined by a weighted average of applicable ZNC targets per space use type. Space use types are provided in Portfolio Manager and via reviews of available drawings. The table also has an alternate target (“EE Standard”), which is higher than the current EUI of the building, indicating that the building would not need to take any action beyond maintaining current performance if the EE Standard was used. The building will need to take action in order to meet the ZNC Target. All the following analysis uses the ZNC target.

Note that the floor areas shown in the table below are approximated based on Table 59.

Table 61. Space Use Target Methodology Summary – Case Study 4

Specific Space Type	Space Type Group	Area %	Floor Areas	ZNC Standard [Site EUI]	EE Standard [Site EUI]	Weighted ZNC EUI (ZNC * Area%)	Weighted EE EUI (EE * Area%)
Multifamily Housing	Multifamily	92%	125,000	35.4	55.1	32.5	50.7
Retail Store	Mercantile Retail (other than mall)	3%	5,000	45.3	53.4	1.4	1.6
Restaurant	Food Service	2%	5,000	170.6	249.7	2.7	3.9
Fitness Center	Public Assembly	3%	5,000	61.3	83.0	2.1	2.8
Total	**-**	**100%**	**140,000**	**-**	**-**	**38.7**	**59.1**

The baseline EUI is derived from whole building 2019 utility data over whole building square footage.

Table 62. ZNC and Interim Targets – Case Study 4

EUI Description	ZNC Target	EE Target
Baseline EUI	50 – 60	50 – 60
2029 – Interim Target 1	46 – 53	50 – 60
2033 – Interim Target 2	42 – 47	50 – 60
2037 – Target	38.7	59.1

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *Less-than-Five-Year Payback Package* is based on the results of a package that would have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax credits.

An EE Target Package was not developed for this building as this building is below the EE Target.

All costs are total costs for the measures, not incremental costs. These costs do not include applicable incentives. The following table offers a financial overview of the packages.

Table 63. EEM Package Summary – Group 4 Case Study 4

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
ZNC Target Package	35 – 38	28%	$45,000	$1,434,000	31.9	3%
Less-than-Five-Year Payback Package	50 – 60	1%	$1,500	$5,000	3.5	28%

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 64 that shows the estimated remaining life of the equivalent replacement system. A “N/A” indicates the existing system is not replaced, and a “DNE” means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 64. ZNC Target Package EEMs – Case Study 4. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

Measure #	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	DOAS Conversion to Electric	Install a dedicated electric outdoor air system with heat recovery capabilities	7.2%	$2,600	$323,000	123.3	1%	15	<5
2	Electrify Retail and Restaurant	Convert tenant gas use to electric	1.4%	($2,600)	$15,000	N/A	N/A	10	Unknown (estimating 5-10)
3	Add Programmable Thermostats	Add programmable thermostats to apartments, provide instructions to occupants on use	0.8%	$2,000	$67,000	33.5	3%	10	Existing thermostats likely <10
4	High-Efficiency Water Aerators	Install low flow aerators in faucets and showers	0.6%	$1,500	$5,000	3.5	28%	10	DNE
5	Solar PV	Install canopied solar PV	16.2%	$41,500	$1,025,000	24.7	4%	15	DNE
Total			**26.2%**	**$45,000**	**$1,435,000**	**31.9**	**3%**	**-**	

Table 65. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 4

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	9%	0%	0%	4%	16%	10%	21%	34%	6%	**100%**
End Use Difference	-100%	0%	0%	-100%	10%	-2%	-3%	-41%	0%	**74%**

EE Target Package

This building already meets the EE target; no EE package was developed.

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback package does not allow the building to meet any interim targets.

Table 66. Less-than-Five-Year Payback Package EEMs – Case Study 4. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

Measure #	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)
1	High-Efficiency Water Aerators	Install low flow aerators in faucets and showers	0.6%	$1,500	$5,000	3.5	28%	10
	Total		**0.6%**	**$1,500**	**$5,000**	**3.5**	**28%**	**-**

Table 67. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 4

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	9%	0%	0%	4%	16%	10%	21%	34%	6%	**100%**
End Use Difference	0%	0%	0%	0%	0%	0%	-3%	0%	0%	**99%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

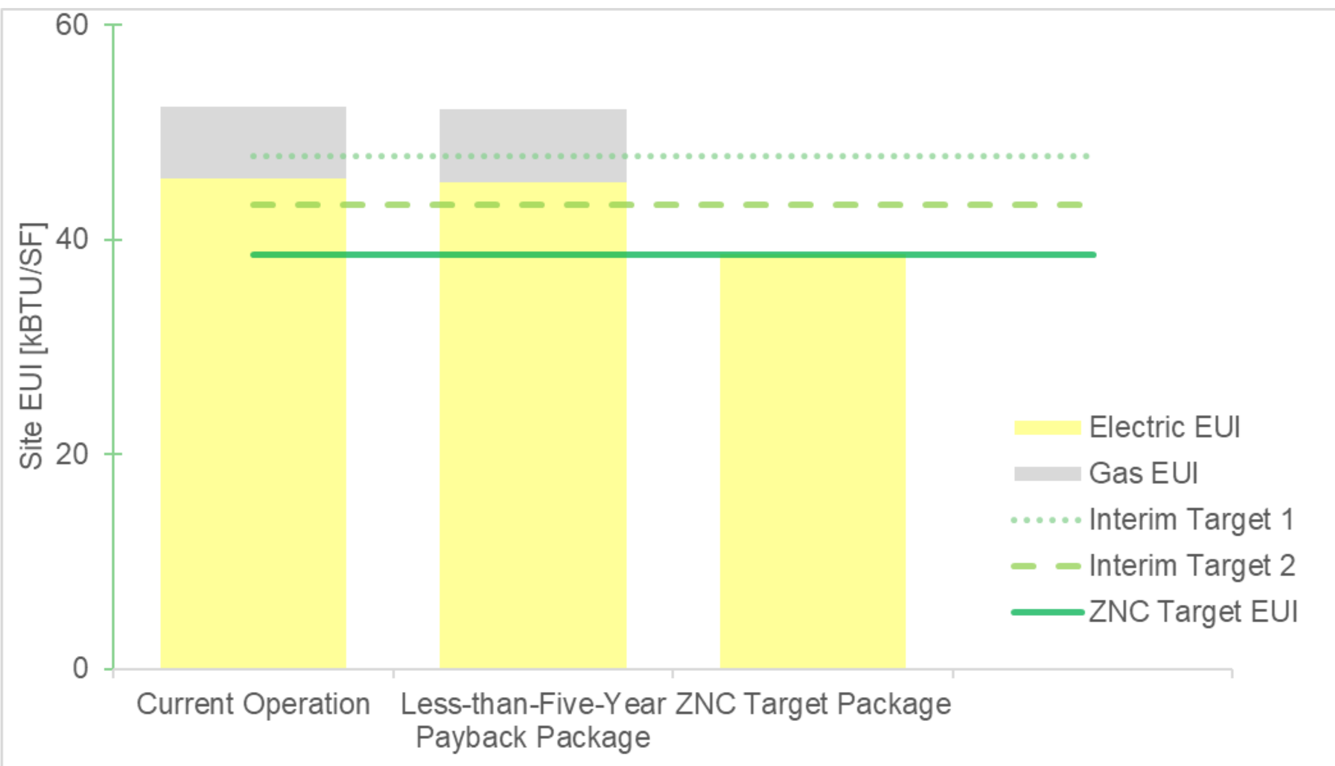

Figure 43. Target-to-Package Comparisons – Case Study 4

As seen in Figure 43, viable measures apply to the ZNC Target Package. However, the ZNC target is well within range for this typology.

Building-Specific Technology Assessment

This multifamily building is a newer building; the only current gas usage in the apartment building is to heat outdoor air for the hallways. Electrification at this building entails converting that outdoor air unit and any restaurant or retail gas usage.

The heating, cooling, and hot water systems in the building use a large portion of the building's energy and upgrades to that equipment may result in energy savings. However, upgrades to this distributed equipment in each apartment would be highly intrusive to residents. Additionally, the equipment is already all electric and while the space and water heating equipment could be upgraded to heat pumps to improve efficiency, the savings may not justify the disruption to tenants. Therefore, improvements to the space heating/cooling and water heating are not included in this package.

Programmable thermostats could improve existing technology while providing an amenity to residents. Programmable thermostat savings are highly dependent upon each resident's actions to ensure that schedules are created and maintained. Actual realized savings for this measure may be notably more or less than the estimated amount.

Following these considerations, other measures affecting building energy demand were then chosen (items like LED lighting conversions and high-efficiency aerators). These measures did not have a large overall impact on savings and were generally non-interactive in nature, meaning any resultant savings from these measures do not appreciably increase or decrease savings from other measures.

Lastly, solar PV was applied. This building has a relatively complex roof structure with both flat and pitched sections, and mechanical equipment distributed on the roof. For this building, a canopy solar PV system was evaluated. A canopy solar PV system is structured to sit above the roof over other equipment. The parking garage for this building is underground, so there is no opportunity to incorporate solar PV on the garage.

Package Comparisons

Reaching the ZNC target for this building is a relatively simple exercise through building upgrades but is not particularly cost effective from a total cost perspective. Most other building typologies take advantage of the savings offered by the Less-than-Five-Year Payback Package to build cost savings to pay for the ZNC Target Package. In this building, there are not measures with high energy cost savings potential to improve the overall package economics.

There are some ways to reduce compliance retrofit costs:

- Some of the total capital cost may be effectively defrayed by accounting for avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment would likely be replaced before the 2035 target. This money can be effectively set aside to help cover parts of the costs.
- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today. These funds are available on three-year cycles, and the program offerings can change during the program cycle, so incentive estimates are not included in this report.

Measures Not Recommended

Measures reviewed for the building but not included in the EEM package are described below.

- HVAC: upgrades to resident heating and cooling equipment to use variable refrigerant flow (VRF) systems would decrease energy use, but because the in-unit heating is already a heat pump with supplemental electric resistance, the savings would be relatively small. This measure would also be highly intrusive to tenants unless completed at apartment turnover across a longer time horizon. Still, long term improvements to in-unit HVAC equipment would gradually decrease whole building electricity use, which can contribute to meeting the performance standard. Given the age of the HVAC systems it is likely some upgrade to the HVAC system is needed prior to 2035; at this time, a VRF system should be considered. However, it was not necessary in this package to meet the ZNC.

- Retro-commissioning: the main benefits from retro-commissioning would be from reviewing and adjusting in-unit HVAC, as that makes up the majority of the heating and cooling energy use. Typically, retro-commissioning is done on large pieces of base building equipment. Most base building equipment replacement is part of the ZNC package, and new equipment would be commissioned as part of the installation process. The maintenance of in-unit equipment is performed by building staff when apartment access is feasible, such as at apartment turnover. A short-term effort to retro-commissioning in-unit equipment would be a highly intrusive process as it would require building staff to enter each apartment and investigate each piece of equipment. Persistence of savings would also be difficult to maintain, as it would require each occupant to commit to not making individual adjustments through the lifetime of the equipment.
- Lighting: completing an LED conversion was reviewed. Conversion options for existing 4-pin fixtures do exist but were determined to be a less cost-effective measure than other measures included within the ZNC Target Package. Utility incentives may help defray some of these costs.
- Appliances: Conversion of in-unit appliances to high-efficiency was reviewed. Similar to lighting, this conversion can occur but would not be as cost-effective as other measures included within the ZNC Target Package.
- Domestic hot water: The in-unit water heaters are electric resistance and upgrading to heat pump water heaters would be a difficult and costly measure. The energy savings from heat pump water heaters was not needed to reach the ZNC target and would be highly intrusive.
- Envelope: Envelope measures are not needed for this building to reach the ZNC target. Being a recently constructed building, the wall and window insulation levels are adequate, making upgrades less cost effective resulting in less energy savings.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
    - Electrified end uses were typically large (i.e., all of a building's heating loads), and
    - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the Less-than-Five-Year Payback Package.
- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.

- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package (Not Applicable for this Case Study)

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 68 below.

Table 68: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[57].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages

[57] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Utility Rates

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.

Case Study 5: Old High-Rise Affordable Multifamily

Building Information

This is an older high-rise multifamily building. It underwent a substantial internal and external renovation within the last decade, including new double-paned windows, central cooling, and solar hot water collector system. Heating and cooling are provided to apartments via a fan-coil distribution system.

Table 69. Building Characteristics – Case Study 5

Category	Building Information
Typology	Multifamily
Square Footage	125,000 $ft.^2$ – 150,000 $ft.^2$ Multifamily Housing: 100%
Year Built	1965 – 1970
2019 ENERGY STAR Score	N/A*
2019 Site EUI (kBTU/SF)	70 – 80

**This building was not benchmarked, as multifamily buildings are not required to benchmark under the County's Benchmarking Law at the time of this case study's completion.*

Building System Information

The basic building system information specific to the case study building is described below.

Table 70. Building System Information – Case Study 5

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	None	N/A	N/A	N/A
Heating	2x gas-fired boilers, which also serve supplemental DHW, hydronic heating distribution	Gas	8	15-20
Cooling	1x 150-ton screw chiller; fan coils in apartments. Both heating and cooling supplied via two-pipe system (i.e., system can only operate in heating or cooling)	Electric	8	15-20
Ventilation	2x rooftop units with gas heat and electric compressors	Electric (cooling); gas (heating)	8	10-15
DHW	Solar DHW with heating boilers as backup	Solar / gas	8	10 (solar) 15-20 (boilers)
Lighting	Most lighting converted to LED	Electric	3	5-8
Envelope	Windows upgraded recently; rest of envelope original	N/A	8 (windows); ~50 years (others)	~30 years (windows); 5-15 years (other envelope components)
Metering	Centrally metered electric and gas	Electric, Gas	N/A	N/A

Utility End Use Assessment

The building's energy usage type and estimated end use are displayed below.

- Gas: used for heating and domestic hot water plus in-unit cooking. Sixty-eight percent of the building's energy use is in the form of gas. The solar hot water collectors serve to partially offset some of the domestic hot water load.
- Electricity: used for cooling, ventilation, lighting, and electric plug loads. Thirty-two percent of the building's energy use is in the form of electricity.

Table 71. 2019 Site EUI by End Use – Case Study 5. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
46%	0%	16%	6%	0%	5%	0%	24%	3%	**100%**

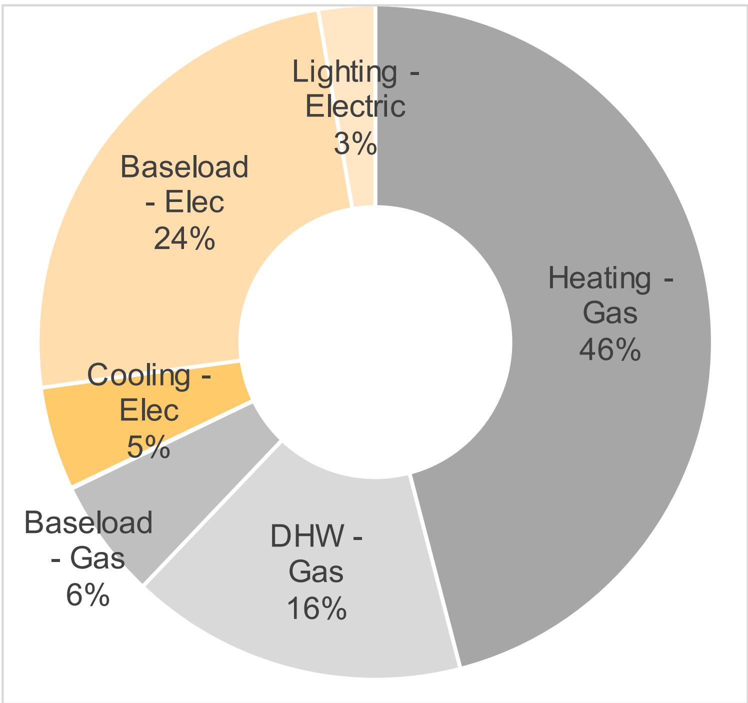

Figure 44. Site EUI Share (%) by End Use – Case Study 5

Target Determination

EUI targets are determined by a weighted average of applicable ZNC targets per space use type. Space use types are provided in Portfolio Manager and via reviews of available drawings. The table also has an alternate target ("EE Standard"); the building will need to take action in order to meet both the ZNC and EE Targets. All the following analysis uses the ZNC target.

Table 72. Space Use Target Methodology Summary – Case Study 5

Specific Space Type	Space Type Group	Area %	Floor Areas	ZNC Standard [Site EUI]	EE Standard [Site EUI]	Weighted ZNC EUI (ZNC * Area%)	Weighted EE EUI (EE * Area%)
Multifamily Housing	Multifamily	100%	125,000	35.4	55.1	35.4	55.1
Total	**-**	**100%**	**125,000**	**-**		**35.4**	**55.1**

The baseline EUI is derived from whole building 2019 utility data over whole building square footage.

Table 73: ZNC and Interim Targets – Case Study 5

EUI Description	ZNC Target	EE Target
Baseline EUI	70 – 80	70 – 80
2029 – Interim Target 1	58 – 65	65 – 72
2033 – Interim Target 2	45 – 50	60 – 65
2037 –Target	35.4	55.1

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *EE Target Package* is based upon energy efficiency measures to reach the EE Target for this building. Note that the ZNC Target Package can also be used to reach the EE Target, but the EE Target Package reduces EUI only as far as needed to meet the EE Target.
- *Less-than-Five-Year Payback Package* is based on the results of a package that would have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax credits.

All costs are total costs for the measures, not incremental costs. These costs do not include applicable incentives. The following table offers a financial overview of these packages.

Table 74. EEM Package Summary – Case Study 5

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
ZNC Target Package	32 – 35	53%	$38,900	$2,221,000	57.1	2%
EE Target Package	50 – 57	28%	$46,000	$1,293,000	28.3	4%
Less-than-Five-Year Payback Package	64 – 73	9%	$31,700	$89,000	2.8	32%

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 75 that shows the estimated remaining life of the equivalent replacement system. An "N/A" indicates the existing system is not replaced, and a "DNE" means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 75. ZNC Target Package EEMs – Case Study 5. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify Space Heating	Convert the central mechanical system to an air-to-water heat pump system	35.4%	$15,300	$1,294,000	84.7	1%	15	15-20
2	Electrify DHW	Convert domestic hot water gas heating to electric air-to-water heat pump systems	10.1%	($2,800)	$625,000	N/A	N/A	15	15-20
3	Central Plant Pump VFDs	Install variable frequency drives on central distribution pumps	2.9%	$10,300	$8,000	0.8	131%	15	DNE
4	Booster Pump VFDs	Install variable frequency drives on domestic water booster pumps	0.4%	$1,400	$5,000	3.7	27%	15	DNE
5	High-Efficiency Water Aerators	Install high-efficiency aerators in faucets and showers	0.2%	$600	$5,000	8.4	12%	10	DNE
6	Solar PV	Install roof-mounted solar PV	4.0%	$14,100	$284,000	20.1	5%	15	DNE
Total			**53.0%**	**$38,900**	**$2,221,000**	**57.1**	**2%**	**-**	

Table 76: Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 5

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	46%	0%	16%	6%	0%	5%	0%	24%	3%	**100%**
End Use Difference	-100%	0%	-100%	0%	100%	16%	100%	-36%	0%	**47%**

EE Target Package

As some EE Target measures entail replacement of existing equipment, an additional column is added to Table 77 that shows the estimated remaining life of the equivalent replacement system. An "N/A" indicates the existing system is not replaced, and a "DNE" means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 77. EE Target Package EEMs – Case Study 5. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify DHW	Convert domestic hot water gas heating to electric air-to-water heat pump systems	10.1%	($2,800)	$625,000	N/A	N/A	15	15-20
2	Install ERV	Install an exhaust recovery ventilation unit	7.9%	$17,000	$317,000	18.7	5%	15	DNE
3	Retro-Commissioning	Retro-commission and implement improvements on central building systems	3.8%	$8,500	$44,000	5.2	19%	5	DNE
4	Central Plant Pump VFDs	Install variable frequency drives on central distribution pumps	2.5%	$8,800	$8,000	0.9	112%	10	DNE
5	CW Pump VFDs	Install variable frequency drives on condenser water pumps	0.3%	$1,100	$6,000	5.2	19%	15	DNE
6	Booster Pump VFDs	Install variable frequency drives on domestic water booster pumps	0.3%	$1,200	$5,000	4.5	22%	15	DNE
7	High-Efficiency Water Aerators	Install high-efficiency aerators in faucets and showers	0.2%	$600	$5,000	8.8	11%	10	DNE
8	Solar PV	Install roof-mounted solar PV	3.2%	$11,300	$284,000	25.1	4%	15	DNE
Total			**28.4%**	**$45,700**	**$1,294,000**	**28.3**	4%	**-**	

Table 78: Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for EE Target Package – Case Study 5

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	46%	0%	16%	6%	0%	5%	0%	24%	3%	**100%**
End Use Difference	-15%	0%	-100%	0%	0%	-22%	0%	-46%	-5%	**72%**

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback package does not allow the building to meet any interim targets.

Table 79. Less-than-Five-Year Payback Package EEMs – Case Study 5. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

Measure #	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)
1	Retro-Commissioning	Retro-commission and implement improvements on central building systems	4.7%	$9,200	$44,000	4.8	21%	5
2	Central Plant Pump VFDs	Install variable frequency drives on central distribution pumps	2.8%	$9,700	$8,000	0.8	124%	10
3	CW Pump VFDs	Install variable frequency drives on condenser water pumps	0.4%	$1,300	$6,000	4.7	21%	15
4	Booster Pump VFDs	Install variable frequency drives on domestic water booster pumps	0.4%	$1,300	$5,000	4.0	25%	15
5	High-Efficiency Water Aerators	Install high-efficiency aerators in faucets and showers	0.4%	$500	$5,000	10.1	10%	10
	Total		**8.6%**	**$22,000**	**$68,000**	**3.1**	**32%**	**-**

Table 80. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 5

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	46%	0%	16%	6%	0%	5%	0%	24%	3%	**100%**
End Use Difference	-5%	0%	-8%	0%	0%	-5%	0%	-19%	-5%	**91%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

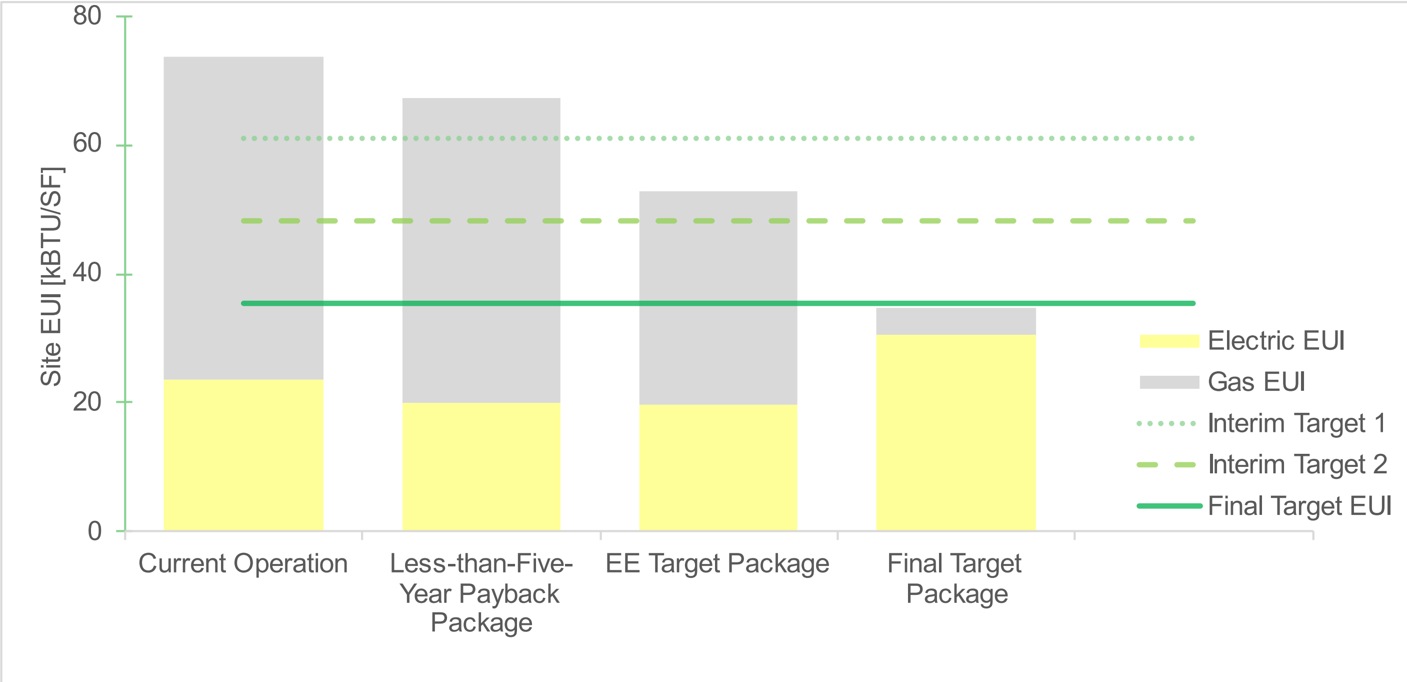

Figure 45. Target-to-Package Comparisons – Case Study 5

Although some low-cost measures make it into the Less-Than-Five-Year Payback Package, this package is insufficient to reach any of the Interim Targets, much less the ZNC Target. The EE Target Package would get the facility most of the way to the 2nd Interim Target; the EE Target Package mostly reduces gas usage compared to the Less-than-Five-Year Payback Package.

The ZNC Target can be reached with substantial onsite electrification converting existing gas loads to electric. Additional discussion is available in the Case Study Measures Identification Methodology.

Building-Specific Technology Assessment

This multifamily building has two major issues making it difficult for it to reach the ZNC Target with the current systems:

- A large amount of gas use (68%) which acts as a limit on how effective non-fuel-switching measures can be in reducing site EUI.
- The distance between current usage and the ZNC Target is substantial, representing a 53% reduction in current energy usage.

Given those items, electrification of building loads represents the only realistic path for this site to reach the ZNC Target. For this building, converting the existing fan coil system to a water-source heat pump system gains the benefit of reusing existing piping risers compared to other electrification conversion technology (i.e., VRF) which entails entirely new piping runs throughout the building.

For this building, reaching the EE target is a comparatively simpler lift, representing only a 28% reduction in energy use. However, this still requires some electrification in order to be reached.

Some electrification considerations for this facility are as follows:

- Aiming for efficiency gains in existing gas-fired equipment is not realistic based on technology available today. While some optimization methods can help (and do appear in the Less-than-Five-Year Payback Package), they do not cover this energy gap.
- Electrifying heating but not DHW does not reach the ZNC Target Package; however, it *does* serve to reach the EE Target on its own. However, this would be a less cost-effective method than the method used in this case study.
- Electrifying DHW but not heating also does not reach the ZNC Target Package, but it does allow for the EE Target Package to take advantage of incremental improvements to the HVAC system of the building, which in turn create a more cost-effective package. This approach was used to develop the EE Target Package.
- Electrifying cooking loads in lieu of electrifying either HVAC or DHW does not do enough on its own to reach ZNC or EE. Electrifying cooking loads *can* be an alternative path compared to the EEMs shown in Table 75 to meet the ZNC target once HVAC and DHW loads are electrified (and this would also remove the remaining on-site fuel used), but other, more cost-effective methods are used in this case study.

The EE Target Package also includes installation of an ERV. This measure is not included in either the ZNC Target Package or the Less-than-Five-Year Payback Package for the following reasons:

- The ZNC Target can be met with space heating, DHW electrification, and other smaller measures indicated in Table 75. These measures offer a better ROI in total than ERV installation.
- ERV installation is not cost-effective enough to include in the Less-than-Five-Year Payback Package.

A handful of measures in the Less-than-Five-Year Payback Package are also included in the EE Target and/or ZNC Target Packages. These are relatively low-cost measures that help bring down the overall payback of this option and include some central plant retrofits such as central plant VFDs and other ancillary upgrades such as low flow aerators; these measures do not have a large overall impact on savings and are generally non-interactive in nature.

Once these measures were identified, solar PV savings are applied to the building. This building has existing solar hot water collectors. In order to make “room” for the solar PV system, these hot water collectors need to be removed. This increases the domestic hot water load met by the hot water system and negatively impacts the finances of the solar PV system. To make the most use of the solar DHW, the solar PV can be installed at the end of the functional life of the solar DHW system, which is likely before the final target date of the performance standard.

Once electrification of HVAC and DHW loads were implemented, the ZNC target for this building can be satisfied by either installing solar PV or by electrifying cooking; since electrifying cooking results in an energy cost increase for the building, solar PV is used instead.

The Less-than-Five-Year Payback Package are largely constructed using similar measures as the ZNC Target Package with two notable exceptions:

- Retro-commissioning is applied to the central plant equipment to remain only. In-unit retro-commissioning would be a highly intrusive process and not realistic for the Less-Than-Five-Year Package. The HVAC system will largely be replaced in the ZNC Target Package and so retro-commissioning is not an eligible measure in the ZNC target.
- Condenser Water Pump VFDs does not apply. With conversion to a heat pump loop, the central plant pumps serve both the heating and condenser water loop, making this measure unnecessary.

Package Comparisons

Reaching ZNC targets incurs a large overall cost to the property; most of these costs are borne from either electrification measures such as heat pump conversion or electrifying domestic hot water. However, the ZNC target for this building is reachable with technologies available today.

There are some ways to reduce compliance retrofit costs:

- Some of the total capital costs may be effectively defrayed by accounting for avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment will likely be replaced before the 2035 target. This money can be set aside to help cover parts of the costs.
- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today. These funds are available on three-year cycles and the program offerings can change during the program cycle; based on this, incentive estimates are not included in this report.

The EE Target Package incurs less overall cost than the ZNC Target Package and higher cost savings.

The Less-than-Five-Year Payback Package largely utilizes retrofits to existing equipment. Applying a higher estimated savings for retro-commissioning may be possible.

Measures Not Recommended

Measures reviewed for the building but not included in either EEM package are described below.

- Envelope: envelope improvements are not needed to meet the ZNC target and are not cost-effective enough to include in the Less-than-Five-Year Payback Package.
- Cooking: electrifying cooking is not needed to meet ZNC or EE as described above. Furthermore, this measure increases energy cost given the utility rates used for this analysis.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
    - Electrified end uses were typically large (i.e., all of a building's heating loads), and
    - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the However, they may appear in the EE Target Package or Less-than-Five-Year Payback Package.

- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 81 below.

Table 81: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[58].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

[58] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Utility Rates

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.

Case Study 6: Garden-Style Multifamily

Building Information

This case study is an affordable housing garden-style apartment complex. The complex has multiple 3-to-4 story buildings with approximately 75 apartment units. The complex has a central heating hot water and domestic hot water plant with window air conditioners for cooling. The building is master metered for electricity and natural gas. There is a common area laundry facility on site, and above ground open parking.

Table 82. Building Characteristics – Case Study 6

Category	Building Information
Typology	Multifamily
Square Footage	50,000 $ft.^2$ – 75,000 $ft.^2$ Multifamily Housing: 100%
Year Built	1950 – 1955
2019 ENERGY STAR Score	N/A*
2019 Site EUI (kBTU/SF)	115 – 125

**This building was not benchmarked, as it was not required to benchmark under the County's Benchmarking Law at the time of this case study's completion.*

Building System Information

The basic building system information specific to the case study building is described below.

Table 83. Building System Information – Case Study 6

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	None	N/A	N/A	N/A
Heating	Two hot water boilers, hydronic heating distribution across all buildings	Gas	Unknown (estimated >10 years)	Unknown (estimated 5-10 years)
Cooling	Window AC units	Electric	Unknown (estimated 1-8 years)	Unknown (estimated 0-5 years)
Ventilation	Sidewall vents in kitchens and bathrooms only	N/A	N/A	N/A
DHW	Two hot water DHW heaters	Gas	3	12-17
Lighting	Primarily fluorescent / CFL	Electric	Unknown (estimated 5 years)	Unknown (estimated 0-5 years)
Envelope	Likely original	N/A	Unknown (estimated 40 years)	Unknown (estimated 40 years)
Metering	One electric meter for the complex Three gas meters: one with the boilers, two for residential cooking	Electric, Gas	N/A	N/A

Utility End Use Assessment

The building's energy usage type and estimated end use is displayed below.

- Gas: used for heating hot water, domestic hot water, and residential cooking. 82% of the building's energy use is in the form of gas.
- Electricity: used for cooling, pumping, ventilation, lighting, and electric plug loads. 18% of the building's energy use is in the form of electricity.

Table 84. 2019 Site EUI by End Use – Case Study 6. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Lighting – Electric	Baseload – Electric	Total EUI
51%	0%	25%	6%	3%	4%	0%	9%	2%	**100%**

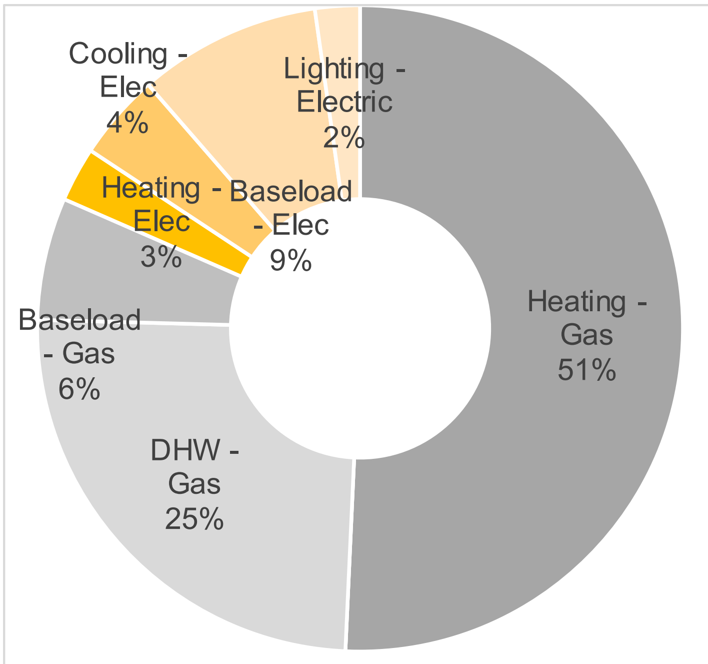

Figure 46. Site EUI Share (%) by End Use – Case Study 6

Target Determination

EUI targets are determined by a weighted average of applicable ZNC targets per space use type. The table also has an alternate target ("EE Standard"); the building will need to take action in order to meet both the ZNC and EE Targets. All the following analysis uses the ZNC target.

Table 85. Space Use Target Methodology Summary – Case Study 6

Specific Space Type	Space Type Group	Area %	Floor Areas	ZNC Standard [Site EUI]	EE Standard [Site EUI]	Weighted ZNC EUI (ZNC * Area%)	Weighted EE EUI (EE * Area%)
Multifamily Housing	Multifamily	100%	50,000	35.4	55.1	35.4	55.1
Total	**-**	**100%**	**50,000**	**-**	**-**	**35.4**	**55.1**

The baseline EUI is derived from whole building 2019 utility data over whole building square footage.

Table 86: ZNC and Interim Targets – Case Study 6

EUI Description	ZNC Target	EE Target
Baseline EUI	115 – 125	115 – 125
2029 – Interim Target 1	90 – 95	95 – 102
2033 – Interim Target 2	60 – 65	75 – 80
2037 – Target	35.4	55.1

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *EE Target Package* is based upon energy efficiency measures to reach the EE Target for this building. Note that the ZNC Target Package can also be used to reach the EE Target, but the EE Target Package reduces EUI only as far as needed to meet the EE Target.
- *Less-than-Five-Year Payback Package* is based on the results of a package that would have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax credits.

All costs are total costs for the measures, not incremental costs. These costs do not include applicable incentives. The following table offers a financial overview of these packages.

Table 87. EEM Package Summary – Case Study 6

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
ZNC Target Package	31 – 34	73%	$60,400	$1,621,000	26.8	4%
EE Target Package	51 – 55	56%	$58,700	$1,261,000	21.5	5%
Less-than-Five-Year Payback Package	107 – 117	7%	$10,500	$30,300	2.9	35%

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 88 that shows the estimated remaining life of the equivalent replacement system. A “N/A” indicates the existing system is not replaced, and a “DNE” means the package adds a system or piece of equipment that does not currently exist onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 88. ZNC Target Package EEMs – Case Study 6. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify Space Heating	Convert the central mechanical system to a ductless split heat pump system	41.0%	$18,500	$745,000	40.2	2%	15	5-10
2	Electrify Water Heating	Convert domestic hot water gas heating to electric air-to-water heat pump systems	17.3%	$1,800	$360,000	201.7	1%	15	12-17
3	High-Efficiency Water Aerators	Install low flow aerators in faucets and showers	0.2%	$500	$3,000	5.9	17%	15	DNE
4	Solar PV	Install roof-mounted solar PV	14.3%	$39,600	$513,000	13.0	8%	15	DNE
Total			**72.8%**	**$60,400**	**$1,621,000**	**26.8**	**4%**	**-**	

Table 89. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 6

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	51%	0%	25%	6%	3%	4%	0%	9%	2%	**100%**
End Use Difference	-100%	0%	-100%	0%	171%	-41%	100%	-41%	-41%	**27%**

EE Target Package

As some EE Target measures entail replacement of existing equipment, an additional column is added to Table 90 that shows the estimated remaining life of the equivalent replacement system. An “N/A” indicates the existing system is not replaced, and a “DNE” means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 90. EE Target Package EEMs – Case Study 6. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify Space Heating	Convert the central mechanical system to a mini-split DX system	41.0%	$18,500	$745,000	40.2	2%	15	15-20
2	High-Efficiency Water Aerators	Install low flow aerators in faucets and showers	0.6%	$500	$3,000	5.4	18%	15	DNE
3	Solar PV	Install roof-mounted solar PV	14.3%	$39,600	$513,000	13.0	8%	15	DNE
Total			**55.9%**	**$58,600**	**$1,261,000**	**21.5**	**5%**	**-**	

Table 91: Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for EE Target Package – Case Study 6

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	51%	0%	25%	6%	3%	4%	0%	9%	2%	**100%**
End Use Difference	-100%	0%	-2%	0%	124%	-51%	0%	-51%	-51%	**44%**

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback package does not allow the building to meet any interim targets.

Table 92. Less-than-Five-Year Payback Package EEMs – Case Study 6. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

Measure #	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)
1	Retro-Commissioning	Retro-commission and implement improvements on central building systems	4.3%	$4,900	$21,000	4.3	23%	5
2	Hot Water Pump VFDs	Install variable frequency drives on heating hot water pumps	1.8%	$5,100	$6,000	1.3	80%	15
3	High-Efficiency Water Aerators	Install low flow aerators in faucets and showers	0.6%	$500	$3,000	5.7	18%	15
	Total		**6.7%**	**$10,500**	**$30,000**	**2.9**	**35%**	**-**

Table 93. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 6

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	51%	0%	25%	6%	3%	4%	0%	9%	2%	**100%**
End Use Difference	-7%	0%	-5%	0%	0%	0%	0%	-25%	-5%	**93%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

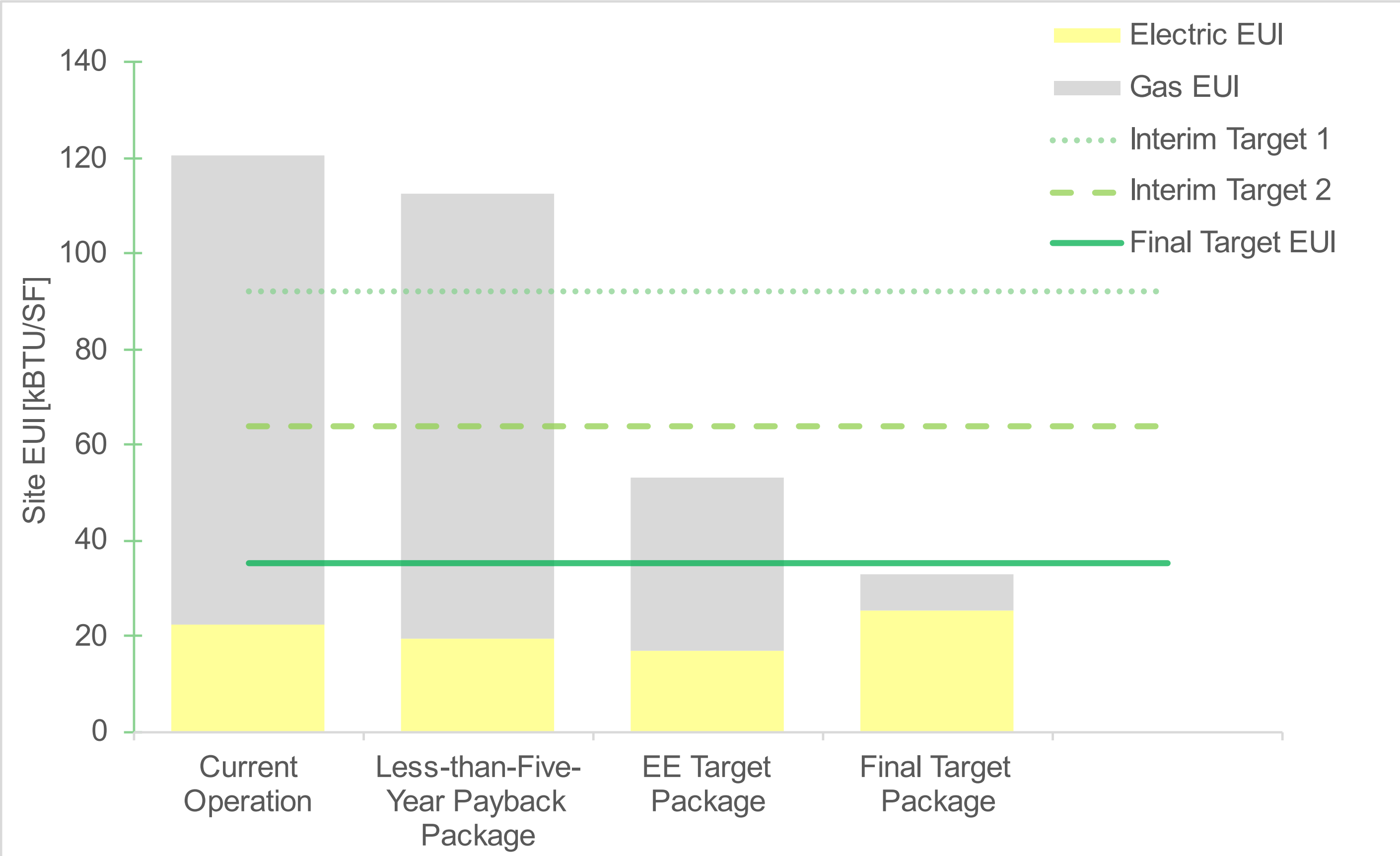

Figure 47. Target-to-Package Comparisons – Case Study 6

The chart above indicates the limitations of the Less-than-Five-Year Payback Package to realize substantial onsite savings. The EE Target Package reaches the second interim target but requires substantial electrification. The building can meet the ZNC target even without fully electrifying. This is due to garden-style building's ability to offset a larger portion of their energy usage effectively by solar.

Building-Specific Technology Assessment

This multifamily building has two issues making it difficult for it to reach the ZNC Target with current technology:

- A large amount of gas use (82%) which acts as a limit on how effective non-fuel-switching measures can be in reducing site EUI. Furthermore, this is the only building among those included in this analysis where heating represents at least 50% of total building energy.
- The distance between current usage and the ZNC Target is substantial, representing a 71% reduction in current energy usage.

Similar issues exist with the EE Target, although the end goal is a 55% reduction instead of a 71% reduction.

Some approaches were discussed:

- Aiming for efficiency gains in existing equipment did not seem realistic based on technology available today. In effect, gas-fired equipment would need to approach or exceed 100% efficiency in order to be in range of the ZNC or EE Targets. While some optimization methods can help (and do appear in the Less-than-Five-Year Payback Package), they do not cover this energy gap.

- Partial electrification was reviewed but this was determined to not appreciably impact the ability of the building to reach ZNC. However, partial electrification was found to be useful for the EE Target Package.

For the EE Target Package, electrification of the space heating system represented the better approach. This was for two reasons:

- A large percentage of energy use (over 50%) is used for space heating. Electrifying this load represented a far better option for saving energy instead of DHW, which is only 25% of building energy use.
- There were not many options “lost” through optimizing the existing mechanical system, as the mechanical system for this building is not easily able to be optimized. As a result, there is minimal opportunity cost loss.

Electrification of the HVAC and DHW end uses represented the only realistic path for this site to reach the ZNC Target. For HVAC, converting the system to distributed ductless heat pumps was chosen as the most realistic option. For DHW, a semi-distributed option with a hot water heat pump plant per building was chosen.

Electrification on its own was not sufficient to reach the ZNC target.

Once electrification measures were identified, other measures affecting building demand were then choisen (items like high-efficiency aerators); these measures did not have a large overall impact on savings and were generally non-interactive in nature.

Applying solar PV to this property reduces grid-supplied electricity use substantially. This building type has a large roof area for its total square footage, which in turn would allow for a large amount of solar to be installed. This amount of solar was sufficient to meet the ZNC target in conjunction with other package measures.

An alternative approach would be to electrify cooking, which would reduce the need to maximize the size of a solar PV array by reduce cooking energy use. However, this is likely to be a less financially attractive approach.

There were minimal differences between the EE Target Package and the ZNC Target Package; as noted above, electrifying the HHW system represented the best option for this building to save energy, but electrifying the DHW system was less financially attractive than solar PV. Only one of these measures would be needed to reach the EE Target; based on the methodology chosen for this study, solar PV was used instead of electrifying DHW.

The Less-than-Five-Year Payback Package was largely constructed using similar measures as the ZNC Target Package with two notable exceptions:

- Retro-commissioning would be applied to the central plant equipment only. In-unit retro-commissioning would be a highly intrusive process, and there isn’t much equipment or savings potential in the apartments, so in-unit retro-commissioning is not included in the Less-Than-Five-Year Package. The HVAC system would be replaced in the ZNC Target Package and EE Target Package.
- Hot Water Pump VFDs would not apply; with conversion to a distributed heat pump system, the central plant pumps would no longer be necessary, making this measure unnecessary.

Package Comparisons

Reaching ZNC targets incur a large overall cost to the property. Most of these costs are borne from either electrification measures such as heat pump conversion or envelope measures such as air sealing and adding insulation. However, the ZNC target for this building is reachable with technologies available today.

There are some ways to reduce compliance retrofit costs:

- Some of the total capital cost may be effectively defrayed by accounting for avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment would likely be replaced before the 2035 target. This money can be effectively set aside to help cover parts of the costs.
- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today. These funds are available on three-year cycles and the program offerings can change during the program cycle; based on this, incentive estimates are not included in this report.

The EE Target Package incurs less overall cost than the ZNC Target Package and higher cost savings.

The Less-than-Five-Year Payback Package largely utilizes retrofits to existing equipment. Applying a higher estimated savings for retro-commissioning may be possible.

Measures Not Recommended

Measures reviewed for the building but not included in the EEM package are described below.

- Envelope: Window replacements were considered but ultimately determined to not be needed to meet the ZNC target and were not cost-effective enough to include in the Less-than-Five-Year Payback Package.
- Cooking: electrifying cooking was not needed to meet ZNC if the solar PV system size is maximized. Furthermore, this measure increases energy cost given utility rates used for this analysis.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
    - Electrified end uses were typically large (i.e., all of a building’s heating loads), and
    - Other measures’ applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the EE Target Package or Less-than-Five-Year Payback Package.
- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).

- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 94 below.

Table 94: General approaches to developing an EE Target Package.

Package Type	**Pros**	**Cons**	**Other Items**
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[59].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other

[59] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Utility Rates

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.

Case Study 7: Mid-Sized Hotel with Conference and Other High-Use Spaces

Building Information

This is a mid-size hotel with notable common areas, such as a conference center, restaurant, and room service. The facility originally had a pool, but it has been converted to additional meeting space.

Fan coil units serve the hotel rooms. A dedicated outdoor air ventilation system provides fresh air to the hotel rooms via hotel corridors.

Table 95. Building Characteristics – Case Study 7

Category	Building Information
Typology	Lodging
Square Footage	150,000 ft.^{2} – 175,000 ft.^{2} Hotel: 100%
Year Built	1990 – 1995
2019 ENERGY STAR Score	30 – 35
2019 Site EUI (kBTU/SF) (calculated for this study)	115 – 125

Building System Information

The basic building system information specific to the case study building is described below.

Table 96. Building System Information – Case Study 7

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	Energy Controls System (main HVAC equipment); central control system installation scheduled for hotel rooms	Electric	Unknown (estimated 10 years)	Unknown (estimated 5-10 years)
Heating	Four hot water boilers, 2000 kBTU each. Four-pipe fan coil distribution	Gas	15	5-10
Cooling	Two recently overhauled 175 ton chillers with a heat exchanger for free cooling in the winter. Four-pipe fan coil distribution	Electric	30	<5
Ventilation	DOAS serving the corridors; FCUs (4-pipe) in hotel rooms. AHUs have separate outdoor air introduction than the DOAS	Electric	Unknown (estimated 25-30 years)	Unknown (estimated 0-5 years)
DHW	Two boilers, non-condensing	Gas	15	5-10
Lighting	Mostly LED – back of house and parking are not LED	Electric	28	<5
Envelope	Largely unchanged in last 5-10 years	N/A	Unknown (estimated 30 years)	Unknown (estimated 15-20 years depending on component, save roof)
Metering	Centrally metered electric and gas	Electric, Gas	N/A	N/A

Utility End Use Assessment

The building's energy usage type and estimated end use are displayed below.

- Gas: used primarily for heating hot water and domestic hot water usage. An onsite restaurant also uses some gas (described in this report as base load), as does onsite laundry. Gas makes up 55% of the building's energy use.
- Electricity: used for cooling, ventilation, lighting, and electric plug loads. Electricity makes up 45% of the building's energy use. Fan coil units (FCUs) in hotel rooms and air handling units (AHUs) in common spaces provide conditioned air from a central heating and cooling plant.

Table 97. 2019 Site EUI by End Use – Case Study 7. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
23%	0%	29%	3%	0%	8%	0%	32%	5%	**100%**

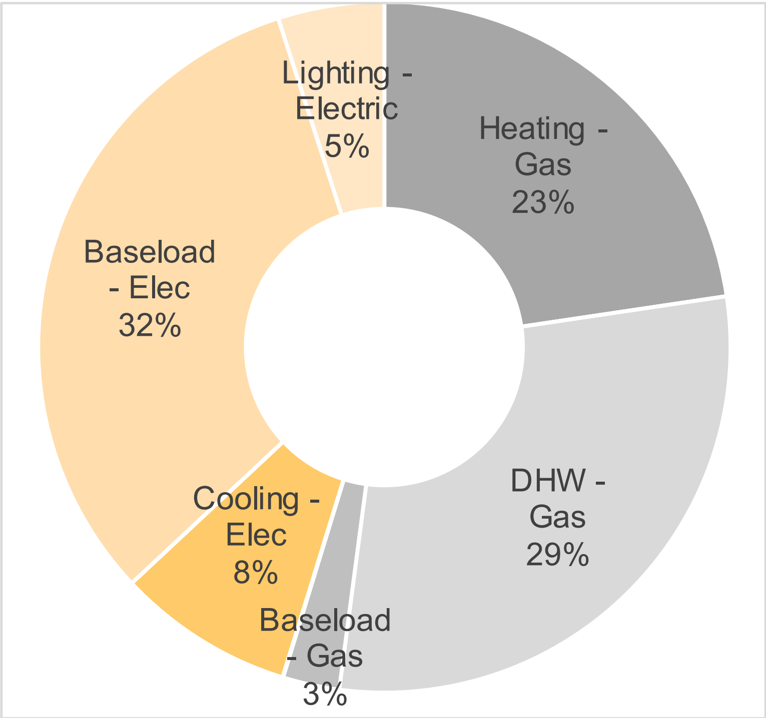

Figure 48. Site EUI Share (%) by End Use – Case Study 7

Target Determination

EUI targets are determined by a weighted average of applicable ZNC targets per space use type. Space use types are provided in Portfolio Manager and via reviews of available drawings. Table 98 contains a breakdown of the space use targets for purposes of calculating the ZNC target. Other building uses are discussed below this table. The table also has an alternate target ("EE Standard"); the building will need to take action in order to meet both the ZNC and EE Targets. All the following analysis uses the ZNC target.

Table 98. Space Use Target Methodology Summary – Case Study 7

Specific Space Type	Space Type Group	Area %	Floor Areas	ZNC Standard [Site EUI]	EE Standard [Site EUI]	Weighted ZNC EUI (ZNC * Area%)	Weighted EE EUI (ZNC * Area%)
Hotel	Lodging	100%	175,000	57.8	75.7	57.8	75.7
Total	**-**	**100%**	**175,000**	**-**	**-**	**57.8**	**75.7**

In addition to the overall hotel space (i.e., rooms, corridors, the main lobby), other support areas are present such as a restaurant with kitchen and conference center. Most of these support areas are small (less than 5% of the overall building footprint).

The baseline EUI is derived from whole building 2019 utility data over whole building square footage.

Table 99. ZNC and Interim Targets – Case Study 7

EUI Description	ZNC Target	ZNC Target
Baseline EUI	115 – 125	115 – 125
2026 – Interim Target 1	95 – 105	102 – 110
2030 – Interim Target 2	75 – 85	88 – 95
2035 – Target	57.8	75.7

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *EE Target Package* is based upon energy efficiency measures to reach the EE Target for this building. Note that the ZNC Target Package can also be used to reach the EE Target, but the EE Target Package reduces EUI only as far as needed to meet the EE Target.
- *Less-than-Five-Year Payback Package* is based on the results of a package that would have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax credits.

All costs are total costs for the measures, not incremental costs of equipment replacement as compared to a business as usual replacement schedule. These costs do not include applicable incentives. The following table offers a financial overview of these packages.

Table 100. EEM Package Summary – Case Study 7

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
ZNC Target Package	53 – 57	53%	$121,600	$5,959,000	48.9	2%
EE Target Package	72 – 76	38%	$138,200	$1,967,000	14.2	7%
Less-than-Five-Year Payback Package	94 – 102	19%	$99,800	$353,000	3.5	28%

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 101 that shows the estimated remaining life of the equivalent replacement system. An "N/A" indicates the existing system is not replaced, and "DNE" means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 101. ZNC Target Package EEMs – Case Study 7. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

Measure #	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify Space Heating	Convert existing HVAC system to an electric heat pump system	17.8%	$19,900	$3,804,000	191.2	1%	18	5-10
2	Electrify Water Heating	Convert existing DHW system to electric DHW	18.5%	($11,300)	$1,270,000	N/A	N/A	15	5-10
3	Electrify Cooking	Convert gas cooking to electric cooking	1.0%	($6,000)	$11,000	N/A	N/A	10	Unknown (estimated 10 years)
4	Install ERV	Install an exhaust recovery ventilation unit	5.3%	$41,900	$432,000	10.3	10%	15	DNE
5	Guest Room Controls	Add automatic guest room controls to limit extra energy usage during unoccupied times	5.2%	$41,300	$88,000	2.1	47%	10	Unknown (estimated 10 years)
6	Wider Deadbands	Expand deadbands for central mechanical equipment	0.1%	$1,000	$3,000	2.6	39%	5	N/A
7	CW Pump VFDs	Install condenser water pump variable frequency drives	0.4%	$3,200	$27,000	8.4	12%	15	DNE
8	Finish LED Conversion	Complete ongoing LED conversion	0.2%	$1,200	$38,000	30.4	3%	15	5-10
9	Plug Load Management	Install smart plug load management tools	1.5%	$11,700	$17,000	1.5	67%	10	DNE
10	High-Efficiency Water Aerators	Install low flow aerators in hotel room faucets and showers	0.3%	$2,200	$10,000	4.6	22%	10	DNE
11	General Air Sealing	Air seal gaps in masonry, between window/wall sealing, doors, and other envelope	0.3%	$2,000	$31,000	15.6	6%	15	DNE
12	Solar PV	Install roof-mounted solar PV	1.8%	$14,500	$228,000	15.7	6%	15	N/A
Total			**52.4%**	**$121,600**	**$5,161,000**	**42.4**	**2%**	**-**	

Table 102. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 7

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	23%	0%	29%	3%	0%	8%	0%	32%	5%	**100%**
End Use Difference	-100%	0%	-100%	-100%	100%	-27%	100%	-26%	-12%	**48%**

EE Target Package

As some EE Target measures entail replacement of existing equipment, an additional column is added to Table 103 (on the following page) that shows the estimated remaining life of the equivalent replacement system. An "N/A" indicates the existing system is not replaced, and a "DNE" means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 103. EE Target Package EEMs – Case Study 7. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Partially Electrify Water Heating	Convert existing DHW system to electric DHW with gas backup	15.1%	($9,200)	$953,000	N/A	N/A	15	5-10
2	Install ERV	Install an exhaust recovery ventilation unit	6.9%	$42,600	$432,000	10.1	10%	15	DNE
3	Retro-commissioning	Retro-commission and implement improvements on central building systems	3.5%	$22,200	$61,000	2.7	37%	5	DNE
4	Guest Room Controls	Add automatic guest room controls to limit extra energy usage during unoccupied times	6.1%	$38,500	$88,000	2.3	44%	10	DNE
5	Wider Deadbands	Expand deadbands for central mechanical equipment	0.4%	$1,300	$3,000	2.3	52%	5	DNE
6	CHW Pump VFDs	Install chilled water pump variable frequency drives	0.4%	$2,900	$23,000	7.9	13%	15	DNE
7	CW Pump VFDs	Install condenser water pump variable frequency drives	0.4%	$3,500	$27,000	7.7	13%	15	DNE
8	HW Pump VFDs	Install hot water pump variable frequency drives	0.3%	$2,000	$8,000	4.0	26%	15	DNE
9	Air Handling Unit VFDs	Install air handling unit fan variable frequency drives	0.9%	$7,000	$48,000	6.9	14%	15	DNE
10	Finish LED Conversion	Complete ongoing LED conversion	0.2%	$1,200	$38,000	31.7	3%	15	5-10
11	Plug Load Management	Install smart plug load management tools	1.3%	$9,900	$17,000	1.7	57%	10	DNE
12	Low Flow Aerators	Install low flow aerators in hotel room faucets and showers	0.2%	$1,700	$10,000	5.9	17%	10	DNE
13	General Air Sealing	Air seal gaps in masonry, between window/wall sealing, doors, and other envelope	0.6%	$2,300	$31,000	13.5	7%	15	DNE
14	Solar PV	Install roof-mounted solar PV	1.6%	$12,300	$228,000	18.5	5%	15	DNE
Total			**37.8%**	**$138,200**	**$1,967,000**	**14.2**	**7%**	**-**	

Table 104: Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for EE Target Package – Case Study 7

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	46%	0%	16%	6%	0%	5%	0%	24%	3%	**100%**
End Use Difference	-26%	0%	-82%	0%	-26%	-31%	0%	-37%	-17%	**62%**

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback package allows the building to meet its first interim target threshold.

Table 105. Less-than-Five-Year Payback Package EEMs – Case Study 7. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

Measure #	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI	Equip. Life (yrs)
1	Retro-commissioning	Retro-commission and implement improvements on central building systems	4.9%	$24,600	$61,000	2.5	41%	5
2	Guest Room Controls	Add automatic guest room controls to limit extra energy usage during unoccupied times	8.4%	$42,500	$88,000	2.1	48%	10
3	Wider Deadbands	Expand deadbands for central mechanical equipment	0.5%	$1,400	$3,000	2.1	58%	5
4	CHW Pump VFDs	Install chilled water pump variable frequency drives	0.4%	$3,300	$23,000	7.0	14%	15
5	CW Pump VFDs	Install condenser water pump variable frequency drives	0.5%	$3,800	$27,000	7.1	14%	15
6	HW Pump VFDs	Install hot water pump variable frequency drives	0.3%	$2,300	$8,000	3.5	29%	15
7	Air Handling Unit VFDs	Install air handling unit fan variable frequency drives	0.7%	$5,200	$48,000	9.2	11%	15
8	Finish LED Conversion	Complete ongoing LED conversion	0.2%	$1,200	$38,000	31.7	3%	15
9	Plug Load Management	Install smart plug load management tools	1.4%	$11,100	$17,000	1.5	64%	10
10	Low Flow Aerators	Install low flow aerators in hotel room faucets and showers	0.7%	$1,800	$10,000	5.6	18%	10
11	General Air Sealing	Air seal gaps in masonry, between window/wall sealing, doors, and other envelope	0.7%	$2,600	$31,000	11.9	8%	15
	Total		**18.5%**	**$99,800**	**$354,000**	**3.5**	**28%**	**-**

Table 106. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 7

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	23%	0%	29%	3%	0%	8%	0%	32%	5%	**100%**
End Use Difference	-18%	0%	-16%	0%	-3%	-16%	0%	-24%	-17%	**-19%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

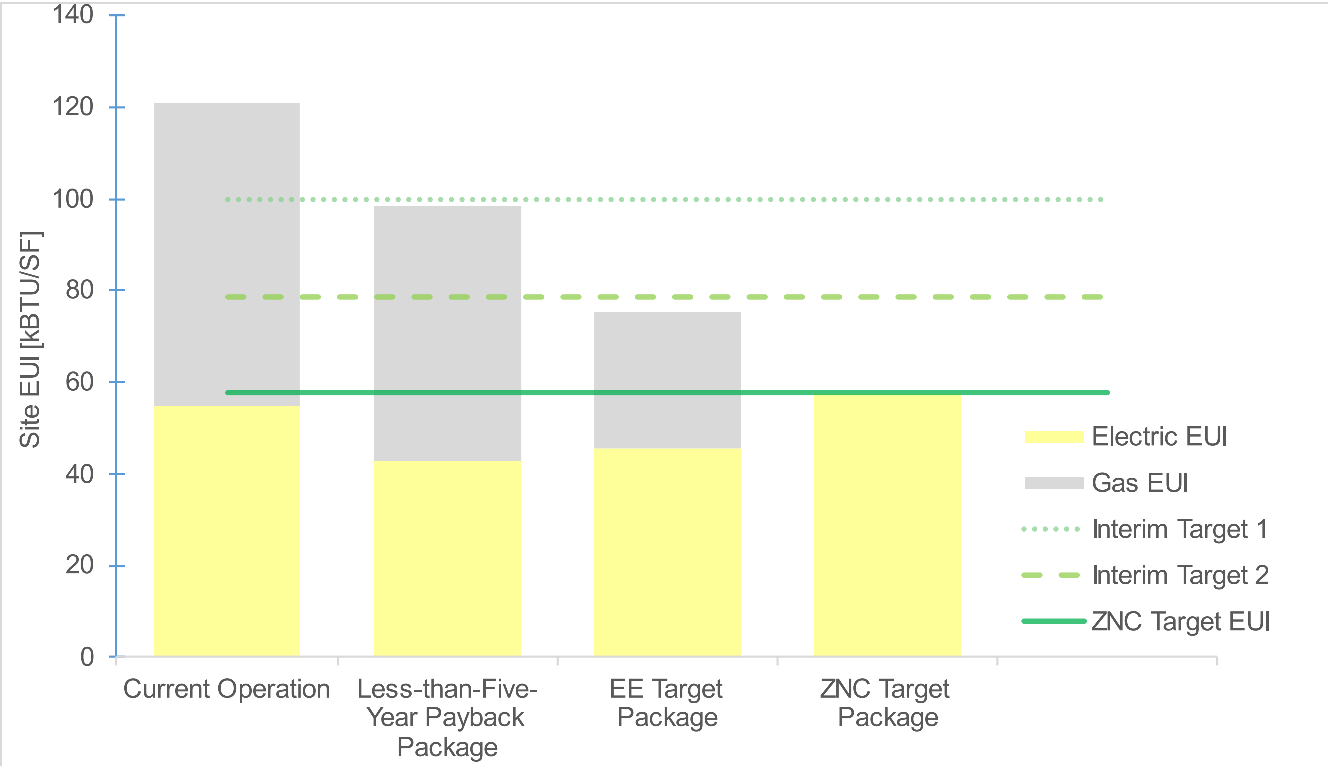

Figure 49. Target-to-Package Comparisons – Case Study 7

As seen in Figure 49, the Less-Than-Five-Year Payback Package results in a savings amount about equivalent to the first interim target. However, this package is still well short of the ZNC Target.

The EE Target Package does not fully electrify the building but does partially electrify some loads. As a result, electric use increases compared to the Less-Than-Five-Year Payback Package while gas use substantially decreases. This approach also gets the building below the 2nd interim target.

Building-Specific Technology Assessment

Given the large gas load at this building, electrification of primary loads-space heating, domestic hot water, cooking, and other similar base loads–are the main drivers behind the ZNC Target Package. These measures entail substantial renovations, but given the age of the mechanical system, a large-scale upgrade is likely during the next 10-15 years. As a result, electrification measures are the main energy savings driver in the ZNC Target Package.

Similarly, electrification of building loads needed to be evaluated for the EE Target. Although this is a comparatively smaller lift than the ZNC Target—on the order of 35% instead of 50%--this target cannot be reached without some amount of electrification.

Electrification considerations for this building are as follows:

- As noted above, electrification of all gas-fired loads is necessary in order to reach the ZNC Target. Electrifying all loads also represents a possible pathway to reaching the EE Target, although not a financially attractive one.
- Electrifying space heating would mean other measures to improve the building mechanical system could not be included in the EE Target Package. Since mechanical upgrades are typically more

common and offer better financial returns than domestic hot water or cooking upgrades, electrifying space heating was *not* included in the EE Target Package.

- *Completely* electrifying domestic hot water loads creates a slightly less attractive financial package than *partially* electrifying domestic hot water loads. In this partial electrification scenario, *only* enough electric DHW would be installed in order to meet the EE Target; the remaining capacity would be handled by gas systems. This also allows for backup gas systems to remain in case of emergency. The percentage of electrified systems was identified as described below.
- Electrifying cooking represents a rather small percentage of overall gas usage; other, more cost-effective measures can be used to reach the EE Target.

Once electrification measures were identified, then other measures to upgrade or optimize the building mechanical system were chosen. This includes items such as installing an ERV to lessen the heating and cooling load of the building. In this building, hotel guest room controls are applicable even with the system conversions so guest room controls were applied to all packages. Variable frequency drives (VFDs) were applied to mechanical systems that were not modified.

Following these mechanical system upgrades, other measures affecting building demand were applied (items like LED lighting conversions and high-efficiency aerators). These measures do not have a large overall impact on savings and were generally non-interactive in nature, meaning any resultant savings from these measures do not appreciably increase or decrease savings from other measures.

Lastly, roof-mounted solar PV is applied to the ZNC and EE Target Packages. In practice, solar PV needs to be coordinated with other measures that require roof space. A possible alternative method of ZNC compliance would be to expand solar PV to include a canopied PV system over the parking lot; however, based on the financial analysis done within this case study this is less financially advantageous than the package of measures chosen.

The Less-than-Five-Year Payback Package is largely constructed using similar measures as the ZNC Target Package with two notable exceptions:

- Retro-commissioning is applied to the existing systems only. Wholesale changeout of building mechanical systems would render any realized retro-commissioning savings irrelevant in the ZNC Target Package and so it was not included.
- Chilled Water Pump VFDs and Hot Water Pump VFDs are included in this package but not in the ZNC Target Package. The ZNC Target Package removes these loops from the building and instead includes a condenser water loop serving as the main building loop.

Once the Less-than-Five-Year Payback Package was constructed, measures for systems that remained were applied to the EE Target Package. These measures on their own were insufficient to reach the EE Target; in order to complete the EE Target Package, Solar PV (from the ZNC Target Package) and partial electrification of the DHW loop was applied. Electrifying approximately 80% of the DHW System was enough to reach the EE Target.

Package Comparisons

Reaching ZNC targets incurs a large overall cost to the property; most of these costs are borne from either electrification measures such as heat pump conversion or envelope measures such as air sealing and adding insulation. However, the ZNC target for this building is reachable with technologies available today.

There are some ways to reduce compliance retrofit costs:

- Some of the total capital costs may be defrayed by accounting for avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment will likely be replaced before the 2035 target. This money can be effectively set aside to help cover parts of the costs.

- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today. These funds are available on three-year cycles and the program offerings can change during the program cycle; based on this, incentive estimates are not included in this report.

The EE Target Package incurs less overall cost than the ZNC Target Package and higher cost savings.

The Less-than-Five-Year Payback Package largely utilizes retrofits to existing equipment. Applying a higher estimated savings for retro-commissioning may be possible. It should be noted that with more retro-commissioning savings realized, the "Install ERV" measure (EEM 4 in the ZNC Target Package) be eligible for inclusion in the Less-than-Five-Year Payback Package.

Advances in technology between now and the ZNC target date may result in viable alternative approaches, meaning reductions in the ZNC costs and payback ranges described here. This applies primarily to envelope measures.

Measures Not Recommended

Measures reviewed for the building but not included in the EEM package are described below.

- Envelope: window and roof replacements were considered but ultimately not needed to meet the ZNC target and not cost-effective enough to include in the Less-than-Five-Year Payback Package.
- Canopy-mounted parking lot solar PV: while parking lot space here may allow for canopy-mounted solar PV, this is a much more expensive option than the roof-mounted solar PV approach chosen; this measure would displace other, more financially attractive measures.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
  - Electrified end uses were typically large (i.e., all of a building's heating loads), and
  - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the However, they may appear in the EE Target Package or Less-than-Five-Year Payback Package.

- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 107 below.

Table 107: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[60].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

[60] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Utility Rates

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.

Case Study 8: Standard Hotel without Extra Use Spaces

Building Information

This is a standard hotel without major extra use spaces such as conference centers. However, a restaurant and small retail space is on the premises. In addition, a covered parking garage serves the facility; its energy usage is on the electricity meter serving the building. Fan coil units are located in individual hotel rooms. Fresh air is provided to the hotel rooms via the hotel corridors; this air is pre-conditioned with exhaust air heat recovery systems.

Table 108. Building Characteristics – Case Study 8

Category	Building Information
Typology	Lodging
Square Footage	200,000 ft.^{2} – 225,000 ft.^{2} Hotel: 100%
Year Built	1990 – 1995
2019 ENERGY STAR Score	30 – 35
2019 Site EUI (kBTU/SF) (calculated for this study)	125 – 135

Building System Information

The basic building system information specific to the case study building is described below.

Table 109. Building System Information – Case Study 8

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	None – pneumatics installed on main equipment.	Electric	30 (estimated)	<5
Heating	Condensing HHW boilers feeding 4-pipe FCU system. Pumps original but have VFDs installed.	Gas (pumps, FCU motors electric)	2	20-25
Cooling	Chilled water; chillers about 30 years old. Cooling towers about 15 years old. No VFDs on CT fans.	Electric	30	<5
Ventilation	Semco heat recovery units serving corridors	Electric	10	10-15
DHW	Two sealed combustion hot water heaters	Gas (pumps, FCU motors electric)	12-14	5-10
Lighting	LED	Electric	2-3	5-10
Envelope	Largely unchanged in last 5-10 years	N/A	30 (estimated)	15-20
Metering	Centrally metered electric and gas	Electric, Gas	N/A	N/A

Utility End Use Assessment

The building's energy usage type and estimated end uses are displayed below.

- Gas: used for heating hot water and domestic hot water usage primarily. An onsite restaurant also uses some gas (described in this report as base load), as does pool heating. 55% of the building's energy use is in the form of gas.
- Electricity: used for cooling, ventilation, lighting, and electric plug loads. 45% of the building's energy use is in the form of electricity. Fan coil units (FCUs) in hotel rooms and air handling units (AHUs) in common spaces provide conditioned air from a central heating and cooling plant. Parking lot lighting energy usage is included in this metric as it was not separately metered.

Table 110. 2019 Site EUI by End Use – Case Study 8. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
16%	0%	35%	4%	0%	8%	0%	33%	5%	**100%**

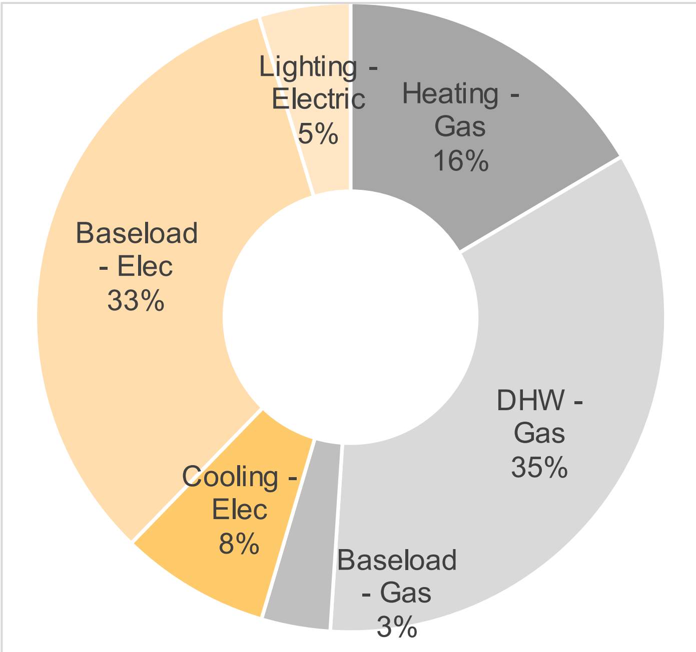

Figure 50. Site EUI Share (%) by End Use – Case Study 8

Target Determination

EUI targets are determined by a weighted average of applicable ZNC targets per space use type. Space use types are provided in Portfolio Manager and via reviews of available drawings. The table also has an alternate target ("EE Standard"); the building will need to take action in order to meet both the ZNC and EE Targets. All the following analysis uses the ZNC target.

Table 111. Space Use Target Methodology Summary – Case Study 8

Specific Space Type	Space Type Group	Area %	Floor Areas	ZNC Standard [Site EUI]	EE Standard [Site EUI]	Weighted ZNC EUI (ZNC * Area%)	Weighted EE EUI (ZNC * Area%)
Hotel	Lodging	100%	225,000	57.8	75.7	57.8	75.7
Total	**-**	**100%**	**225,000**	**-**	**-**	**57.8**	**75.7**

In addition to the overall hotel space (i.e., rooms, corridors, the main lobby), other support areas are present such as a restaurant with kitchen, conference center, and above-ground covered parking. Most of these support areas are small (less than 5% of the overall building footprint), and parking is not included in any target-setting metrics.

The baseline EUI is derived from whole building 2019 utility data over whole building square footage.

Table 112. ZNC and Interim Targets – Case Study 8

EUI Description	ZNC Target	EE Target
Baseline EUI	125 – 135	125 – 135
2026 – Interim Target 1	101 – 110	108 – 115
2030 – Interim Target 2	77 – 85	90 – 96
2035 – Target	57.8	75.7

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *EE Target Package* is based upon energy efficiency measures to reach the EE Target for this building. Note that the ZNC Target Package can also be used to reach the EE Target, but the EE Target Package reduces EUI only as far as needed to meet the EE Target.
- *Less-than-Five-Year Payback Package* is based on the results of a package that would have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax credits.

All costs are total costs for the measures, not incremental costs. These costs do not include applicable incentives. The following table offers a financial overview of these packages.

Table 113. EEM Package Summary – Case Study 8

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
Final Target Package	53 – 57	56%	$209,600	$7,170,000	34.2	3%
EE Target Package	72 – 76	42%	$213,400	$2,105,000	9.9	10%
Less-than-Five-Year Payback Package	89 – 96	29%	$214,300	$751,000	3.5	29%

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 114 that shows the estimated remaining life of the equivalent replacement system. An "N/A" indicates the existing system is not replaced, and "DNE" means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 114. ZNC Target Package EEMs – Case Study 8. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify Space Heating	Convert existing HVAC system to an electric heat pump system	11.5%	$4,400	$4,844,000	N/A	N/A	19	20-25
2	Electrify Water Heating	Convert existing DHW system to electric DHW	21.7%	($13,800)	$1,370,000	N/A	N/A	19	5-10
3	Electrify Cooking	Convert gas cooking to electric cooking	1.4%	($11,000)	$11,000	N/A	N/A	10	Unknown (estimated 10 years)
4	Guest Room Controls	Add automatic guest room controls to limit extra energy usage during unoccupied times	6.4%	$69,500	$112,000	1.6	62%	15	Unknown (estimated 5-10 years)
5	Pneumatic Conversion to DDC	Convert central plant pneumatics to DDC and calibrate/optimize system	8.9%	$96,000	$440,000	4.6	22%	15	<5
6	Recommission Heat Recovery	Recommission existing heat recovery ventilation system	2.2%	$23,400	$22,000	0.9	106%	5	N/A
7	Cooling Tower Fan VFDs	Install cooling tower fan variable frequency drives	0.4%	$3,900	$12,000	3.0	33%	15	DNE
8	Plug Load Management	Install smart plug load management tools	1.5%	$15,900	$22,000	1.4	72%	10	DNE
9	High-Efficiency Water Aerators	Install low flow aerators in hotel room faucets and showers	0.3%	$3,000	$11,000	3.7	27%	10	DNE
10	Solar PV	Install roof-mounted solar PV	1.7%	$18,300	$326,000	17.8	6%	15	DNE
Total			**56.2%**	**$209,600**	**$7,170,000**	**34.2**	**3%**	**-**	

Table 115. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 8

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	16%	0%	35%	4%	0%	8%	0%	33%	5%	**100%**
End Use Difference	-100%	0%	-100%	-100%	0%	-28%	0%	-34%	-23%	**44%**

EE Target Package

As some EE Target measures entail replacement of existing equipment, an additional column is added to Table 116 that shows the estimated remaining life of the equivalent replacement system. An "N/A" indicates the existing system is not replaced, and a "DNE" means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 116. EE Target Package EEMs – Case Study 8. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify Water Heating	Convert existing DHW system to electric DHW with gas backup	17.8%	($14,900)	$1,028,000	N/A	N/A	15	15-20
2	Install Free Cooling HX	Install a plate-and-frame heat exchanger to provide chilled water during cold ambient conditions	1.3%	$13,800	$107,000	7.8	13%	15	15-20
3	Guest Room Controls	Add automatic guest room controls to limit extra energy usage during unoccupied times	7.0%	$63,800	$112,000	1.8	57%	10	DNE
4	Pneumatic Conversion to DDC	Convert central plant pneumatics to DDC and calibrate/optimize system	9.6%	$88,100	$440,000	5.0	20%	5	0-5
5	Recommission Heat Recovery	Recommission existing heat recovery ventilation system	2.4%	$21,800	$22,000	1.0	99%	15	DNE
6	Cooling Tower Fan VFDs	Install cooling tower fan variable frequency drives	0.3%	$3,700	$12,000	3.2	31%	15	DNE
7	Air Handling Unit VFDs	Install air handling unit fan variable frequency drives	0.3%	$2,700	$25,000	9.1	11%	10	DNE
8	Plug Load Management	Install smart plug load management tools	1.4%	$14,800	$22,000	1.5	67%	15	DNE
9	Low Flow Aerators	Install low flow aerators in hotel room faucets and showers	0.2%	$2,500	$11,000	4.5	22%	10	DNE
10	Solar PV	Install roof-mounted solar PV	1.6%	$17,000	$326,000	19.2	5%	15	DNE
Total			**41.8%**	**$213,300**	**$2,105,000**	**9.9**	**10%**	**-**	

Table 117: Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for EE Target Package – Case Study 8

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	46%	0%	16%	6%	0%	5%	0%	24%	3%	**100%**
End Use Difference	-27%	0%	-82%	0%	0%	-40%	0%	-39%	-23%	**58%**

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback package allows the building to meet its first interim target threshold.

Table 118. Less-than-Five-Year Payback Package EEMs – Case Study 8. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)
1	Install Free Cooling HX	Install a plate-and-frame heat exchanger to provide chilled water during cold ambient conditions	1.3%	$13,800	$107,000	7.8	13%	15
2	Guest Room Controls	Add automatic guest room controls to limit extra energy usage during unoccupied times	9.3%	$64,500	$112,000	1.7	57%	15
3	Pneumatic Conversion to DDC	Convert central plant pneumatics to DDC and calibrate/optimize system	12.9%	$89,100	$440,000	4.9	20%	10
4	Recommission Heat Recovery	Recommission existing heat recovery ventilation system	2.4%	$21,800	$22,000	1.0	99%	5
5	Cooling Tower Fan VFDs	Install cooling tower fan variable frequency drives	0.3%	$3,700	$12,000	3.2	31%	15
6	Air Handling Unit VFDs	Install air handling unit fan variable frequency drives	0.4%	$4,000	$25,000	6.1	16%	15
7	Plug Load Management	Install smart plug load management tools	1.4%	$14,700	$22,000	1.5	67%	10
8	Low Flow Aerators	Install low flow aerators in hotel room faucets and showers	0.7%	$2,600	$11,000	4.2	24%	15
	Total		**28.7%**	**$214,200**	**$751,000**	**3.5**	**29%**	**-**

Table 119. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 8

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	16%	0%	35%	4%	0%	8%	0%	33%	5%	**100%**
End Use Difference	-27%	0%	-25%	0%	0%	-40%	0%	-34%	-23%	**71%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

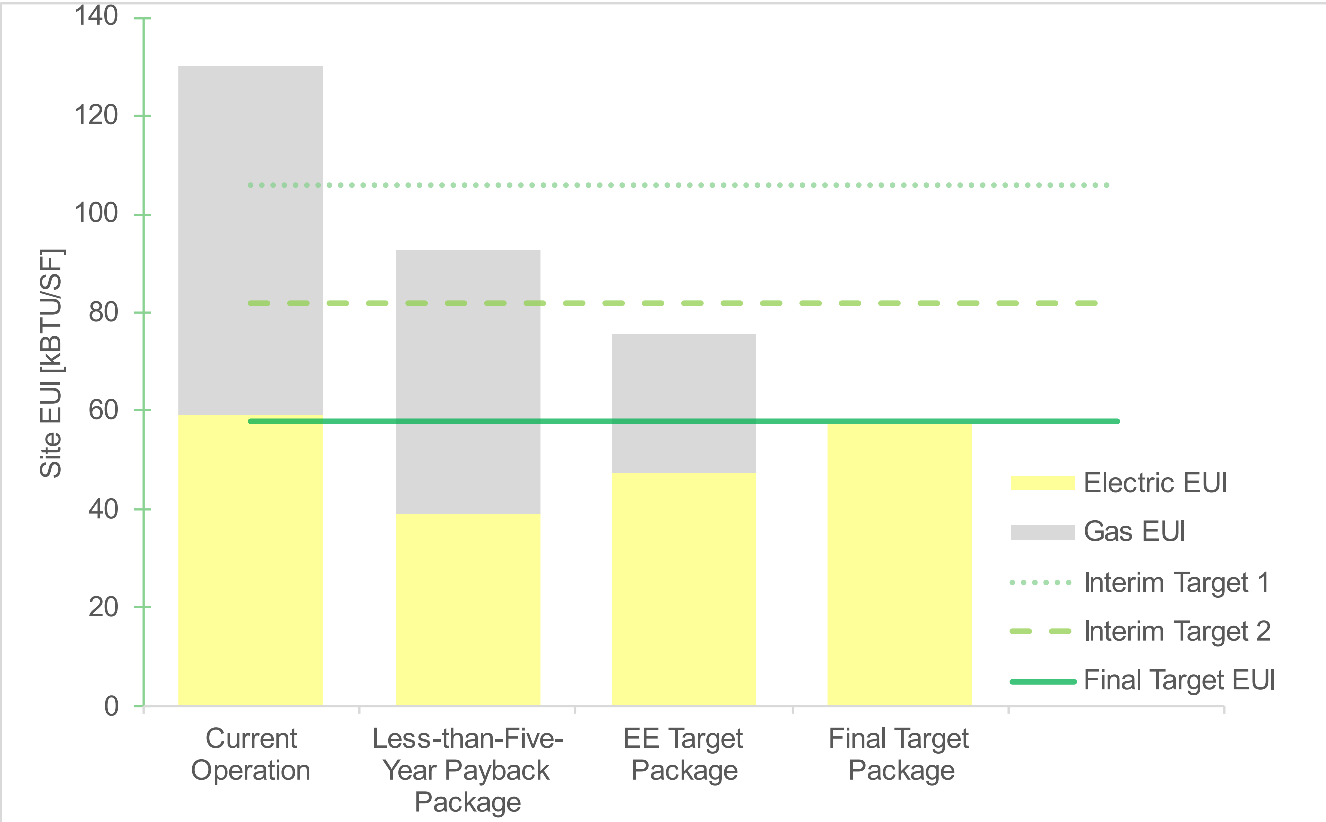

Figure 51. Target-to-Package Comparisons – Case Study 8

As seen in Figure 51, the Less-Than-Five-Year Payback Package results in a savings amount approximate to the first interim target.

The EE Target Package does not fully electrify the building but does partially electrify some loads. As a result, electric use increases compared to the Less-Than-Five-Year Payback Package while gas use substantially decreases. This approach also gets the building below the 2nd interim target.

Building-Specific Technology Assessment

This hotel has a large gas load which is dominated by domestic hot water use. In addition, this hotel has a central control system which is a large source of building inefficiencies.

Given the large gas load at this building, electrification of primary loads-mechanical heating and cooling, domestic hot water, cooking, and other similar base loads–are the main drivers behind the ZNC Target Package. These measures entail substantial renovations, but given the age of the mechanical system, a large-scale upgrade is likely during the next 10-15 years. As a result, electrification measures are included in the ZNC Target Package.

Similarly, electrification of building loads needed to be evaluated for the EE Target. Although this is a comparatively smaller lift than the ZNC Target—on the order of 40% instead of 55%--this target cannot be reached without some measure of electrification.

Electrification considerations for this building are as follows:

- As noted above, electrification of all gas-fired loads is necessary in order to reach the ZNC Target. Electrifying all loads also represents a possible pathway to reaching the EE Target, although not a financially attractive one.
- Electrifying space heating would mean other measures to improve the building mechanical and controls systems could not be included in the EE Target Package. Since mechanical upgrades are typically more common and offer better financial returns than domestic hot water or cooking upgrades, electrifying space heating was *not* included in the EE Target Package.
- *Completely* electrifying domestic hot water loads creates a slightly less attractive financial package than *partially* electrifying domestic hot water loads. In this partial electrification scenario, *only* enough electric DHW would be installed in order to meet the EE Target; the remaining capacity would be handled by gas systems. This also allows for backup gas systems to remain in case of emergency. The percentage of electrified systems was identified as described below.
- Electrifying cooking represents a rather small percentage of overall gas usage; other measures can be used to reach the EE Target.

For this building, converting the existing fan coil system to a water-source heat pump system gains the benefit of reusing existing piping risers compared to other electrification conversion technology (i.e., VRF) which entails entirely new piping runs throughout the building.

Some alternative approaches were reviewed:

- Aiming for efficiency gains from existing equipment is not realistic based on technology available today. In effect, gas-fired equipment needs to approach or exceed 100% efficiency in order to be in range of the ZNC target. While some optimization methods can help and do appear in the Less-than-Five-Year Payback Package, they do not cover this energy gap.
- More efficient similar system types have the same issues. While—for example—replacement of aged chillers with new chillers would generate substantial chilled water savings, it does not solve the issue around gas usage as described above.

Once electrification measures are completed, other measures to improve building controls were chosen, including advanced guest room controls and converting the existing pneumatic control system to direct digital controls (DDC). Pneumatic controls are old, inefficient mechanical system controls that use compressed air to start and stop equipment and control critical points such as space temperature. However, they require frequent calibration (recommended every six months) and are prone to failure. Direct digital controls use electronic devices and control signals to control mechanical equipment; these require less frequent calibration, are more accurate, and allow for more advanced, energy savings control. Because the system upgrades undertaken for electrification leave some piping and pumping in place, upgrading these controls to DDC are necessary to realize the total system benefit.

Smaller but still significant mechanical optimization measures such as recommissioning the existing heat recovery system and installing VFDs on fans were chosen.

Following these mechanical system upgrades, other measures affecting building demand were applied (items like LED lighting conversions and high-efficiency aerators). These measures do not have a large overall impact on savings and were generally non-interactive in nature, meaning any resultant savings from these measures do not appreciably increase or decrease savings from other measures.

Lastly, roof-mounted solar PV is applied to the ZNC and EE Target Packages. In practice, solar PV needs to be coordinated with other measures that require roof space.

The Less-than-Five-Year Payback Package and EE Target Package uses similar measures as the ZNC Target Package with a handful of exceptions or changes:

- Installing a free cooling heat exchanger (HX) is viable for a chilled water plant system, but not viable if the building is converted to a heat pump loop. Free cooling heat exchangers use water as a medium to remove heat from the building without the use of electricity or other fuels when ambient conditions are cool enough; this can result in substantial energy savings in buildings requiring cooling during colder months.
- Pneumatic Conversion with DDC assumed the central plant and primary air handling units would also be converted from their existing pneumatics to DDC. Pneumatic controls operate equipment in the building (usually key mechanical equipment) but are a much older type of control system that frequently falls out of calibration, generating energy waste. DDC controls eliminate this issue.
- Air Handling Unit Fan VFDs apply to the Less-than-Five-Year Payback Package and EE Target Package, but not the ZNC Target Package; electrifying space heating in the ZNC Target Package would replace these air handling units.

Package Comparisons

Most energy cost savings with this building are achieved with the Less-than-Five-Year Payback Package. This is due to two factors:

- Most equipment at the building is running relatively inefficiently, most notably the regular presence of pneumatic controls. Removal of these controls and addition of direct digital (DDC) controls drives a large portion of both total cost and total savings.
- Electrification measures have high costs. Based on the usage profile of this hotel, large-scale electric conversion of domestic hot water and cooking incur not only upgrade costs, but also higher energy costs.

Reaching ZNC targets incurs a large overall cost to the property; most of these costs are borne from either electrification measures such as heat pump conversion or envelope measures such as air sealing and adding insulation. However, the ZNC target for this building is reachable with technologies available today.

The EE Target Package incurs less overall cost than the ZNC Target Package and higher cost savings.

There are some ways to reduce compliance retrofit costs:

- Some of the total capital costs may be defrayed by accounting for avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment will likely be replaced before the 2035 target. This money can be effectively set aside to help cover parts of the costs.
- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today on three-year cycles. The program offerings can change during the program cycle; based on this, incentive estimates are not included in this report.

Note that some of the differences between savings amounts reflected in the different packages (most notably the pneumatic conversion to DDC) are dependent on existing or replaced technology. Specifically, if the mechanical system is converted to a heat pump system, the chilled water plant will not be needed and no savings will be realized.

Advances in technology between now and the ZNC target date may result in other viable approaches, meaning reduction in the ZNC costs and payback ranges described here. This applies primarily to envelope measures.

Measures Not Recommended

Measures reviewed for the building but not included in the EEM package are described below.

- Envelope: window and roof replacements were considered but ultimately unneeded to meet the ZNC target and not cost-effective enough to include in the Less-than-Five-Year Payback Package.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
    - Electrified end uses were typically large (i.e., all of a building's heating loads), and
    - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the However, they may appear in the EE Target Package or Less-than-Five-Year Payback Package.
- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 120.

Table 120: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[61].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

[61] Energy conservation by occupants can drive significant energy savings (EPA, slide 33). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

Where possible, supplemental energy audit information performed by others is incorporated into the case studies. These energy audits, which may contain onsite observations, were completed prior to this desktop audit process.

Utility Rates

Utility rate assumptions are $0.129 per kWh and $1.228 per therm, based on the US Energy Information Administration (EIA) average rates for the area. While energy rates differ by service class and usage profile, these rates are assumed to represent the average costs for these types of buildings in Montgomery County. These rates are meant to be inclusive of taxes and fees applicable throughout the state, including the current Fuel Energy Tax of $0.01978 per kWh on electricity and $0.17026 per therm on natural gas use.

Case Study 9: Worship/Education Mixed-Use

This is a multi-function building that acts as a worship facility, school, and gathering place. The facility was built in two phases. The old building houses mostly school spaces. Space uses are generally divided across the new and old building. Similarly, the mechanical and other building systems are largely separate between the old building and the addition, with the exception of the outdoor air system which is shared across both buildings.

This case study distinguishes measures between the old and new buildings, as specific measures may only be applicable to specific parts of the building. This type of approach would be common in buildings that have substantially different types of building systems in additions.

Table 121. Building Characteristics – Case Study 9

Category	Building Information
Typology	Worship/Education
Square Footage	75,000 ft.^{2} – 100,000 ft.^{2} School: 50% Religious Worship: 50%
Year Built	1995 – 2005 (old building) 2005 – 2015 (new addition)
2019 ENERGY STAR Score	30 – 35
2019 Site EUI (kBTU/SF) (calculated for this study)	80 – 90

Building System Information

The basic building system information specific to the case study buildings are described below.

Table 122. Building System Information – Case Study 9

Category	Type	Fuel	Approximate Equipment Age (Years)	Expected End of Useful Life (Years)
Central BMS	Building automation system in the new building No central controls in the old building	Electric	10 (new) N/A (old)	5-10 (new); <5 (old)
Heating	Gas-fired boilers (primary) in new building WSHP with electric boiler backup in old building	Electric/Gas	10 (new) 20 (old)	10-15 (new) 5-10 (old)
Cooling	Chilled water in new building WSHP in old building	Electric	10 (new) 20 (old)	10-15 (new) <5 (old)
Ventilation	ERVs in new building; through-wall ventilation in old building. ERVs and some AHUs serve some old building spaces	Electric	10 (new) 20 (old)	5-10 (new) <5 (old)
DHW	Unitized electric DHW for both buildings	Electric	10 (new) 20 (old)	10-15 (new) 5-10 (old)
Lighting	Converted to LED in 2016 (including parking lot spaces)	Electric	5	5 – 10
Envelope	Largely unchanged in last 5-10 years	N/A	10 (new) 20 (old)	30-40
Metering	One electric and one gas meter for both buildings	Electric, Gas	N/A	N/A

Utility End Use Assessment

The buildings' energy usage type and estimated end use are displayed below.

- Gas: used for heating hot water in the new building only. Forty percent of the building's energy usage is in the form of gas.
- Electricity: used for cooling and heating in the old building; ventilation, lighting, and electric plug loads. Sixty percent of the building's energy use is in the form of electricity.

Table 123. 2019 Site EUI by End Use – Case Study 9. Components may not sum to 100% due to rounding.

Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
40%	0%	0%	0%	6%	10%	1%	37%	7%	**100%**

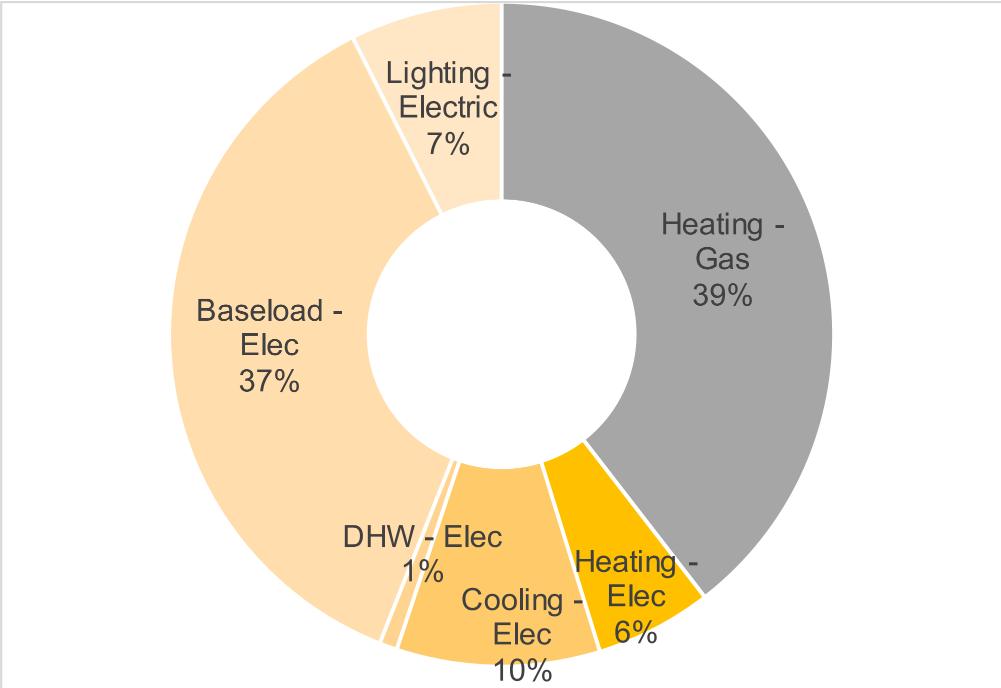

Figure 52. Site EUI Share (%) by End Use – Case Study 9

Target Determination

EUI targets are determined by a weighted average of applicable ZNC targets per space use type. Space use types are provided in Portfolio Manager and via reviews of available drawings. The table also includes an alternate "EE Standard" target. The building will need to take action in order to meet both the ZNC and EE Targets. All the following analysis uses the ZNC target.

Table 124. Space Use Target Methodology Summary – Case Study 9

Specific Space Type	Space Type Group	Area %	Floor Areas	ZNC Standard [Site EUI]	EE Standard [Site EUI]	Weighted ZNC EUI (ZNC * Area%)	Weighted EE EUI (ZNC * Area%)
K-12 School	Education – K-12 School	50%	50,000	36.0	47.1	26.0	24.3
Worship Facility	Religious Worship	50%	50,000	36.9	48.8	10.2	23.6
Total	**-**	**100%**	**100,000**	**-**	**-**	**36.2**	**47.9**

The baseline EUI is derived from whole building 2019 utility data over whole building square footage.

Table 125. ZNC and Interim Targets – Case Study 9

EUI Description	ZNC Target	ZNC Target
Baseline EUI	80 – 90	80 – 90
2026 – Interim Target 1	65 – 72	70 – 77
2030 – Interim Target 2	50 – 56	59 – 64
2035 – Target	36.4	47.9

Package Overview

EEM packages were compiled based on existing technology for two scenarios:

- *ZNC Target Package* is based upon electrification and energy efficiency measures to reach the ZNC Target for this building.
- *EE Target Package* is based upon energy efficiency measures to reach the EE Target for this building. Note that the ZNC Target Package can also be used to reach the EE Target, but the EE Target Package reduces EUI only as far as needed to meet the EE Target.
- *Less-than-Five-Year Payback Package* is based on the results of a package that would have a simple payback of less than five years, not accounting for supplemental funding tools such as utility incentives or tax credits.

All costs are total costs for the measures, not incremental costs. These costs do not include applicable incentives. The following table offers a financial overview of these packages.

Table 126. EEM Package Summary – Case Study 9

Package	Package EUI (kBTU/ft.^{2}/yr)	% Site EUI Savings	Cost Savings ($/yr.)	Capital Costs ($)	SP (yrs)	ROI (%)
ZNC Target Package (Option 1)	33 – 36	55%	$80,800	$3,062,000	37.9	3%
ZNC Target Package (Option 2)	33 – 36	56%	$155,300	$2,445,000	15.7	6%
EE Target Package	45 – 48	42%	$105,700	$1,400,000	13.3	8%
Less-than-5-year Payback Package	72 – 81	10%	$18,800	$53,000	2.8	35%

Note that for the ZNC Target Package, SWA determined that two packages were viable based on energy savings and applicability to this building. This case study contains the results of both of these packages.

ZNC Target Package

As some ZNC Target measures entail replacement of existing equipment, an additional column is added to Table 127 and Table 129 that shows the estimated remaining life of the equivalent replacement system. An "N/A" indicates the existing system is not replaced, and a "DNE" means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 127. ZNC Target Package EEMs – Case Study 9, Option 1. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Electrify Space Heating (new bldg.)	Convert existing gas heating system in the old building to an electric heat pump system	27.7%	$2,600	$978,000	369.0	0%	15	10 – 15
2	Install ERV (old bldg.)	Install a dedicated outdoor air system with heat recovery capabilities in the old building	3.6%	$12,600	$114,000	9.0	11%	15	DNE
3	Retro-commissioning (new building)	Retro-commission and implement improvements on central building systems for the new building	2.7%	$7,500	$16,000	2.1	48%	5	N/A
4	Retro-commissioning (old building)	Retro-commission and implement improvements on central building systems for the old building	2.7%	$7,300	$16,000	2.2	46%	5	N/A
5	Loop Pump VFDs (old bldg.)	Install VFDs on the loop pumps for the old building	0.9%	$2,500	$21,000	8.7	12%	15	DNE
6	Solar PV	Install roof-mounted solar PV and some canopy-mounted solar PV over the parking lot	17.5%	$48,200	$1,918,000	39.8	3%	15	DNE
Total			**55.1%**	**$80,700**	**$3,063,000**	**37.9**	3%	**-**	

Table 128. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 9, Option 1.

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	40%	0%	0%	0%	6%	10%	1%	37%	7%	**100%**
End Use Difference	-100%	0%	0%	0%	170%	-16%	-8%	-63%	-8%	**45%**

Table 129. ZNC Target Package EEMs – Case Study 9, Option 2. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Retro-commissioning (new building)	Retro-commission and implement improvements on central building systems for the new building	5.1%	$8,200	$16,000	1.9	53%	5	N/A
2	Retro-commissioning (old building)	Retro-commission and implement improvements on central building systems for the old building	2.9%	$16,200	$16,000	1.0	102%	5	N/A
3	Loop Pump VFDs (old 172ldg.)	Install VFDs on the loop pumps for the old building	0.9%	$2,600	$21,000	8.3	12%	15	DNE
4	Solar PV	Install roof-mounted solar PV and canopy-mounted solar PV over the parking lot	46.6%	$128,300	$2,392,000	18.6	5%	15	DNE
Total			**55.6%**	**$155,300**	**$2,445,000**	**15.7**	**6%**	**-**	

Table 130. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for ZNC Target Package – Case Study 9, Option 2.

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	40%	0%	0%	0%	6%	10%	1%	37%	7%	**100%**
End Use Difference	-8%	0%	0%	0%	-86%	-86%	-86%	-87%	-86%	**44%**

EE Target Package

As some EE Target measures entail replacement of existing equipment, an additional column is added to Table 131 that shows the estimated remaining life of the equivalent replacement system. An “N/A” indicates the existing system is not replaced, and a “DNE” means does not exist and the package adds a system or piece of equipment not currently onsite. This is discussed in more detail in the Case Study Measures Identification Methodology section below.

Table 131. EE Target Package EEMs – Case Study 9. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)	Estimated Remaining Life of Equivalent System (yrs)
1	Install ERV (old bldg.)	Install a dedicated outdoor air system with heat recovery capabilities in the old building	3.6%	$9,900	$114,000	11.5	9%	15	15-20
2	Retro-commissioning (new building)	Retro-commission and implement improvements on central building systems for the new building	5.1%	$8,200	$16,000	1.9	52%	5	15-20
3	Retro-commissioning (old building)	Retro-commission and implement improvements on central building systems for the old building	3.7%	$7,400	$16,000	1	47%	5	DNE
4	Loop Pump VFDs (old bldg.)	Install VFDs on the loop pumps for the old building	0.9%	$2,500	$21,000	8.7	11%	15	DNE
5	Solar PV	Install roof-mounted solar PV and some canopy-mounted solar PV over the parking lot	28.2%	$77,700	$1,234,000	15.9	6%	15	DNE
Total			**41.5%**	**$105,700**	**$1,401,000**	**13.3**	**8%**	**-**	

Table 132: Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for EE Target Package – Case Study 9

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	46%	0%	16%	6%	0%	5%	0%	24%	3%	**100%**
End Use Difference	-12%	0%	0%	0%	-61%	-62%	-58%	-61%	-58%	**58%**

Less-than-Five-Year Payback Package

The Less-than-Five-Year Payback package allows the building to meet its first interim target threshold.

Table 133. Less-than-Five-Year Payback Package EEMs – Case Study 9. All costs are total capital cost estimates without incentives and without subtracting the cost of replacing existing systems at end of life.

#	Measure	Description	Whole Bldg. EUI Svgs. (%)	Cost Savings ($/yr.)	Measure Cost ($)	SP (yrs)	ROI (%)	Equip. Life (yrs)
1	Retro-commissioning (new building)	Retro-commission and implement improvements on central building systems for the new building	5.1%	$8,200	$16,000	1.9	52%	5
2	Retro-commissioning (old building)	Retro-commission and implement improvements on central building systems for the old building	2.9%	$8,000	$16,000	2.0	50%	5
3	Loop Pump VFDs (old bldg.)	Install VFDs on the loop pumps for the old building	0.9%	$2,600	$21,000	8.3	12%	15
	Total		**8.9%**	**$18,800**	**$53,000**	**2.8**	**35%**	**-**

Table 134. Post Retrofit Site EUI by End Use & Percent Reductions from Baseline for Less-than-Five-Year Payback Package – Case Study 9

Project	Heating – Gas	Cooling – Gas	DHW – Gas	Baseload – Gas	Heating – Electric	Cooling – Electric	DHW – Electric	Baseload – Electric	Lighting – Electric	Total EUI
Baseline	40%	0%	0%	0%	6%	10%	1%	37%	7%	**100%**
End Use Difference	-8%	0%	0%	0%	-8%	-8%	-8%	-11%	-8%	**91%**

Package Comparisons to ZNC Target

The following chart shows the site EUI and split between fuels today and for the EEM packages in comparison to the three Targets.

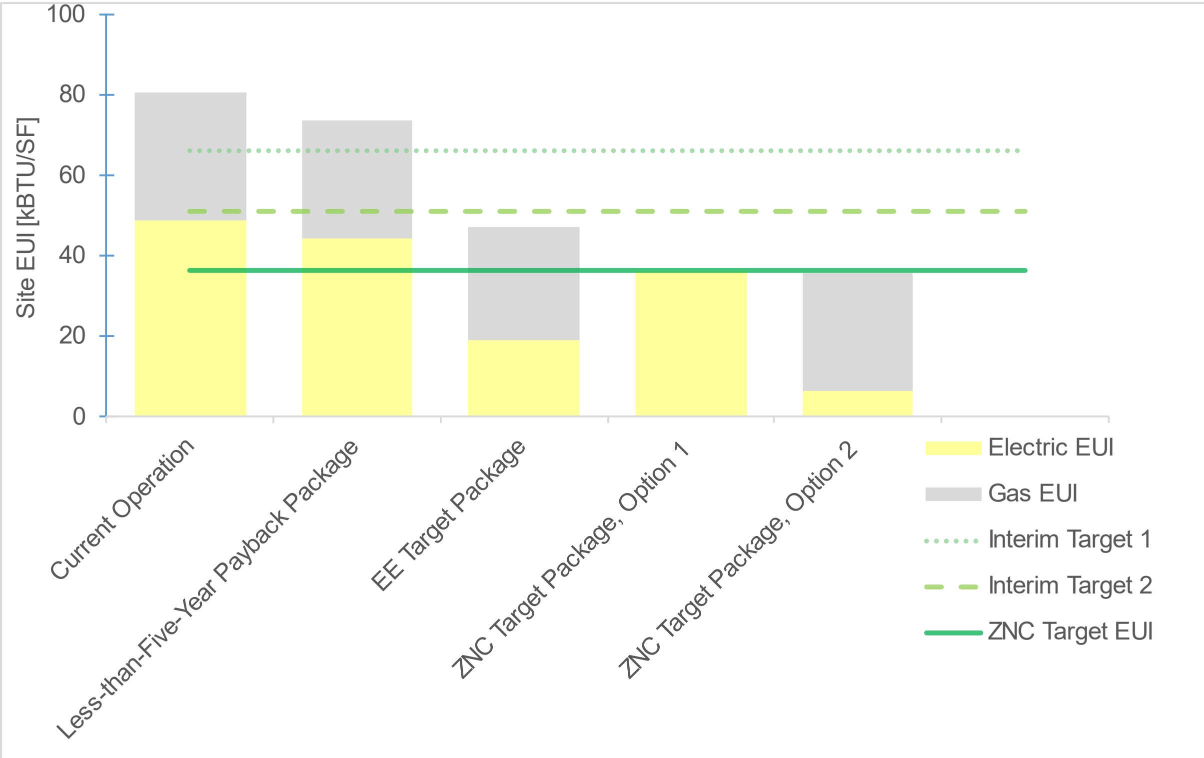

Figure 53. Target-to-Package Comparisons – Case Study 9

As referenced above, both ZNC Target Packages do reach ZNC. However, while one ZNC Target Package reaches the target via electrification, the other package reaches the target through extensive use of solar PV.

The EE Target Package is similar in approach to the ZNC Target Package, Option 2 and looks similar in Figure 53 as a result. However, less solar PV is required to meet the EE Target. This approach also gets the building below the 2nd interim target.

Building-Specific Technology Assessment

This building has multiple uses, varied operating hours, and different mechanical systems across the old and new areas of the building. As a result, addressing building systems needs to consider unique solutions per building wing.

The only item to electrify is the heating hot water loop in the new building. An ERV can also be installed on the old building, and retro-commissioning can be applied to both wings of the building. This represents a reasonable first pass at predominantly mechanical system measures to reach ZNC.

Alternatively, this building is relatively flat compared to its total square footage with a high roof to total square footage ratio, and it also has a large parking lot. Given both of these features, the site is a natural candidate for solar PV.

Current electric demand can be met by solar PV. Additional solar PV is physically possible on additional available roof space and extra parking lot space If approximately 40% of the parking lot is covered in PV, the site can reach satisfy all onsite electricity needs without electrifying the hot water loop.

Since this building was unique among the case study buildings in having two reasonably obvious options for reaching the ZNC Target, both options were presented.

Similar methodology was used to create the EE Target Package as the ZNC Target Package, Option 2. However, less solar PV would be required to meet the EE Target. This also implies that midpoints between the ZNC and EE Targets could be satisfied using different amounts of solar PV.

Following electrification and solar PV consideration, other measures affecting building demand were chosen such as distribution loop pump VFDs. These measures do not have a large overall impact on savings and were generally non-interactive in nature meaning savings from these measures do not appreciably increase or decrease savings from other measures.

The Less-than-Five-Year Payback Package is constructed using applicable measures from either ZNC Target Package.

Package Comparisons

Reaching ZNC targets incur a large overall cost to the property; most of these costs are borne from either electrification measures such as heat pump conversion or solar PV. However, the ZNC target for this building is reachable with technologies available today.

There are some ways to reduce compliance retrofit costs:

- Some of the total capital costs may be defrayed by accounting for avoided replacement costs of existing mechanical equipment. For example, most mechanical equipment will likely be replaced before the 2035 target. This money can be effectively set aside to help cover parts of the costs.
- Financing methods such as the Montgomery County Green Bank are viable.
- Utility incentives through the EmPOWER Maryland program may help offset upfront costs. While not a significant amount relative to the overall project investment, these funds are available today. These funds are available on three-year cycles and the program offerings can change during the program cycle; based on this, incentive estimates are not included in this report.

The EE Target Package incurs less overall cost than the ZNC Target Package and higher cost savings.

The Less-than-Five-Year Payback Package largely utilizes retrofits to existing equipment. Applying a higher estimated savings for retro-commissioning may be possible.

Measures Not Recommended

Measures reviewed for the building but not included in the EEM package are described below.

- Building controls: while adding controls to the old building HVAC system may result in savings, this was not deemed as necessary to meet ZNC in either of the approaches taken.
- DHW: domestic hot water is a minimal load and was not examined.
- Envelope: Window and roof replacements were considered but ultimately unneeded to meet the ZNC target and are not cost-effective enough to include in the Less-than-Five-Year Payback Package.

General Methodology Applied to All Case Studies

The following text describes components of this technical analysis that were applied to all case studies about EEM Package Development, Building Desktop Audits, and Utility Rates. After those sections are discussions of the analysis methodology applied specifically to this case study.

EEM Package Development

Three packages of EEMs were developed.

Zero Net Carbon-Compatible (ZNC) Target Package

This package compiles measures necessary to meet the Zero Net Carbon-Compatible target for the respective building. These measures typically include electrification of natural gas uses. The aim of this package was to create a series of measures that result in the ability of the case study building to meet the ZNC target. Project financials were not a primary driver, but financially desirable measures were included wherever possible.

Descriptions of each package are included in the individual case studies below.

The methodology for developing these packages was generally as follows:

- Potential electrification measures were implemented first when determined they were necessary to meet the ZNC target. This was done for two reasons:
  - Electrified end uses were typically large (i.e., all of a building's heating loads), and
  - Other measures' applicability may change based on these electrified systems. Note that for packages where mechanical systems were changed, some measures that are appropriate based on *existing mechanical equipment* may not be included in the ZNC package. However, they may appear in the However, they may appear in the EE Target Package or Less-than-Five-Year Payback Package.
- Next, measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Energy Efficiency (EE) Target Package

This package compiles measures necessary to meet the Energy Efficiency target for the respective building. Initial analysis returned multiple ways to think about developing an approach, each with pros and cons. These can be found in Table 135 below.

Table 135: General approaches to developing an EE Target Package.

Package Type	Pros	Cons	Other Items
Fewest Measures	• Simplest to implement • Easiest to understand	• Higher cost and lower ROI	• Electrification of some end uses guaranteed
Best ROI that Meets the EE Target	• Most attractive financial package • Best speaks to financial concerns	• Still will electrify some loads • Better ROI may not be the easiest to implement measures	• This will likely introduce partial electrification of end uses to the study
Minimize Electrification	• Best speaks to the theory behind the EE package	• Would necessitate replacement of gas-fired equipment with new gas-fired equipment	• May not really be viable with case study buildings (but could be viable with other buildings)

This study opted to use the Best ROI that Meets the EE Target approach. The following guidelines apply to this approach:

- Electrification of end uses needed to be considered in practice. Most case study buildings were far enough away from the EE Target that reaching the EE Target without electrification was infeasible without significant occupant energy pattern changes[62].
- Electrification of DHW loads was considered first. Most mechanical systems (which include space heating systems) have low-cost opportunities for optimization while most DHW systems have limited optimization opportunities. This means the combined mechanical system optimization measures plus DHW electrification had a more attractive ROI than space heating electrification measures.
- Mechanical system optimization and retro-commissioning measures were then implemented.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Electrification of space heating loads was considered only if electrification of DHW loads was not enough in conjunction with other measures to meet the EE Target *and* minimal system optimization was possible.
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.

Less-than-Five-Year Payback Package

This package compiles a set of measures that results in a five year or less total simple payback. This package represents a reasonable approximation of possible outcomes from an energy audit. These measure packages represent the types of low cost and lower-savings measures often recommended during standard energy audits. These measures are often investigated by buildings first. Note that an energy audit may include other financial tools such as utility incentives, tax deductions/credits, or other assistance, which were not included in this technical analysis.

Where applicable, measures from the Less-than-Five-Year Payback Package were also applied to the ZNC Package. The methodology described under the ZNC Target Package applied to the Less-than-Five-Year Payback Package as well. The following guidelines apply to the Less-than-Five-Year Payback Package:

- Measures with large interactive effects were reviewed. These measures were typically either mechanical or controls-based in nature.
- Retro-commissioning was applied; see below for details.
- Next, smaller end use reduction measures with limited interactive effects were implemented. These measures typically have a small impact (i.e., less than 5% of overall building usage).
- Lastly, where applicable and necessary, photovoltaic solar (PV) was applied.
- Major building systems were *not* modified in this package. Most system conversions (for example, converting from chilled water to water-source heat pumps) have longer paybacks and would not realistically be included. However, this also means that measures that impact *existing mechanical equipment* would appear here (for example, chilled water pump VFDs when the ZNC Target Package converted a building from chilled water to water-source heat pumps).
- New fossil fuel measures were not included.
- Overall energy savings were not a primary goal of this target; the energy savings resulting from this package was simply the end result of measures that would result in a less than five year project payback for all measures considered.

Typically, this package may be useful in reviewing progress toward interim targets.

Note that for some newer buildings that have less opportunity for low-cost incremental savings, the Less-than-Five-Year Payback Package may be either small or non-existent.

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[62] Energy conservation by occupants can drive significant energy savings ([EPA, slide 33]). Because of the difficulty in predicting savings (and the persistence of savings) for these sorts of behavioral measures in typical buildings, those savings are not included in this study.

Building Desktop Audits

Case studies were developed through interviews with building managers and site staff to collect – for major equipment only – equipment type, equipment age, operating parameters, types of fuel used for various end uses, information on recent capital upgrades, and any comments on plans for future upgrades and decision-making processes in relation to energy management. Architectural and mechanical drawings and supporting documentation were reviewed when available.

Desktop audits were performed in order to develop the case studies contained in this report. Desktop audits use information provided from building owners and operators to develop recommendations, but do not contain any onsite observations. This methodology is effective for informing policy-level decisions as it can effectively capture broad-stroke approaches; however, this methodology does not tend to capture measures are more limited in impact (e.g., mechanical systems that only serve part of the building). Applicability of desktop audit measures to a specific building typically requires some amount of onsite investigation in order to determine applicability of measures for any specific building in a given typology. This technical analysis is limited to desktop audits and measure recommendations are limited to what could be recommended based on the data collected by the auditor.

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Utility Rates

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Case Study 10: Retail

No retail candidate elected to participate in the case studies.

The analysis team searched for a retail case study that met specific criteria (e.g., EUI was above the ZNC target, roughly the 30th percentile, for that buildings group, larger single retailer already benchmarking in Portfolio Manager and reporting to Montgomery County, would be covered under the amended building definition), but were unable to identify an appropriate case study candidate that was able to participate. If a candidate is identified, this analysis can be amended with the additional case study.