Steven Winter Associates, Inc.

Prepared For:
Montgomery County, MD
Department of Environmental Protection

Prepared By:
Steven Winter Associates

Date:
February 2022

Building Energy Performance Standards Development – Technical Analysis

Montgomery County, MD

EXECUTIVE SUMMARY

BACKGROUND AND SUMMARY OF PROPOSED BEPS LEGISLATION

Montgomery County, MD (County) released its final Climate Action Plan (CAP) in June 2021 with a goal to cut community-wide greenhouse gas emissions (GHG) by 80% by 2027 and 100% by 2035. According to the CAP, "the County will need to deploy a combination of energy performance standards, code requirements, and incentives to support 100% building electrification by 2035."[1]

The County has introduced legislation[2] that would set site energy use intensity (site EUI) building energy performance standards (BEPS) for large commercial and multifamily buildings. The site EUI metric was recommended by Montgomery County stakeholders[3] and is a building energy performance metric that rewards energy efficiency and the electrification of fossil fuel systems. The legislation would segment covered buildings into groups according to their building type and size, phasing in compliance with the performance standards. Each group would be subject to a final performance standard between 2035 and 2037, depending on the group. Each building within a group would be required to meet its final performance standard as well as interim standards in earlier years in 4-year intervals.

GOALS OF THIS REPORT

This report is meant to provide policy makers with technical information relevant to the setting of building energy performance standards. The following goals were identified by the County to consider during the study:

- Create a framework to generate potential energy performance standards for covered buildings.
- Understand how the timing and stringency of potential energy performance standards impact cumulative GHG emissions over the next two decades.
- Evaluate what retrofits are technically feasible, what the total cost might be (independent of who pays), and the cost and carbon benefits of achieving the energy performance standards.
- Assess how a BEPS intervention affects the performance of the covered buildings towards a zero-emissions buildings goal by 2035.

Steven Winter Associates, in close coordination with the Montgomery County Department of Environmental Protection (the "study team") completed this study which provides the following information:

- A review of the building stock and energy benchmarking information of Montgomery County and development of an approximate list of buildings projected to be subject to a BEPS policy. This building stock was separated into building types to set technically feasible site EUI targets.
- A recommended method for setting building performance standards, what the targets can be, and the estimated impacts of meeting those targets.
- Case studies detailing how different energy performance standards can be achieved for a representative sample of buildings.
- An estimate of the total capital investment to reach the standards, which would inform both the cost to building owners and the level of economic impact of the recommended standards.

---

[1] Montgomery County. "Montgomery County Climate Action Plan Public Draft". https://www.montgomerycountymd.gov/green/Resources/Files/climate/draft-climate-action-plan-printable.pdf Page xvii.
[2] Bill 16-21 - Environmental Sustainability - Building Energy Use Benchmarking and Performance Standards - Amendments: https://apps.montgomerycountymd.gov/CCLLIMS/BillDetailsPage?RecordId=2707
[3] Montgomery County. "BEPS Stakeholder Recommendation Report". https://www.montgomerycountymd.gov/DEP/Resources/Files/ReportsandPublications/Energy/MC-BEPS-Stakeholder-Report.pdf page 10.

RESULTS

Target Setting Method

Site EUI building performance standards were developed based on technically achievable performance using typical energy use profiles in various building types representative of Montgomery County's building stock and assuming retrofits using commercially available technology. This approach is described in depth in the section *Site Energy Use Intensity Performance Targets*.

The countywide impact analysis evaluated three potential targets. These targets were developed by applying the following methodology to each building type. The result is that all buildings in the same occupancy type grouping have the same EUI targets (e.g., all office buildings have the same site EUI targets, all multifamily buildings have the same site EUI targets, all hospitals have the same site EUI targets).

- **Energy Efficiency (EE) Target**: Sets a target such that all energy end uses were deeply optimized and tuned without impacting occupant use patterns. This target-setting method assumed that typical buildings could maintain the use of fossil-fuel burning systems for typical end uses such as space and water heating but would minimize inefficiencies of those systems.
- **Zero Net Carbon-Compatible (ZNC) Target**: Sets the target to a level simulating the electrification of fossil-fuel end uses using market-ready technology in an energy efficient building. Electrification is one of the deepest forms of energy efficiency since electric equipment operates at a much higher efficiency than fuel-fired equipment This target was intended to be most compatible with Zero Net Carbon goals because it implicitly required the elimination of most on-site fuel burning.
- **Mid-point between EE and ZNC Targets**: This target type exemplifies how the site EUI targets can be chosen anywhere along this spectrum between the EE and ZNC targets. A mid-point target was calculated to identify the impact of splitting the difference between the two targets. This target could be achieved using a combination of energy efficiency measures and partial electrification, or electrification of some, but not all, fossil-fuel-driven systems.

In framing this report, a site EUI target higher than the EE target was deemed unsuitable as it would not drive enough countywide savings. At the other end of the spectrum, a site EUI target lower than the ZNC target may not be technically achievable for most buildings.

Potential site EUI target options and the 2019 median site EUI for each occupancy type are shown in Figure 1.

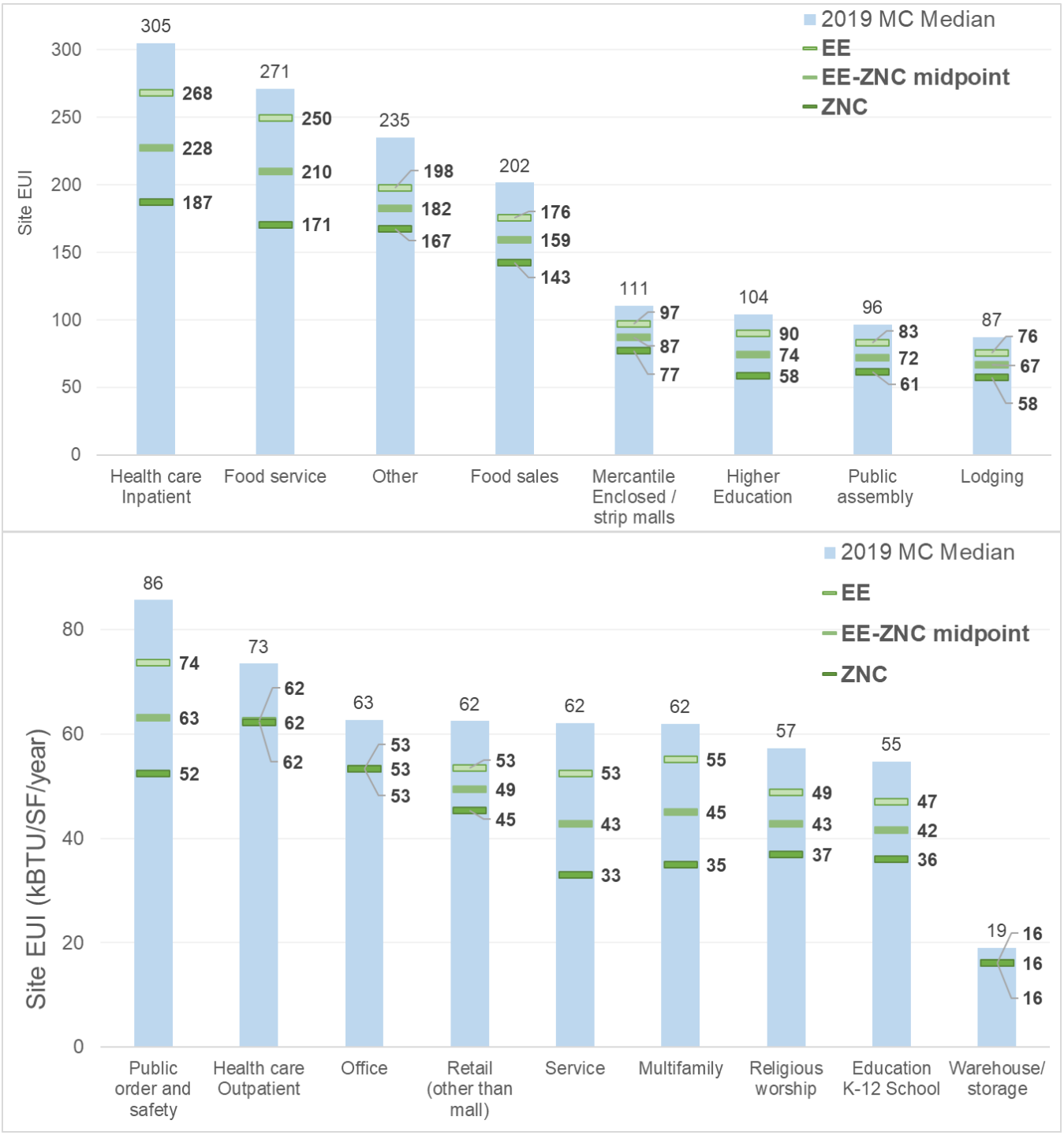

Figure 1. Options for Site EUI targets in Montgomery County based on this study. Building types that are already substantially all-electric, such as Health Care Outpatient, Office, and Warehouse/Storage have nearly identical EE and ZNC targets. Multifamily data median EUI comes from Washington, DC 2019 benchmarking information as multifamily buildings are not currently subject to Montgomery County's benchmarking law.

Energy Use Impacts

Significant energy savings would result from covered buildings reaching any of the identified site EUI targets, both in electricity use and on-site fuel burning. Projected energy savings compared to estimated 2019 energy use is shown in Table 1.

The eliminated energy use is primarily driven by reduction in on-site fuel burning through energy efficiency and electrification. Electric energy efficiency is also incorporated, though reductions in overall electricity use are partially offset by increases due to electrification of fossil fuel systems. Note that electricity savings are lower for the ZNC target than for the EE target. This is because achieving the ZNC target involves more electrification, which increases electricity use, albeit through more efficient electric systems and equipment. The total energy reduction in gas use outweighs the increase in electricity use from electrification. Note that this study did not project new construction trends, so energy use changes only relate to existing buildings.

Table 1. Energy Use Impacts for final Site EUI target options compared to baseline 2019 countywide building energy use.

Countywide Energy Impact of BEPS	Energy Efficiency (EE) Target	EE-ZNC midpoint	Zero-Net-Carbon (ZNC) Compatible Target
Reduction in Site EUI (annual)	23%	28%	35%
Reduction in On-site Fossil Fuel Emissions	46%	66%	86%

Setting the site EUI standards to the ZNC target shows estimated reductions of on-site fossil fuel emissions by 86% by the year of the final standards for the latest group ("final year"). This is because electrification is one of the deepest forms of energy efficiency since electric equipment operates at a much higher efficiency than fuel-fired equipment. Therefore, most buildings would need to electrify their on-site fossil fuel burning systems to reduce site EUI to the level necessary to meet the ZNC standards. The elimination of on-site fuel burning will have a direct contribution to local air quality improvements. The eliminated energy use is primarily driven by reduction in on-site fuel burning through energy efficiency and electrification. The ZNC target provides overall site EUI reductions (for all fuels) of 35%.

In contrast, the EE target is estimated to reduce on-site emissions by 46%, allowing more on-site emissions from fuel-fired equipment that remains in buildings by the final year of compliance compared to the ZNC target. The EE target provides overall site EUI reductions of 23%.

Greenhouse Gas Emissions Impacts

Overall, greenhouse gas emissions reductions result from improved efficiency (i.e., using less energy to perform the same task), electrification of fossil-fuel burning systems, and the decarbonization of the electricity grid. The annual and cumulative greenhouse gas (GHG) impact of each building performance standard option was calculated using current and projected electricity supply and compliance deadlines of different building types.

If the electricity supply is maintained at today's level of emissions, building efficiency improvements would still yield emissions savings from the proposed BEPS policy. Assuming no change to today's electricity grid, the EE target would provide annual GHG reductions of 19% and the ZNC target would provide annual GHG reductions of 26%, compared to the baseline year.

Maryland's current Renewable Portfolio Standard is currently set at a maximum of 50% renewable electricity by 2030. The County's Climate Action Plan (CAP) endeavors for a 100% carbon free electricity supply by 2035 (i.e., considered "zero-emissions" or "carbon-free" by the by the time BEPS is fully implemented[4]).

If the emissions intensity (EEI, in kilograms of carbon dioxide equivalent per kilowatt-hour, kgCO2e/kWh) for electricity supplied to the County was zero the annual emissions from building energy use would drop from the

[4] Supra 1, page 88.

2019 baseline by 87% for covered buildings reaching the EE target or 97% for covered buildings reaching the ZNC target.

While BEPS may appear to have a relatively lesser impact on community-wide emissions compared to transitioning the electric grid to carbon-free sources, the proposed BEPS policy's emphasis on energy efficiency allows building owners to "right-size" their energy use such that the amount of clean energy needed to meet building demand via the grid is less than a business-as-usual scenario. The building energy performance standard would do two things to help achieve the county's climate goals: 1) the reduction in electricity use through efficiency measures would ease the burden on the supply side to provide electricity from carbon-free sources, and 2) the reduction of on-site emissions through fossil fuel efficiency and eventual electrification may be the only way to achieve carbon neutrality.

Policy options to further credit renewable energy in pursuit of BEPS targets were outside of the scope of this study, thus not fully evaluated. Considering this type of credit could serve as a flexible tool for building owners to meet targets in the spirit of the County's climate goals.

The effect of the BEPS policy overlaid with potential electricity supply changes is shown in Table 2.

Table 2: The annual emissions reduction impact of the site EUI targets in this study. Reductions are of annual emissions at the final target year (e.g., 2037 or beyond).

Annual Million Metric Tons CO_2e (% reduction from baseline)	**No BEPS**	**EE**	**EE-ZNC midpoint**	**ZNC**
Electricity supply does not change from today	1.53 (0%)	1.24 (19%)	1.19 (22%)	1.13 (26%)
"Carbon-free" electricity supply	0.36 (76%)	0.19 (87%)	0.12 (92%)	0.05 (97%)

Case Studies that Evaluated the Technical Feasibility of Performance Targets

The study team selected buildings from various building types to test if the ZNC target – the lowest site EUI target – is technically achievable, and to estimate the total capital cost and energy cost savings of meeting or exceeding the ZNC target. The nine case study examples were meant to be representative of Montgomery County's building stock that would have to undertake building energy upgrades to meet a potential BEPS target.

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

- **A ZNC Target Package**: what measures are needed to reach the building's ZNC Target. This is meant to test whether the ZNC target (and by extension the mid-point target) is technically feasible with today's technology.
- **An EE Target Package:** what measures are needed to reach the building's EE Target. Measures that maximized a building's return on investment were prioritized. In some case studies, partial electrification of end uses may meet this target but some further-optimized, fossil-fuel based systems may remain in the building.
- **A Less-than-Five-Year Payback Package:** what measures may be recommended in the near term without contradicting long-term deep energy efficiency work. These measure packages represent the types of low-cost and lower-savings measures often recommended during standard energy audits and may be useful in reviewing progress toward interim targets. These measures are often investigated by buildings first, regardless of existing equipment replacement cycles, because they can provide cost savings after less than five years of operation. Five years is also an estimate of the capital planning

cycle length for many buildings. The study team selected a "do no harm approach" that did not include installation of new fossil-fuel equipment. These measures were analyzed to compare this type of work and the ZNC target packages needed to achieve larger climate goals. 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.

Most buildings have substantial work to do in order to reach the ZNC target; however, this does not mean reaching the targets is impossible. In all case studies, the ZNC target was technically achievable with existing technology and systems through a ZNC Target Package combining energy efficiency, electrification, and on-site solar PV.

In general, the highest energy savings correspond with relatively high upfront cost, with that cost mainly driven by electrification measures in fossil fuel-heated buildings. 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.

Capital costs identified via the case studies represent total equipment and labor costs. These total costs evaluate the full cost of a new system, not incremental costs of a more efficient system compared to costs the building would already incur to replace equipment in-kind at the end of its useful life. System electrification or upgrade is assumed to take place at the end of useful life of existing equipment, which was due to occur before the final BEPS year in all case study buildings. Total costs also do not include any other factors that may improve the financial performance of the investment, such as utility incentives, tax credits or depreciation, or financing through entities such as the Montgomery County Green Bank. 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).

Costs for the ZNC Target Package ranged from $11 to $36 per square foot with an average $/SF across all case study buildings of approximately $25.08/SF to reach the ZNC target, where multiple electrification measures drive up the capital cost intensity. This implies some realistic level of expected capital outlay across building typologies. The ZNC Target Package resulted in savings of $0.30 to $1.50 per square foot with an ROI between 2% and 5%. Though the ZNC Target Package resulted in far greater levels of efficiency via electrification, annual dollar savings per square foot are more modest due to the relatively higher cost of electricity compared to natural gas today.

Costs for the EE Target Package ranged from $10 to $26 per square foot with an average $/SF for applicable buildings of approximately $17.10/SF. Similar to the ZNC Target Packages, electrification measures, where included, drive up the capital cost intensity. These EE Target Packages resulted in savings of $0.35 to $1.40 per square foot with an ROI between 3% and 10%. Note that some buildings' EE targets were the same as their respective ZNC targets.

Costs for the Less-than-Five Year Payback Package ranged from $0.20 to $3.60 per square foot and resulted in savings of $0.10 to $1 per square foot with simple payback between 2 and 4 years (per the package parameters). 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.

As a result of meeting the ZNC or EE targets, the case study buildings would significantly reduce GHG emissions. The emissions reductions achieved by implementing the ZNC Target packages are substantial Assuming today's electricity supply, the ZNC Target would reduce the case study buildings emissions by 36% on average. A ZNC target yields an average reduction of 99% with a completely emissions-free grid.

For comparison, the emissions reductions achieved by setting the standards using the EE Target method would lead to less decarbonization. Assuming today's electricity supply, the EE Target would reduce the case

study buildings emissions by 32% on average. With a completely emissions-free grid, emissions are reduced by 86%.

Table 3. The emissions reduction impact of the site EUI targets in this study among case study buildings.

% Emissions Reduction in Case Study Buildings (Emissions reductions range)	**EE**	**ZNC**
Electricity supply does not change from today	32% average (Range: 0-52%)	36% average (Range: 22%-62%)
"Carbon-free" electricity supply	86% average (Range: 64% - 100%)	99% average (Range: 95%-100%)

Estimated Total Costs and Benefits for Owners of Covered Buildings

The study team calculated the annual and cumulative energy use and associated costs and emissions for the years 2021-2039 without and with a BEPS policy. No capital cost was assumed under the baseline case, as the study considered the total capital cost of upgrades without including business as usual equipment replacements.

The eliminated energy use is primarily driven by reduction in on-site fuel burning through energy efficiency and electrification. Electric energy efficiency is also incorporated, though those reductions in overall electricity use are partially offset by increases due to electrification of fossil fuel systems.

The results of the countywide model without a BEPS policy intervention are shown in Table 4.

Table 4. The estimated covered buildings' energy and GHG emissions characteristics, both annual and cumulative over the study period.

Cumulative Countywide Baseline 2021-2039	**Annual Total (2021)**	**2021-2039 Cumulative Totals (without a BEPS policy)**
Electricity Use [Billion BTU]	12,212	244,200
Gas Use [Billion BTU]	6,574	131,500
GHG emissions of covered buildings [Million tonsCO_2e]	1.33	16.54
Energy Cost [Million$]	$602	$10,860
Capital Cost [Million$]	N/A	N/A

The three potential BEPS target approaches were evaluated for the impact on energy and emissions, energy costs, and capital costs. The countywide results are shown in Table 5. The ZNC target requires the deepest energy use reductions of the three targets, and results in the greatest emissions reductions, both on-site and from purchased electricity.

Table 5. Estimated countywide impact of three building energy performance targets, summing cost, energy savings, and GHG for each Target Method.

Countywide Impact of BEPS 2021 to 2039	**No BEPS**	**Energy Efficiency (EE)**	**EE-ZNC midpoint**	**Zero-Net-Carbon (ZNC) Compatible**	
Electricity Use (2021-2039 cumulative total)	244,200	231,900	233,600	235,600	Billion BTU
Electricity Site Energy Savings *(2021-2039 cumulative total)*	N/A	12,300	10,600	8,600	Billion BTU
% Electricity Energy Savings (2021-2039 cumulative total)	N/A	5%	4%	4%	% lower than baseline cumulative
% Electricity Energy Savings (annual, final year)	N/A	10%	8%	8%	% lower than baseline
Gas Use (2021-2039 cumulative total)	131,500	103,000	91,800	78,500	Billion BTU
Gas Site Energy Savings (2021-2039 cumulative total)	N/A	28,500	39,700	53,000	Billion BTU
% Gas Energy Savings (2021-2039 cumulative total)	N/A	22%	30%	40%	% lower than baseline cumulative
% Gas Energy Savings (annual in final year)	N/A	46%	66%	86%	% lower than baseline
GHG emissions of covered buildings (2021-2039 cumulative total, with grid cleaning)	16.54	14.85	14.25	13.55	Million Tons CO_2e
GHG Savings of Policy	0	1.70	2.30	2.99	Million Tons CO_2e
GHG % Savings of Policy	N/A	10%	14%	18%	% lower than baseline cumulative
GHG Savings by grid cleaning (external to a BEPS program)	14	14	14	14	Million Tons CO_2e
Annual GHG Reduction Including Grid Cleaning (% lower than 2019 baseline)	76%	87%	92%	97%	Percent lower than annual baseline
Energy Costs (2021-2039 cumulative total)	$10.86	$10.05	$9.97	$9.88	Billion
Energy Cost Savings (2021-2039 cumulative total)	$0	$0.82	$0.89	$0.98	Billion
% Energy Cost Savings (2021-2039 cumulative total)	0%	8%	8%	9%	% lower than baseline cumulative
Total Capital Cost* (2021-2039 cumulative total)	$0.00	$1.66	$2.41	$3.22	Billion
Carbon Abatement Cost (2021 - 2039 average)		$980	$1,050	$1,080	dollars / ton CO_2e
Total Capital Cost / SF	0	$7.20	$10.40	$13.90	$ / SF

**Total capital cost does not include avoided cost from the replacement of existing equipment. Cost does not include financial assistance available for energy efficiency retrofits.*

TECHNICAL ANALYSIS CONCLUSIONS

These findings stood out to the study team as key takeaways:

1) While the County has not taken a prescriptive approach to this policy, as the BEPS target gets more stringent, the variety of options to comply with the standard are more limited such that electrification becomes necessary to meet the final target, as illustrated by the case studies.
2) Achieving the ZNC target was technically achievable across the building types analyzed as case studies. In some cases, the ZNC target was met via measures that had significant costs and with a low ROI, especially where electrification would be required to meet the target.
3) Most, but not all, buildings would need to electrify nearly all fossil fuel use to meet the ZNC target. In certain cases, electrification of all end uses was not always the most cost-effective path to meet the whole-building site EUI targets. Other measures, such as on-site solar PV or other efficiency measures, were sometimes more cost effective than the complete elimination of on-site fossil fuels.
4) There is little to no difference between the EE target and the ZNC target for building occupancy types that currently have limited use of on-site fossil fuels, such as commercial offices. The difference between targets is large for building types that have greater use of fossil-fuel systems, such as multifamily and lodging (e.g., hotels, motels). Choosing where to set the targets should consider the impact to these fossil-fuel-dependent building types.
5) A BEPS final year target set to the ZNC target, if implemented along with the realization of a 100% carbon-free electricity supply, would result in the deepest emissions reductions. The EE and EE-ZNC midpoint targets would result in enough on-site combustion to remain in buildings that the County's CAP goal of zero GHG emissions by 2035 is unattainable.
6) The ZNC target would force nearly complete electrification of buildings subject to the BEPS policy. It would be technically attainable, although for some buildings the costs and level of effort, including work inside tenant spaces, would be significant.
7) Selecting an EE target would delay achieving the County's deepest emissions reduction goals because it would allow new fossil-fuel equipment to be installed, locking buildings into a long period of fossil fuel use until the next replacement cycle.
8) Countywide emissions would be reduced if buildings were to meet either the EE or ZNC site EUI targets, regardless of whether the electricity supply becomes emission-free or not. Even with today's relatively fossil-fuel powered electricity supply, efficiency and electrification of buildings would result in significant total emissions reductions compared to a business-as-usual scenario (see Table 19).

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.

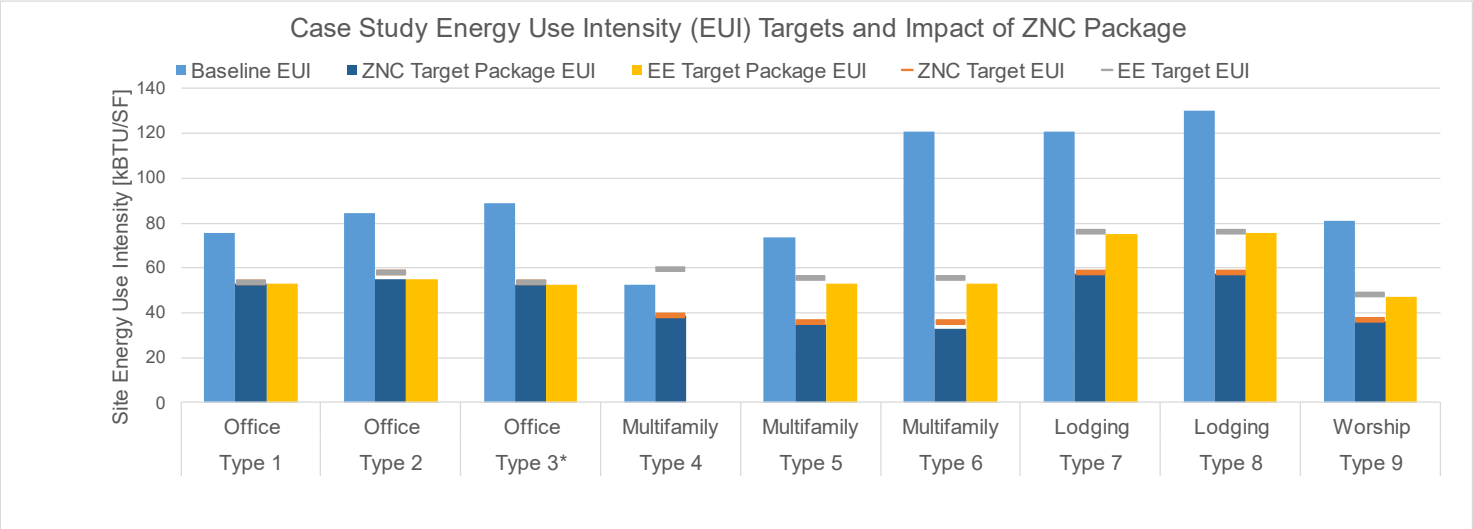

Figure 2. Comparisons of current energy usage of case study buildings to proposed targets and the end results of the ZNC Target Package and EE Target Package. The asterisk denotes an all-electric building.

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.

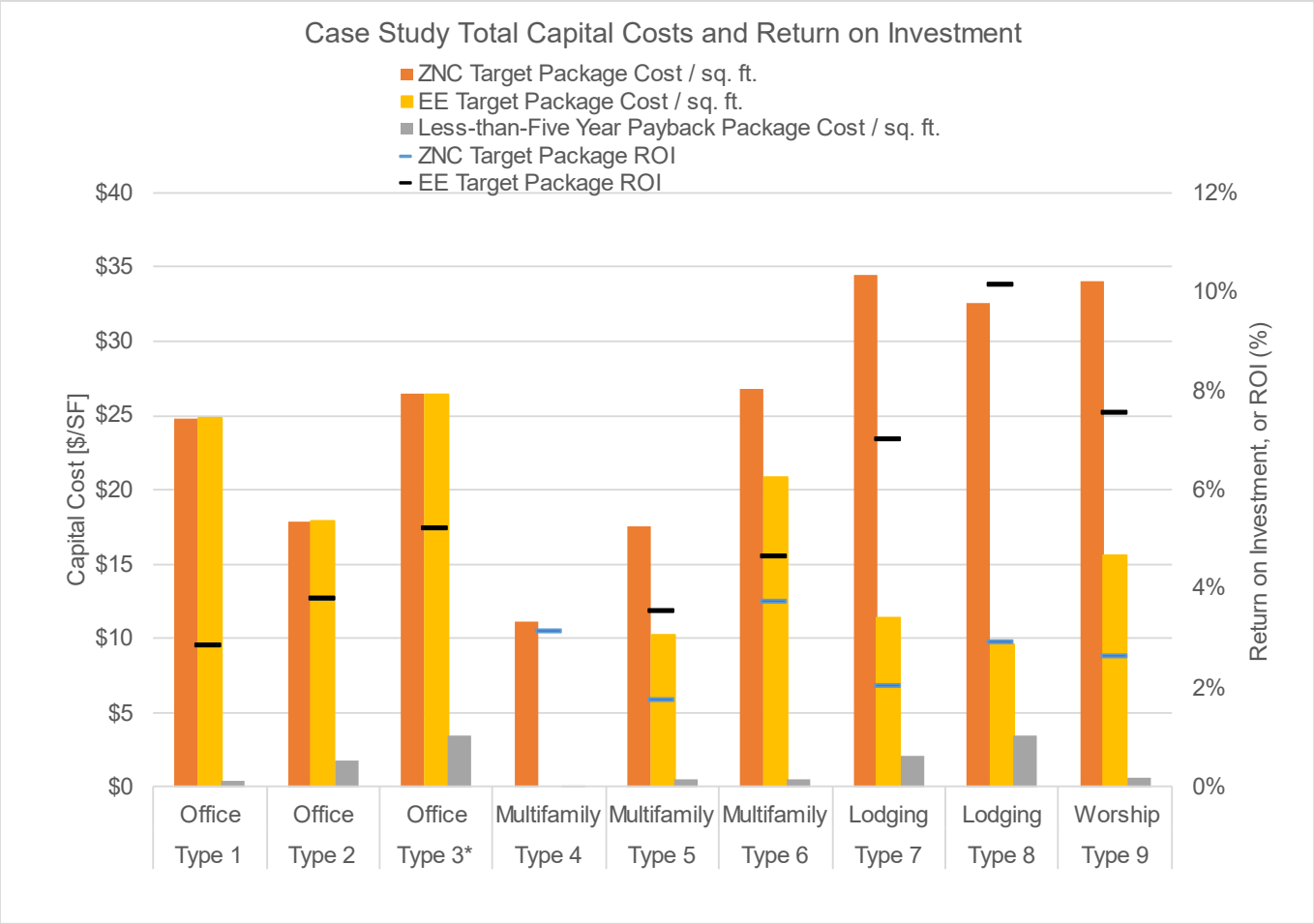

Figure 3. Costs to implement the ZNC Target Package identified for each case study building compared to the EE Target Package and Less-than-Five-Year Payback Package. ROI for the ZNC Target Package is included as a blue line and ROI for the EE Target Package is included as a black line. The ROI for the 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.

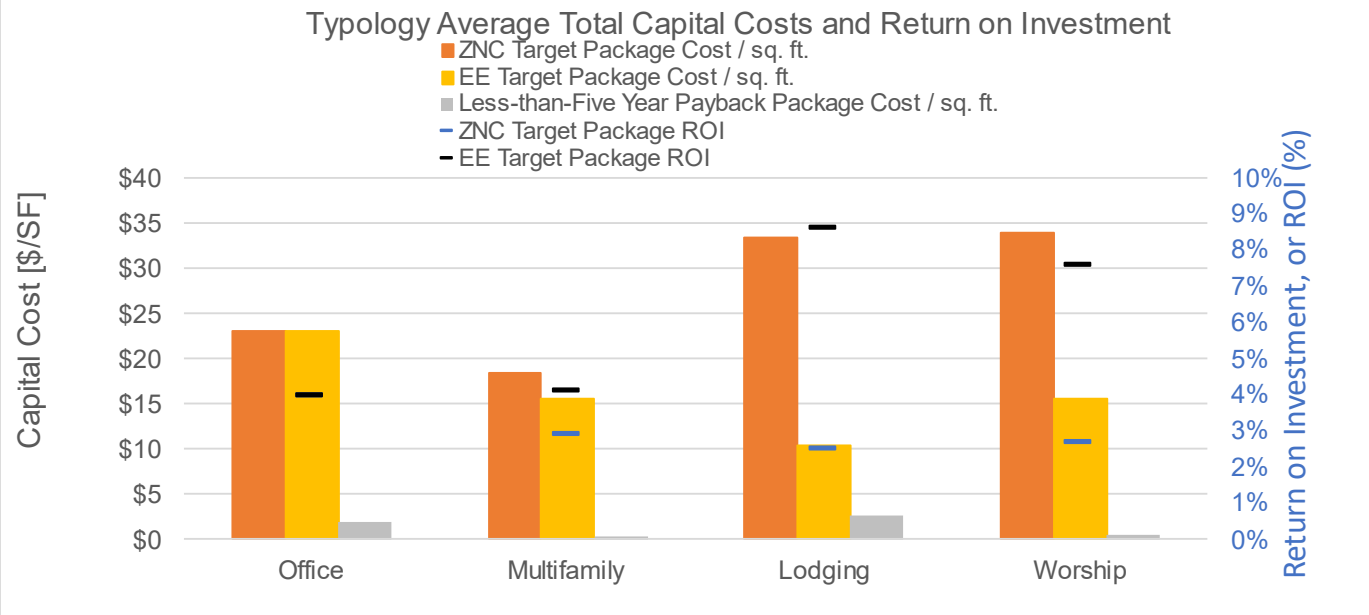

Figure 4. Costs to implement the ZNC Target Package identified for each building typology compared to the EE Target Package and Less-than-Five-Year Payback Package. ROI for the ZNC Target Package is also included as a blue line and ROI for the EE Target Package is included as a black line. The ROI for 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.

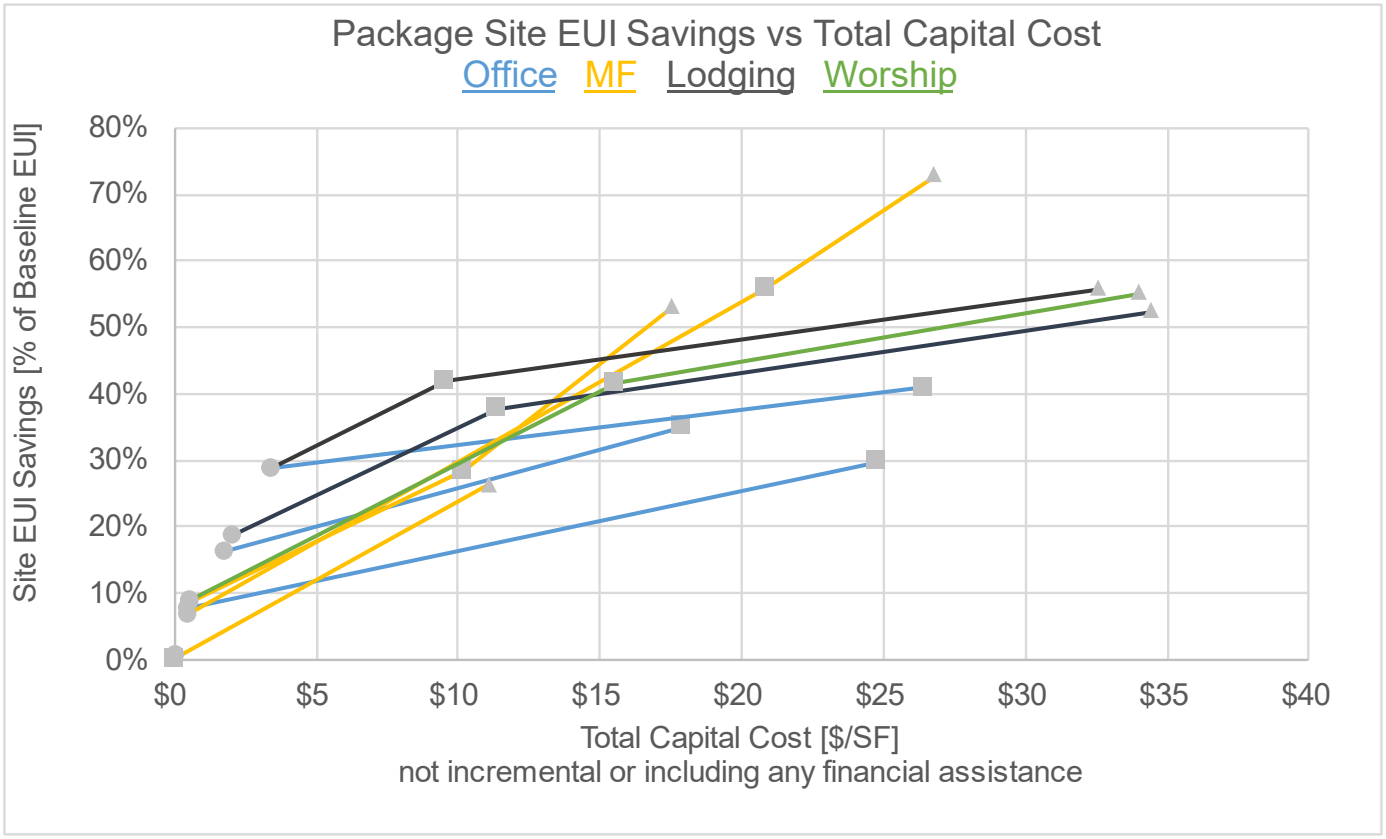

Figure 5. Comparison of capital cost to energy reduction trends, showing that generally more money is needed for deeper savings. This is partly driven by the fossil fuel dominated buildings having high starting EUIs. With electrification being one of the more expensive measures, those buildings spend 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

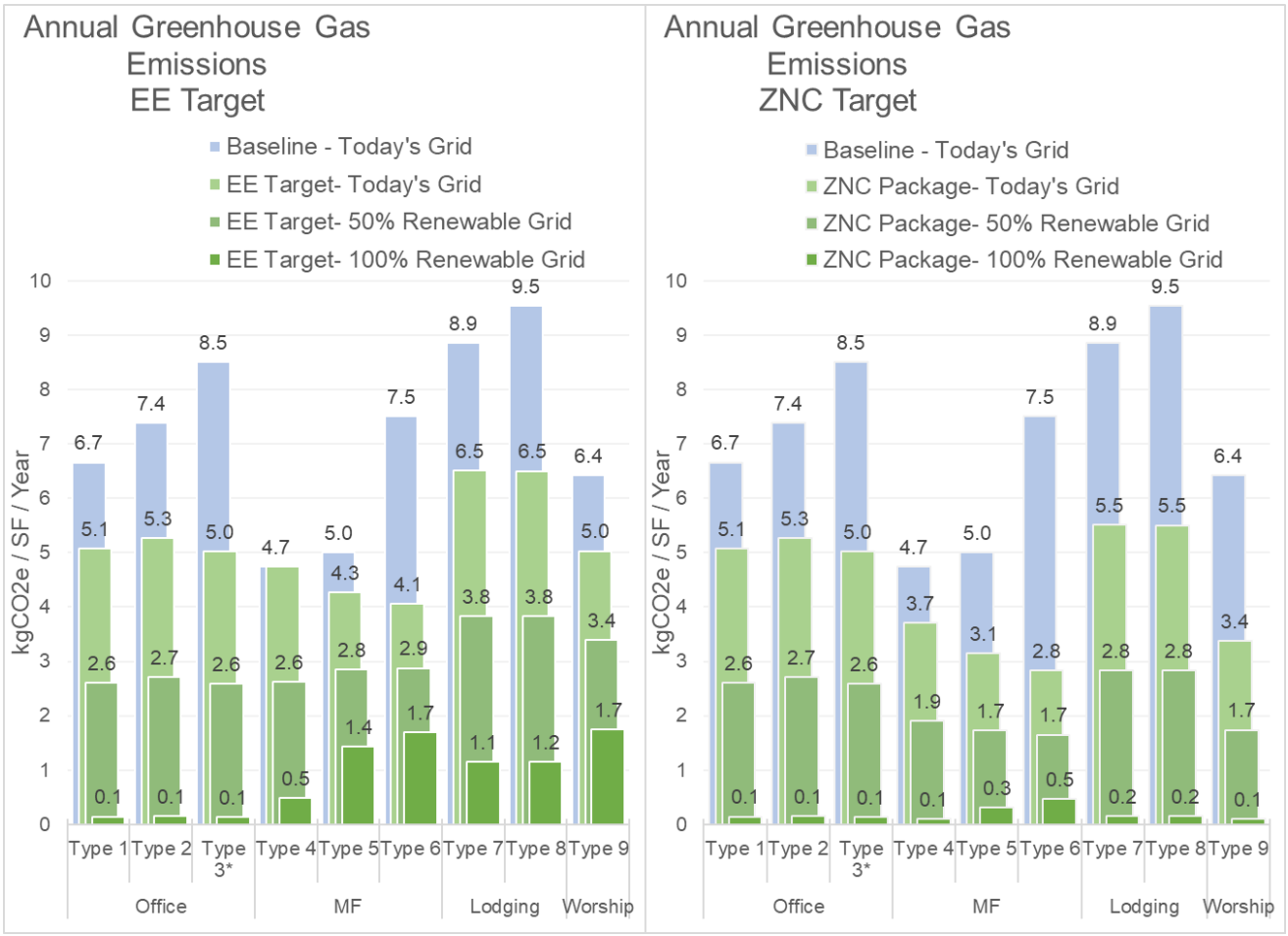

Figure 6. Greenhouse gas emissions impact of implementing the ZNC Target packages (right) under different potential electricity scenarios. At left, an estimate of the emissions reductions if the EE Targets were used, allowing fewer high-cost measures such as electrification, to be used to meet the targets.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

[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.