An Exelon Company

Andrea H. Harper
Assistant General Counsel

EP9628
701 Ninth Street, NW
Washington, DC 20068

202.428.1100
ahharper@pepcoholdings.com

January 31, 2021

Ms. Brinda Westbrook-Sedgwick
Commission Secretary
Public Service Commission
of the District of Columbia
1325 G Street, NW
Suite 800
Washington, DC 20005

Re: Formal Case No. 1167

Dear Ms. Westbrook-Sedgwick:

Enclosed herein is "Pepco's Climate Solutions 5-Year Action Plan: Benefits and Costs," assessing the costs and benefits of the 5-Year Action Plan programs—the final filing in accordance with Order No. 20754 regarding Pepco's plan to support the District's climate and clean energy goals. Order No. 20754 directed Potomac Electric Power Company ("Pepco") to submit to the Public Service Commission of the District of Columbia ("Commission"), *inter alia*, its climate and clean energy strategy and plans and its timeline for filing its electrification study. Order No. 21024 approved Pepco's revised proposed procedural schedule for filing the required plans and studies, including the Full Analytical Filing. In accordance with Order Nos. 20754 and 20124, Pepco filed its Climate Solutions Plan on July 20, 2021, its Electrification Study on August 27, 2021, its 5-Year Action Plan on October 8, 2021, and its 30-Year Transition Strategy on November 30, 2021. Together, these filings demonstrate a robust and cost-effective path to advancing the District's leading policies to achieve climate goals through electrification and clean energy in the near and long term. Pepco is committed to advancing a clean energy future as part of it broader effort to provide a cleaner and brighter future for it customers and communities.

Climate change threatens the communities Pepco serves and the energy grid Pepco operates. The impacts of climate change on District residents and businesses are well documented. These impacts magnify the urgent need for deliberate decarbonization focused on providing reliability, resilience, and an equitable and inclusive transition with an emphasis on under-resourced communities. The programs in the Company's 5-Year Action Plan are a direct response to the need for decarbonization and are in alignment with the District's specific climate and clean energy goals. The Company presented a range of 62 programs in its 5-Year Action Plan, and in this submission, Pepco provides an independent assessment of those programs for cost-effectiveness and evaluation of benefits. Using a methodology and test performed by the Brattle Group, the results are significantly positive. Herein, Pepco attaches a detailed benefit-cost analysis ("BCA") that demonstrates that the near-term climate solutions put forward in Pepco's 5-Year Action Plan have a positive net present value ("NPV") of $154 million over the 20-year study horizon. Pepco also recognizes that there may be opportunities to offset program costs, including through existing federal grants as well as funding made available from the recently enacted

infrastructure legislation. Pepco will work with the District government and other stakeholders to identify and leverage these funds to maximize benefits for customers.

In summary, the enclosed BCA report shows that Pepco's approach to decarbonization programs, one focused on equitable and inclusive access to electrification and innovation, is net beneficial and cost effective. For every $1 Pepco spends on the 5-Year Action Plan programs, the plan produces $1.68 in quantified benefits. These results clearly demonstrate the important role that Pepco will have in helping to facilitate the cost-effective achievement of the District's decarbonization goals and the wide-ranging benefits that will be realized with the Company's approach. The 5-Year Action Plan is Pepco's critical near-term first step to support the District's goal of net zero economy-wide carbon emissions and will establish a dynamic and adaptable platform for future decarbonization program development.

Climate change poses a major threat to the District.

Pepco is a committed partner to achieve the District's goals to abate greenhouse gas ("GHG") emissions and build resilience to help mitigate the impact of climate change, with affordability, equity and inclusion at the center. Pepco's Climate Solutions Plan is both a reflection of policy supporting decarbonization and a response to the need for resilient communities and enabling local clean energy resources. It is Pepco's objective to plan for customer solutions and grid enhancements that not only meet the District's goals but also (1) meet these anticipated challenges and (2) help to mitigate expected impacts. Pepco's 5-Year Action Plan, and its proposed programs, result in greater opportunities to reinforce resilience and prepare for the longer-term impacts of climate change.

The District of Columbia's climate adaptation plan—Climate Ready DC—identified significant risks linked to climate change, including increased flooding, extended heat waves, severe storms, and extreme wind.[1] These impacts will affect District residents and businesses directly as well as impact the physical infrastructure that serves the District's homes and businesses, with the most vulnerable being impacted the most. A recent United Nations Intergovernmental Panel on Climate Change report[2] states that GHG emissions from human activities are responsible for approximately 1.1°C of warming since 1850-1900 and finds that averaged over the next 20 years, global temperature is expected to reach or exceed 1.5°C of warming. The report adds that unless there are immediate, rapid, and large-scale reductions in GHG emissions, limiting warming to close to 1.5°C or even 2°C will be beyond reach.

The impacts of these levels of warming and extreme weather associated with climate change paints a dire picture of the future and points to the need for urgent action in mitigation and adaptation. Pepco's 5-Year Action Plan is presented against this backdrop and is an actionable pathway for near-term, accelerated decarbonization that is tailored to the District's needs.

[1] https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/CRDC-Report-FINAL-Web.pdf
[2] Sixth Assessment Report (ipcc.ch)

Pepco's 5-Year Action Plan will be a catalyst to achieving District policy goals equitably and inclusively.

Pepco's 5-Year Action Plan aligns with the District's GHG abatement goals and policies, including a strong emphasis on equity and inclusion, from program outcomes to consideration of local workforce development. Longstanding socioeconomic inequities make under-resourced communities, who often have the highest exposure to hazards and the fewest resources to respond, most vulnerable to the impacts of climate change. Through the efforts outlined in the 5-Year Action Plan, Pepco has a unique opportunity to develop a wide range of programs, from programs focused on developing electric vehicle charging stations to programs enabling efficient, electric heating and cooling, with equitable access and outcomes as a core component. This focus on equity and inclusion is imperative to ensure that all District residents have access to the benefits of the District's policies for decarbonization through clean energy and electrification.

Equity is a key principle for Pepco's 5-Year Action Plan, and the Company has incorporated equity considerations directly into programs described in that document. There are at least ten programs designed specifically to support low-to-moderate-income ("LMI") communities, increasing the accessibility of the programs to District residents that live in under-resourced areas as well as program design elements—such as increased rebates for decarbonization programs in under-resourced communities—to enable residents and businesses across the District to benefit from programs, including improved local air quality and resilience. Similarly, Pepco already works with local workforce development programs and is a partner on the DC Infrastructure Academy, which was recently cited by President Biden, and anticipates a growing need for this local workforce to support the electrification and efficiency programs in the 5-Year Action Plan. These programs also create contracting opportunities for local and diverse businesses to advance a true green economy, resulting in the creation of sustainable careers and local business creation, expansion, and retention.

Pepco has worked with local stakeholders to shape the 5-Year Action Plan and will continue to gather feedback on how best to meet diverse needs of District residents and businesses. The Company conducted public webinars and additional outreach to stakeholders—including the District of Columbia Commission on Climate Change and Resiliency, DOEE, the District Department of Transportation, the DC Sustainable Energy Utility, the Washington Metropolitan Area Transit Authority, environmental groups, and electric vehicle charging company providers, among others. Pepco will continue this outreach as it continues to hone the programs and specific offerings in anticipation of future applications.

Pepco's 5-Year Action Plan is cost effective and provides significant environmental benefits.

In response to Order No. 20754, Pepco engaged The Brattle Group to perform an assessment of the benefits and costs of Pepco's 5-Year Action Plan. The analysis and the results indicate the 5-Year Action Plan has a positive NPV of $154 million over the 20-year study horizon. More specifically, the analysis concludes that the Plan's $225 million in program costs will result in $379 million of energy system and societal emissions benefits. The major drivers of the 5-Year Action Plan's benefits are (1) reduced power supply costs due to an expanded energy efficiency

portfolio, (2) reduced emissions from residential and commercial buildings due to heating electrification, and (3) reduced fuel costs and emissions from increased electric vehicle adoption, enabled by the Electrifying Transportation portfolio.

The 5-Year Action Plan outlines actions Pepco can take in the next five years to help facilitate the achievement of the District's economy-wide decarbonization policy goals. This policy context requires a cost-effectiveness analysis framework that specifically compares the cost of Pepco's proposed programs to the benefits associated with advancing the District's climate policy objectives. To comprehensively analyze programs within this policy context, The Brattle Group developed a cost-effectiveness framework—the Climate Policy Enablement Test or CPE Test. The CPE Test draws from established best practices for utility program benefit-cost analyses to create a BCA test focused on analyzing utility climate change programs.

The cost effectiveness of the 5-Year Action Plan is robust across a range of alternative assumptions pertaining to system impacts, benefits, and costs of the programs. The benefits in this analysis are quantified relying on actual market data and widely cited, publicly available forecasts, using data specific to the District, where possible. The Brattle Group performed sensitivity analyses on the NPV results, establishing plausible high and low values for key input assumptions that drive the results. Importantly, none of the sensitivity assumptions result in a negative NPV, reinforcing that the programs in the 5-Year Action Plan are cost effective. In some cases, the sensitivity assumptions result in significant upside potential. For example, a higher social cost of carbon based on a 1% discount rate (instead of a 2% discount rate) roughly quadruples the NPV of the 5-Year Action Plan to $638 million.

In addition to emissions benefits and cost savings, the BCA shows that the 5-Year Action Plan will reduce the overall energy resource needs of the District. For example, in 2027, the analysis calculates that the 5-Year Action Plan will result in 105 GWh of net energy reductions, 35 MW of net reduction to system-wide peak demand, 571,000 MMBtu reduction of natural gas consumption, 95,000 metric tons reduction of greenhouse gas emissions and a reduction of 5 million gallons of gasoline consumption. Although energy efficiency programs are a core piece of Pepco's 5-Year Action Plan, the BCA filing and the results referenced above exclude the impact of the first three years of the energy efficiency programs filed in Formal Case No. ("FC") 1160, as those programs have already been filed with the Commission. However, had these programs been included, the full impact of the 5-Year Action Plan would lower the District's carbon footprint even more dramatically. For example, in 2024, Pepco expects the filed FC 1160 programs to result in 216 GWh of net energy reductions, 43 MW of net reduction to system-wide peak demand, and 86,846 MMBtu reduction of natural gas consumption. Overall, these and many other findings within the BCA report clearly demonstrate that the programs in the 5-Year Action Plan will have a positive and significant impact on achievement of District's decarbonization goals and the communities it is designed to benefit.

Pepco intends to work collaboratively to seek implementation of the 5-Year Action Plan programs.

As the only electric distribution utility serving District customers, Pepco recognizes and embraces its core role in supporting the District's decarbonization and clean energy goals.

Achieving the District's leading decarbonization goals will require coordination and collaboration across multiple stakeholders, including District and regional agencies, District partners such as the District of Columbia Sustainable Utility, transit organizations, non-profit and community-based partners, individual customers, building owners, operators, and associations, innovators, academic institutions, environmental organizations, workforce development organizations and agencies, and businesses, including Pepco. These partnerships will be essential to ensure interrelated initiatives across individuals, organizations and sectors are aligned and mutually supportive. In addition, through the 5-Year Action Plan, the programs have the ability to contribute to local job creation and economic development. Therefore, Pepco has and will continue to meet with customers, stakeholders and organizations across the District and nationally to align the 5-Year Action Plan programs with evolving decarbonization needs and strategies for our customers and communities and to identify best practices from around the country to gain important insights from existing programs and initiatives implemented elsewhere.

To date, Pepco has filed high-level strategies, detailed program plans, and analyses with the Commission in a series of filings in FC 1167. To move forward with implementing the programs in the 5-Year Action Plan, Pepco must file applications with the Commission that contain detailed programs and specific program benefits and costs for Commission approval. When Pepco applies for specific approval to implement programs, it will also specify which type of cost recovery it believes would be appropriate for each program and seek approval of the cost-recovery mechanism at that time. Pepco is committed to advancing the 5-Year Action Plan formally, bringing the benefits enumerated in the attached BCA report and other filings within FC 1167 to the District and its businesses and residents for feedback and input. It is important to underscore that Pepco has filed a plan for the Commission and other key partners to consider in helping to achieve the District's important climate and clean energy goals. In addition, Pepco will be exploring available opportunities to reduce program costs, working collaboratively with the District of Columbia Government, and other partners.

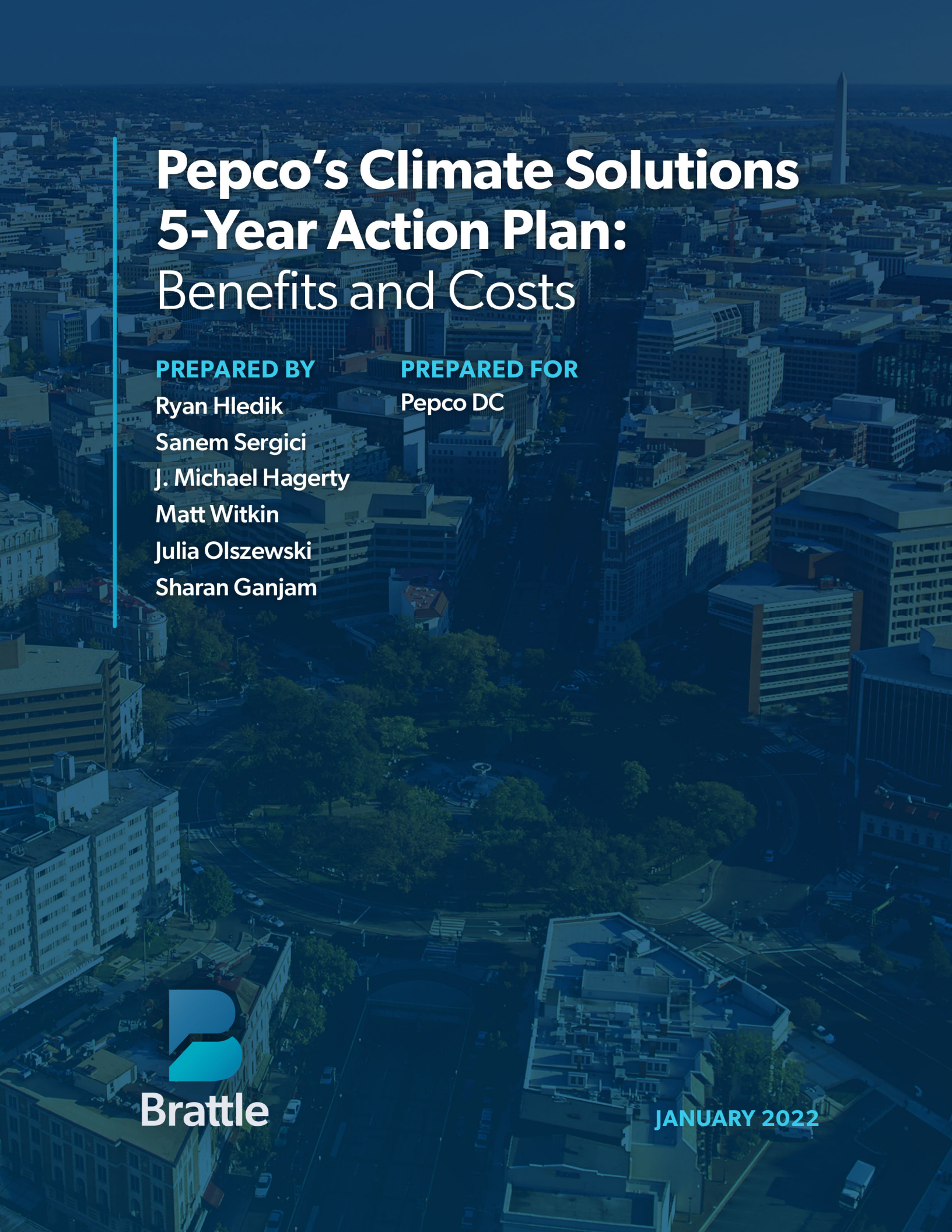
Pepco looks forward to continued engagement with District stakeholders and implementing the Commission-approved 5-Year Action Plan programs for the benefit of its customers, District residents, businesses, and the communities Pepco is privileged to serve.

Please contact me if you have any further questions.

Sincerely,

Andrea H. Harper
Andrea H. Harper

Enclosures



Pepco's Climate Solutions 5-Year Action Plan: Benefits and Costs

PREPARED BY

Ryan Hledik
Sanem Sergici
J. Michael Hagerty
Matt Witkin
Julia Olszewski
Sharan Ganjam

PREPARED FOR

Pepco DC

Brattle

JANUARY 2022

TABLE OF CONTENTS

Executive Summary

The District of Columbia (DC or District) has established leading decarbonization goals with the aim to achieve economy-wide carbon neutrality by 2050 through reductions in energy use and increased reliance on carbon-free electricity. To advance these objectives, the Public Service Commission of the District of Columbia (Commission or DCPSC) issued Order No. 20754, requiring District utilities to file their plans for facilitating achievement of the District's policy goals. In response, Pepco DC submitted its Climate Solutions 5-Year Action Plan in October 2021, which includes 62 programs to be launched over the next five years. To accompany that filing and satisfy the requirements of Order No. 20754, Pepco DC commissioned The Brattle Group to conduct an assessment of the benefits and costs of Pepco DC's 5-Year Action Plan.

We started our analysis by establishing the appropriate framework for analyzing the cost-effectiveness of the 5-Year Action Plan. The 5-Year Action Plan targets actions that Pepco DC can take in the next five years to facilitate achieving the District's economy-wide decarbonization policy goals. This policy context requires a cost-effectiveness analysis framework that specifically compares the cost of Pepco DC's proposed programs to the benefits associated with advancing the District's climate policy objectives through those programs. To address this need, we developed a cost-effectiveness framework which we refer to as the Climate Policy Enablement Test" (CPE Test). The CPE Test draws from established best practices for utility program benefit-cost analyses, takes into account stakeholder feedback on benefit-cost analysis methodology for utility climate change programs, and aligns with Pepco DC's role in enabling the achievement of the District's decarbonization goals. Specifically, the CPE Test compares the program costs of the 5-Year Action Plan to the projected benefits of reducing fuel and electricity consumption and reducing harmful air emissions, including greenhouse gas (GHG) emissions and criteria air pollutant (CAP) emissions. At a high level, this framework assesses whether or not the strategic programs proposed in the 5-Year Action Plan will achieve energy system and emissions benefits that exceed the costs of those programs.

Next, we reviewed the details of each program proposed in the 5-Year Action Plan to determine its applicability in the benefit-cost analysis (BCA). The BCA includes all programs other than those that Pepco determined (1) are pilot or demonstration projects, (2) are baseline infrastructure investments needed to safely and reliably enable distributed and clean energy applications, or (3) have budgets that were already submitted to the Commission for review or had been approved (such as 3-year energy efficiency programs currently pending approval in

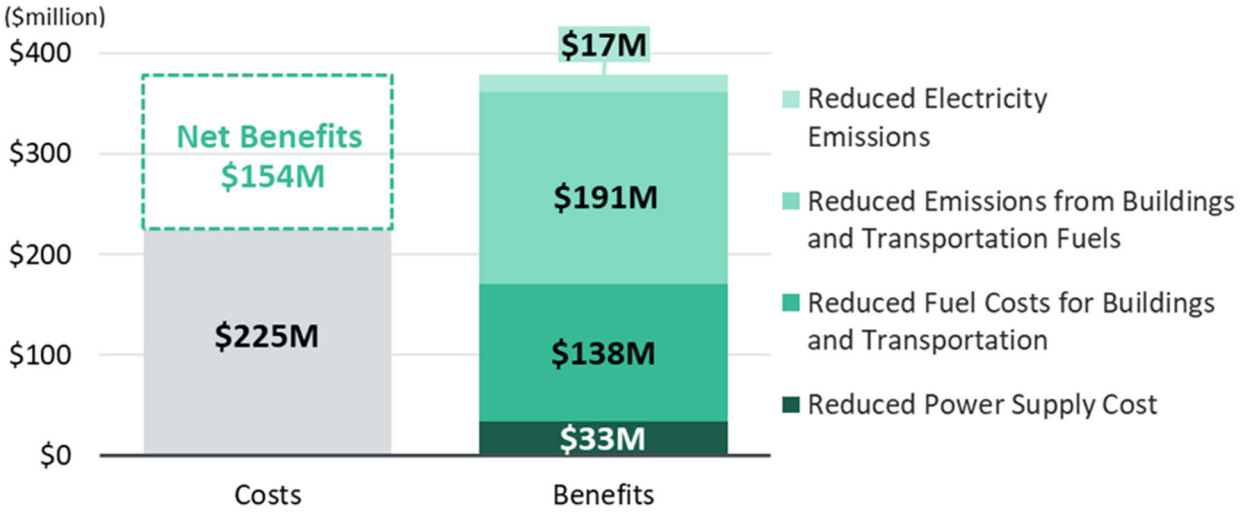
Formal Case No. (FC) 1160). Based on this review of the programs, we included 47 programs in the analysis that account for over 70% of the budget of the 5-Year Action Plan.

To assess the benefits of the 5-Year Action Plan, we first estimate the change in fuel and electricity consumption and air emissions that would be enabled by each program. We then quantify the benefits of reduced building and transportation fuel costs, power supply costs, and societal emissions costs. To quantify these benefits, we rely on actual market data and widely-cited, publicly-available forecasts, using data specific to the District where possible. Sources include recent District climate-related reports, the District Department of Energy and Environment (DOEE), the U.S. Department of Energy (DOE), the Energy Information Administration (EIA), the National Renewable Energy Laboratory (NREL), the U.S. Environmental Protection Agency (EPA), the U.S. Department of Transportation (DOT), and the PJM Interconnection (PJM). In cases where public sources were not available, we worked with Pepco DC to develop assumptions tailored to Pepco DC's system and market conditions. All key methodological assumptions and data sources are summarized in the Appendices to this report.

We estimate that Pepco DC's 5-Year Action Plan has a positive net present value (NPV) of $154 million over the 20-year study horizon, with $225 million in program costs resulting in $379 million of energy system and societal emissions benefits.[1] For every $1 spent by Pepco DC through the 5-Year Action Plan, the plan produces $1.68 in quantified benefits. The major drivers of the 5-Year Action Plan's benefits are reduced power supply costs due to an expanded energy efficiency portfolio, reduced emissions from residential and commercial buildings due to heating electrification, and reduced fuel costs and emissions from increased electric vehicle (EV) adoption driven by the charging infrastructure deployment in the plan. **FIGURE ES-1** summarizes the quantified cost and benefits of the 5-year Action Plan.

[1] We assume project costs are incurred at the beginning of the deployment period as a simplifying modeling assumption; this assumption should be refined as Pepco continues to develop the programs. In contrast, our estimates of benefits assume a 5-year deployment schedule and are discounted back to a present value. In this regard, our analysis overstates costs relative to benefits, and therefore understates the cost-effectiveness of the 5-year Action Plan.

FIGURE ES-1: BENEFITS AND COSTS OF 5-YEAR ACTION PLAN (20-YR PRESENT VALUE)



Notes:
"Reduced Power Supply Cost" reflects net savings from reduced costs associated with electricity generation, capacity, distribution, and RECs. "Reduced Fuel Costs for Buildings and Transportation" reflects savings from reduced costs associated with gasoline, diesel, natural gas, heating oil and propane use. "Reduced Emissions from Buildings and Transportation Fuels" reflects savings from reduced GHG emissions and criteria air pollutant (i.e., NOx, SOx, PM2.5) emissions associated with gasoline, diesel, natural gas, heating oil and propane use. "Reduced Electricity Emissions" reflects net savings from reduced GHG and criteria air pollutant emissions associated with electricity generation, as well as savings from Pepco's Green Rider program. We use Pepco DC's after-tax weighted average cost of capital (WACC) of 6.49% to discount all benefits and costs that are not "societal." To discount "societal" benefits and costs (i.e., those associated with changes in carbon emission and criteria air pollutants), we use the same discount rate used to calculate the social cost of carbon (2% in the Base Case). Program costs shown are "base case" cost estimates.

Our findings regarding the cost effectiveness of the 5-Year Action Plan are robust across a range of alternative assumptions about the system impacts, benefits, and costs of the programs. For each of the key drivers of the results, we establish plausible high- and low-sensitivity assumptions and analyze the change in the NPV of the 5-Year Action Plan attributable to each. None of the sensitivity assumptions result in a negative NPV. In some cases, the sensitivity assumptions result in significant upside potential. For example, a higher social cost of carbon based on a 1% discount rate (instead of a 2% discount rate) roughly quadruples the NPV of the 5-Year Action Plan to $638 million.

In addition to emissions benefits and cost savings, the 5-Year Action Plan will reduce the overall energy resource needs of the District. The programs in the 5-Year Action Plan will reduce overall electricity use, electricity system peak demand, natural gas use in buildings, and gasoline use for transportation. **TABLE ES-1** summarizes the impacts of the 5-Year Action Plan on energy demand and emissions once it has been fully deployed in 2027.[2]

[2] We note that, while Pepco DC's 3-year FC 1160 energy efficiency programs were considered outside the scope of our BCA, their inclusion would significantly increase the impacts reported in this table.

TABLE ES-1: ENERGY DEMAND AND EMISSIONS REDUCTIONS OF THE 5-YEAR ACTION PLAN

System Metric	Net Impact of the 5-Year Action Plan in 2027
Electricity Consumption	105 GWh reduction, or 1.1% of 2020 Pepco DC system-wide electricity sales.
Electricity Peak Demand	35 MW reduction, or 1.8% of 2020 Pepco DC system-wide peak demand.
Natural Gas Consumption	571,000 MMBtu reduction, the equivalent annual consumption of over 1,000 average-sized commercial buildings.[3]
Gasoline Consumption	5 million gallon reduction, the equivalent annual consumption of over 15,000 light duty vehicles.[4]
GHG Emissions	95,000 metric tons reduction, the equivalent GHG footprint of over 11,000 residential homes.[5]

The net benefits of Pepco DC's 5-Year Action Plan highlight the important role that Pepco DC will play in facilitating the cost-effective achievement of the District's decarbonization goals. The 5-Year Action Plan is a critical first step by Pepco DC to support the District's goal of net zero economy-wide carbon emissions and will establish a dynamic and adaptable platform for future decarbonization program development.

[3] Average natural gas consumption per 16,000 sq. ft. commercial building in the South Atlantic region is 566 MMBtu according to EIA 2018 CBECS Survey, Tables B1 and C28.

[4] Based on LDV gasoline efficiency assumptions from EIA Annual Energy Outlook 2021, Table 7. Transportation Sector Key Indicators and Delivered Energy Consumption.

[5] Estimated using the EPA's GHG Equivalencies Calculator.

I. Introduction

The District of Columbia (DC or District) has established policy goals that put the District at the leading edge of decarbonization initiatives across the United States. The District's overarching goal is to reduce greenhouse gas (GHG) emissions across all sectors of the economy to achieve carbon neutrality by 2050. As of 2019, the District Greenhouse Gas Inventory estimates that total GHG emissions in the District were 7.2 million metric tons (MMT) of carbon dioxide equivalents. Approximately half of the GHG emissions are from electricity generation (3.5 MMT), with the remaining emissions split between transportation fuel emissions (1.6 MMT) and fuel consumption in residential and commercial buildings (1.7 MMT). The District has set policies through legislation and other initiatives, such as CleanEnergy DC, Carbon Free DC, and Sustainable DC 2.0 that define actionable targets foundational to the achievement of the District's decarbonization goal. These include a renewable portfolio standard (RPS) requiring 100% of the District's electricity consumption to be served from renewable generation by 2032, and electrification and energy efficiency initiatives focused on decarbonizing the transportation and buildings sectors.

In that context, the Commission issued Order No. 20754 requiring Pepco DC to file a list of programs that the utility "has already filed or intends to file, as part of its overall Climate Change Commitment plan, over a short term (five year) horizon and a long term (30-year) horizon."[6] In response to this requirement, Pepco DC filed its 5-Year Action Plan, which describes 62 individual programs organized into four portfolios: Electrifying Transportation, Decarbonizing Buildings, Activating the Local Energy Ecosystem, and Enhancing Infrastructure for Climate Solutions.[7]

---

[6] Formal Case No. 1167, In the Matter of the Implementation of Electric and Natural Gas Climate Change Proposals, Order No. 20754. Public Service Commission of the District of Columbia, June 4, 2021, p. 16. https://edocket.dcpsc.org/apis/api/Filing/download?attachId=125555&guidFileName=a43e32dd-d6d5-4145-bb8c-e06a8f929775.pdf

[7] Climate Solutions Plan, Pepco's Blueprint to Support the District of Columbia's Climate and Clean Energy Goals. Case No. FC1167, June 20, 2021. Note that Pepco also filed its 30-year Transition Plan, though that is not the focus of our BCA. https://edocket.dcpsc.org/apis/api/Filing/download?attachId=126283&guidFileName=c8e06843-892f-413c-b260-bcbe969be456.pdf

Order No. 20754 required Pepco DC to subsequently file an implementation plan including a BCA.[8] To address this requirement, Pepco DC commissioned The Brattle Group (Brattle) to evaluate the benefits and costs of the 5-Year Action Plan. Specifically, Pepco DC asked Brattle to conduct a BCA of the 5-Year Action Plan across all of the portfolios as well as each of the Plan's four portfolios individually. The purpose of this report is to summarize the findings of the 5-Year Action Plan BCA as well as the key methodological assumptions behind the analysis.

How to Use this Report

This report provides a comprehensive bottom-up analysis of the program costs, energy system impacts, and emissions impacts of Pepco DC's 5-Year Action Plan. Chapter II describes the methodology for the BCA, including the cost effectiveness framework, the programs included in our analysis, and the approach to estimating the system and emissions impacts of the programs. Chapter III summarizes the key findings of our analysis, including the benefits and costs of the programs in present value terms and by year, the system and emissions impacts of the programs, the key drivers of uncertainty in the results, and additional considerations of the Plan. Chapter IV provides our conclusions from the analysis. Chapter V includes a comprehensive list of sources we referenced in our report. We provide further detail of the analysis in the appendices; Appendix A contains our assumptions for estimating the energy system costs and emissions. Appendix B contains our assumptions for estimating the system and emissions impacts of the 5-Year Action Plan programs.

The program designs in the 5-Year Action Plan are currently high-level descriptions and may continue to evolve with feedback from stakeholders prior to a formal request for program approval by the Commission. Thus, the results of the BCA are indicative of the magnitude of the benefits and costs and cost effectiveness of the programs in the 5-Year Action Plan. The analysis can be used as an initial screening tool for understanding the relative benefits and costs of Pepco DC's proposal and how it relates to facilitating achievement of the District's broader decarbonization goals, as defined in Order No. 20754. As such, the BCA is not intended to be a substitute for the business case that would be included in a future regulatory filing seeking approval of the finalized programs.

[8] Formal Case No. 1167, In the Matter of the Implementation of Electric and Natural Gas Climate Change Proposals, Order No. 20754. Public Service Commission of the District of Columbia, June 4, 2021, p. 16. https://edocket.dcpsc.org/apis/api/Filing/download?attachId=125555&guidFileName=a43e32dd-d6d5-4145-bb8c-e06a8f929775.pdf

II. Methodology

Chapter II provides an overview of the methodology and key assumptions used to evaluate the cost-effectiveness of Pepco DC's 5-Year Action Plan. The methodology draws heavily from established industry practices for evaluating demand-side initiatives. We have tailored our approach to properly evaluate the benefits and costs of Pepco DC's diverse portfolio of decarbonization programs aimed at advancing the District's existing deep decarbonization goals.

Cost-Effectiveness Framework

As the District's provider of electricity, Pepco DC will play an important role in enabling achievement of the District's climate change goals. Those goals rely heavily on electric sector energy efficiency, transportation electrification, and heating electrification to reduce GHG emissions. In this context, Pepco DC developed its 5-Year Action Plan to enable the transition to a zero-carbon economy by supporting key pathways for reducing GHG emissions over the next five years. This policy context requires a cost-effectiveness analysis framework that specifically compares the cost of Pepco DC's proposed programs to the benefits associated with advancing the District's climate policy objectives through those programs. To address this need, we developed a cost-effectiveness framework which we refer to as the Climate Policy Enablement (CPE) Test. We developed the CPE Test by applying industry-standard principles of cost effectiveness tests to the particular policy context and objectives for Pepco DC's portfolio of programs.[9] At a high level, the CPE Test compares Pepco DC's program costs of the 5-Year Action Plan to the programs' projected benefits of reducing fuel and electricity consumption and reducing harmful air emissions, including GHG emissions and criteria air pollutant (CAP) emissions. This definition of cost-effectiveness allows for the conclusion that "every $1 spent by Pepco DC will result in '$X' of net energy system and emissions benefits."

The CPE Test effectively is a hybrid of two established cost-effectiveness tests—the Societal Cost Test (SCT) and the Utility Cost Test (UCT)—and is tailored to the specific policy context in which we are evaluating Pepco DC's 5-Year Action Plan. As the District has already committed to leading decarbonization goals, the CPE Test's hybrid approach evaluates whether the energy

[9] Support for the use of a jurisdiction-specific test is provided in the *National Standard Practice Manual*. See: https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/.

system and emissions benefits Pepco DC's proposed programs created to advance District's goals outweigh the costs Pepco DC will incur in the process.

Societal Cost Test (SCT)	Like the Societal Cost Test, the CPE Test includes a reduction in the system costs of supplying electricity and other fuels and the societal benefits of reduced emissions.[10]
Utility Cost Test (UCT)	The CPE Test mimics the Utility Cost Test by focusing on the utility-incurred costs for implementing the programs ("program costs").

With this approach, we exclude participant (or "site host") costs from the analysis. For example, we do not consider the incremental cost of an electric vehicle (EV) that is purchased by a customer who otherwise would have bought a conventional internal combustion engine (ICE) vehicle, if not for Pepco DC's programs. Our objective is to evaluate the economics of how Pepco DC's proposed programs *enable* achievement of the District's decarbonization goals, not to evaluate the cost-effectiveness of the goals themselves (as they are already set by the District). In this regard, participant costs fall outside of the study scope. Additionally, including participant costs would require consideration of offsetting participant benefits to balance against the higher costs. For instance, including the incremental customer cost of purchasing an EV compared to an ICE vehicle would also require the inclusion of savings on maintenance costs and the benefit of federal tax incentives. Further, the broader consideration of participant costs and benefits would necessitate assigning a value to non-energy customer benefits, such as customer preferences for the vehicle performance of an EV compared to an ICE vehicle, which are inherently difficult to quantify. In many instances, we would expect these participant benefits to roughly equal or outweigh the incremental participant costs and therefore would not change the results of our analysis.

TABLE 1 indicates how the costs and benefits included in the CPE Test compare to those of other cost-effectiveness frameworks.[11]

[10] The analysis accounts for increases in energy system costs associated with increased use (e.g., increased electricity consumption attributable to electrification programs). Thus, the energy system benefits are net of these costs.

[11] For further discussion of the cost-effectiveness tests, see: California Public Utilities Commission, "California Standard Practice Manual," October 2001.

TABLE 1: SUMMARY OF COST-EFFECTIVENESS TESTS

Test	Key Question	Benefits	Costs
Climate Policy Enablement (CPE) Test *Used in Pepco DC BCA*	- Does the program support cost-effective achievement of established climate policy goals?	- Avoided societal costs, inclusive of supply-side costs and harmful pollutants	- Customer Incentives - Program Costs (Utility)
Participant Test	- Is the participant better off?	- Bill Decrease - Customer Incentives	- Program Costs (Participant) - Participation Fees
Total Resource Cost (TRC) Test	- Is resource efficiency improved?	- Avoided supply-side costs	- Program Costs (Total)
Ratepayer Impact Measure (RIM) Test	- Are rates lowered?	- Avoided supply-side costs - Participant Fees	- Revenue loss - Customer Incentives - Program Costs (Utility)
Utility Cost Test (UCT)	- Are revenue requirements lowered?	- Avoided supply-side costs - Participant Fees	- Customer Incentives - Program Costs (Utility)
Societal Cost Test (SCT)	- Are societal costs lower?	- Avoided societal costs, inclusive of supply-side costs and social externalities	- Program Costs (Total)

Quantified Benefits

The breadth of Pepco DC's proposed programs means that a wider range of energy system and environmental impacts must be considered in the CPE Test. Unlike conventional cost effectiveness analysis of energy efficiency and demand response measures, the impacts of the 5-Year Action Plan will extend beyond the electric power system to include changes in energy demand and emissions from other sectors as well, such as natural gas for heating and gasoline for transportation.

The programs in the 5-Year Action Plan in some cases reduce fuel demand outright (*e.g.*, energy efficiency programs) and in other cases shift fuel demand from one source to another (*e.g.*, electrification programs). Energy efficiency programs will reduce power supply costs, such as electricity generation costs, renewable energy credit (REC) costs, generation capacity costs, and electricity distribution costs, which we include in the CPE Test as a benefit. However, electrification programs will increase these power supply costs while simultaneously decreasing end-use fuel costs, such as natural gas or gasoline costs. In the case of electrification programs, the CPE Test treats the avoided fuel costs as a positive benefit and the increased power supply costs as a negative benefit (which is different than the program cost).

Below, we describe each of the system impacts analyzed quantitatively as a benefit, along with brief information about our methodology for quantifying their impact. The benefits fall into three categories: reduced power supply costs, reduced transportation and building fuel costs, and reduced societal emissions costs. To quantify these benefits, we rely on actual market data and widely cited publicly-available forecasts, using data specific to the District where possible. In cases where public sources were not available, we worked with Pepco DC to develop assumptions tailored to Pepco DC's system and market conditions. See Appendices A and B for further technical detail on our assumptions for developing the system impact estimates.

REDUCED POWER SUPPLY COSTS

- **Electricity generation costs:** The production costs (fuel, variable O&M) associated with generating electricity to serve electricity demand. Energy efficiency programs reduce electricity generation costs, while electrification programs increase electricity generation costs. We estimate changes in electricity generation costs using both near-term electricity futures reported by NYMEX and an NREL long-run forecast of hourly locational marginal prices (LMPs) in the Pepco DC service territory, and account for changes in energy losses.
- **REC costs:** The cost to purchase RECs to satisfy the District's RPS requirement. Similar to electricity generation costs, increases in electricity demand increase REC purchases, whereas reductions in electricity demand decrease REC purchases. We estimate REC prices based on recent historical prices reported by S&P Global and our assessment of the future prices needed to support additional renewable generation. We account for the higher price of SRECs associated with the carve-out for DC-sited solar generation (5% in 2032).[12]
- **Generation capacity cost:** The cost of procuring capacity from the PJM capacity market to satisfy Pepco DC's capacity obligation as a load serving entity. Generation capacity costs

[12] CleanEnergy DC Omnibus Amendment Act of 2018 (D.C. Law 22-257), effective March 22, 2019.

increase as Pepco DC's system peak demand grows but can decrease through peak demand reductions or by selling demand reductions into the capacity market. We estimate future generation capacity costs based on the recent prices from PJM's three-year forward capacity auctions and an NREL long-run forecast of capacity market prices.

- **Electricity distribution costs:** The annualized costs of capital investment in distribution infrastructure associated with increases or decreases in electricity demand due to Pepco DC's proposed programs. Changes in distribution costs are inherently difficult and time consuming to estimate and require bottom-up analysis of the distribution system to analyze precisely. In this case, we use an approximate approach to establish a range of distribution cost estimates based on recent capacity additions due to load growth.
- **Electricity line losses:** The electricity lost on the distribution system. We assume 5.7% energy line losses and 8.9% capacity line losses on the distribution system to estimate the impacts of the 5-Year Action Plan on wholesale electricity and capacity demand.[13] We assume no change in these line loss percentages due to the programs. Electricity line losses are embedded in our estimates of changes generation capacity costs, electricity costs, and distribution costs.

REDUCED FUEL COSTS FOR TRANSPORTATION AND BUILDINGS

- **Transportation fuel costs:** The wholesale cost of gasoline and diesel used for transportation in Internal Combustion Engine (ICE) vehicles. Reduced fuel costs are a benefit associated with electrification of transportation. We base the avoided fuel costs on the EIA's forecasted wholesale price of gasoline and diesel. Consistent with the cost-effectiveness framework developed for this study, the use of wholesale costs for gasoline, electricity, and other fuels treats avoided fuel use as a societal benefit, rather than as a benefit from the perspective of the program participant.
- **Building fuel costs:** The wholesale cost of natural gas and other fuels for heating buildings and other operating other end-uses considered in the Building Electrification portfolio. Reduced fuel costs are a benefit associated with building electrification programs. We estimated avoided fuel costs based on the EIA's forecasted wholesale prices for each fuel type, while the avoided gas infrastructure costs are considered qualitatively.

[13] Values provided by Pepco DC.

REDUCED EMISSIONS COSTS

- **Greenhouse gas (GHG) costs:** The societal costs of GHG emissions due to changes in energy consumption and fuel switching. Our analysis accounts for changes in GHG emissions associated with changes in electricity consumption, fuel consumption for transportation, and fuel consumption for buildings. The change in GHG emissions is valued at the social cost of carbon assuming a 2% discount rate, as described in Appendix A. The power sector GHG emissions rate is based on recent historical marginal emissions rates reported by PJM, adjusted for the reduction in marginal emissions rates forecasted for the Pepco zone of PJM and the impact of Pepco DC's RPS over the study horizon. Non-power sector emissions rates are based on the emissions rate specific to the direct use of each fuel type. For simplicity, the BCA focuses on CO_2 and does not include other GHGs (such as methane or nitrous oxide, N2O) since CO_2 accounts for the vast majority of direct GHG emissions from the power sector and other end-uses in our analysis.[14] The net benefits of the 5-Year Action Plan reported in this study would be higher if we included other GHGs.
- **Criteria air pollutant (CAP) costs:** The societal costs of criteria air pollutant emissions due to changes in energy consumption and fuel switching. In addition to GHGs, the 5-Year Action Plan reduces local air pollutants, particularly through transportation electrification. The change in criteria air pollutant emissions is valued at the societal costs of each pollutant specific to the source of the emissions, as described in Appendix A. The power sector emissions rates are based on recent marginal emissions rates in PJM that are scaled downward by the forecasted trend in GHG emissions, as a proxy for criteria pollutant emissions. The emissions rates are further decreased to adjust for the rising RPS requirements in the District, similar to GHG emission rates.

Additionally, there are other relevant impacts that were not included in the quantitative analysis due to having low impact, being speculative in nature, or otherwise being outside the scope of this study's cost-effectiveness framework. These include, for example, changes in incremental resilience, indoor air quality, natural gas distribution infrastructure costs, and electricity transmission costs. We discuss these impacts qualitatively in Chapter III of this report. Further, we exclude impacts such as changes in water use, vehicle maintenance,

[14] We include NOx emissions in our assessment of the local criteria air pollutants associated with heating and transportation fuels, which includes a mix of nitric oxide (NO), nitrogen dioxide (NO2), and nitrous oxide (N2O). According to the EPA, the most prevalent nitrogen oxide emitted from fuel combustion is nitric oxide (NO). However, nitrous oxide (N2O) is the only nitrogen oxide that is a GHG. Due to the lack of an accurate estimate of the specific N2O emissions and the relatively small share of total GHG emissions that N2O accounts for (only 3% of total power sector GHG emissions), we have not included an estimate of the social costs of N2O related to climate change. EPA, Nitrogen Oxides (NOx), Why and How They Are Controlled, November 1999.

property value, jobs, and customer comfort due to limited empirical basis for developing a quantitative estimate, relevance to the scope of this study's cost-effectiveness framework, or if such impacts are unlikely to significantly alter the findings of the analysis.

Program Costs

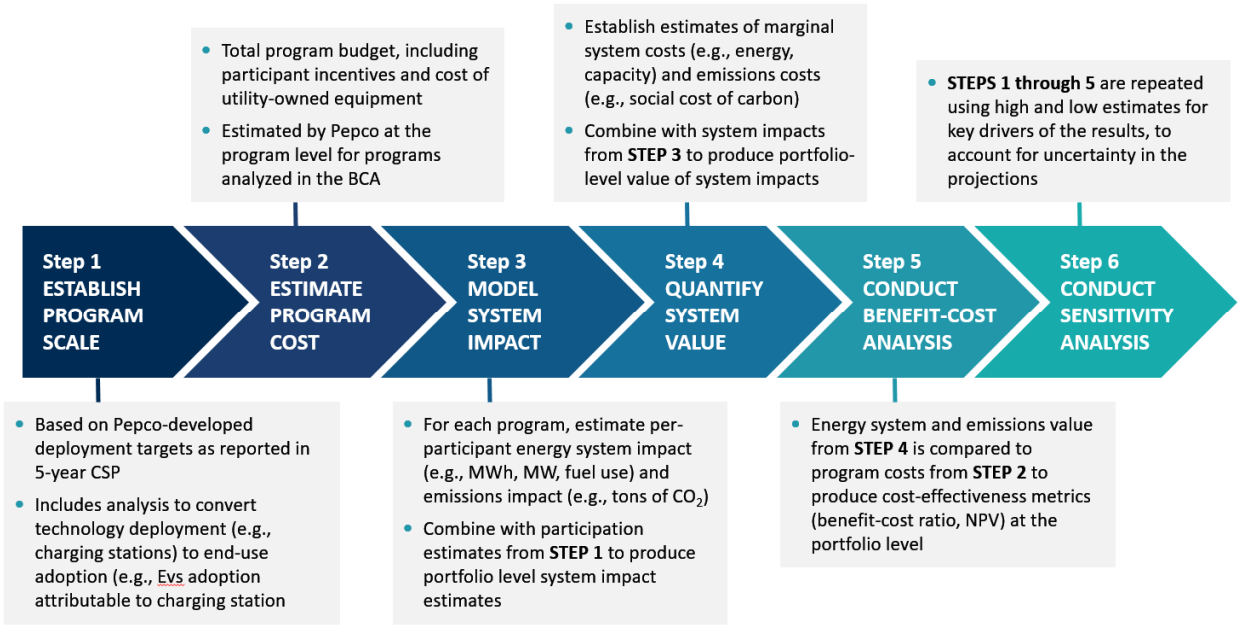
Program costs are based on Pepco DC's approximate estimates of total utility-specific budgets associated with deploying the programs in Pepco DC's 5-Year Action Plan. The total program cost estimates include the following types of costs:

- **Equipment costs** such as the costs of a new battery energy storage system (if owned and paid for by Pepco DC)
- **Equipment installation costs** such as the cost of in-home installation of smart thermostats (if provided by Pepco DC)
- **Utility incentive payment to customers** such as the rebate for a heat pump purchase
- **Ongoing costs** such as equipment maintenance costs (if provided by Pepco DC)
- **Program administration costs** such as the costs of dedicated program management staff
- **Supporting software costs** such as third party vendor software licensing fees

Benefit-Cost Analysis Approach

We analyze each portfolio's cost-effectiveness using a six-step approach, as illustrated in **FIGURE** 1 shown below.

FIGURE 1: BCA METHODOLOGY



The first step is to **establish the scale of each program**. "Program scale" refers to Pepco DC's target deployment level, and its measurement varies by program. For example, the scale of the Dynamic Pricing program is represented by the number of customers that are anticipated to participate in the program. In contrast, the scale of the Residential Charging program is represented by the number of level 2 home chargers for which Pepco DC will provide the necessary make ready infrastructure. In cases such as the Residential Charging program, the program scale is not a direct estimate of the number of participants or system impacts. In these cases, we analyze how the target technology deployment would be expected to impact customer or end-use participation. For example, the target number of chargers supported through the Residential Charging program contributes to the estimate of the total incremental number of EVs adopted by Pepco DC customers.

The second step is to **estimate program costs**. As noted earlier in this chapter, Pepco DC subject matter experts developed total cost estimates for each program analyzed in the BCA. Program costs are developed to be consistent with the scale of each program, as discussed above.

The third step is to **model the system impact** of each portfolio. The system impact includes impacts of the programs on the energy system, such as changes in consumption of electricity, natural gas, gasoline, and other fuels, as well as changes in investment in infrastructure to deliver electricity to customers. These impacts include changes in emissions, including carbon dioxide (CO_2) and, where applicable, criteria air pollutants. We conduct bottom-up modeling of

each program to estimate its system impacts. In some cases, such as Pepco DC's proposed energy efficiency programs, we rely on system impact data developed by Pepco DC, which we vet for analytical consistency with the other programs. We establish system impacts at the per-participant level and then aggregate for consistency with the program scale estimates from step 1.

The fourth step is to **quantify the system value** of each portfolio. In the case of energy system impacts, system value is typically represented by the avoided (or increased) marginal cost of electricity, heating or transportation fuels, or electricity infrastructure investment. In the case of environmental/emissions benefits, we value the avoided social cost of changes in emissions. We then calculate energy system value and emissions value by multiplying the system impacts from step 3 by these marginal cost forecasts.

The fifth step is to **conduct the benefit-cost analysis** by comparing the change in system value from step 4 to the program costs from step 2 for each portfolio and the 5-Year Action Plan overall. Cost-effectiveness is measured as the net present value of the portfolio over a 20-year study horizon, which is the present value of the benefits net of the program costs.[15,16]

The sixth and final step in the BCA is to **conduct sensitivity analysis**. For each key assumption in the analysis, we develop alternative low and high estimates representing outcomes that are plausible but less likely than the Base Case estimate. Individually, for each assumption, we estimate how the NPV of the 5-Year Action Plan would change by repeating steps 1 through 5 above with that single assumption changed to the high or low value. This provides both an indication of the overall sensitivity of the portfolio's cost effectiveness to the assumptions as well as an indication of the relative importance of each key assumption to the findings of this study.

Programs Analyzed

We reviewed the details of each program in the 5-Year Action Plan to determine which programs to include in the benefit-cost analysis. Based on our review, we organized the programs into three categories:

---

[15] We use Pepco DC's after-tax WACC of 6.49% to discount all benefits and costs that are not "societal." To discount "societal" benefits and costs (i.e., those associated with changes in carbon emission and criteria air pollutants), we use the same discount rate used to calculate the social cost of carbon (2% in the Base Case).

[16] Note that the analysis does not assume that the system impacts of each program persist for 20 years. System impacts are assumed to last for the life of each program's applicable equipment or technology, with no replacement upon expiration of the equipment.

- **Category 1: Modeled Benefits and Costs.** Programs in this category have sufficient data for estimating their cost and benefits and are given full consideration in the quantitative economic analysis. 35 out of 62 programs in the 5-year Action Plan fall in Category 1 and account for 63% of the total cost of the Plan.
- **Category 2: Modeled Costs Only.** Programs in this category provide benefits that are indirect, fall outside the definition of benefits quantified in this study, or otherwise do not have sufficient empirical support for providing a quantitative estimate. For example, Pepco DC's "Distribution System Power Up" Rebate program provides commercial customers with rebates to reduce the cost of front-of-meter distribution system upgrades that support building electrification. While this program will facilitate building electrification and support the District in achieving its policy goals, it does so indirectly, by enabling other programs that directly incentivize adoption of electric end-uses. For this reason, the Distribution System Power Up Rebate program is included as a cost in the BCA, with no directly associated benefits. 12 programs in the 5-year Action Plan fall into Category 2, accounting for 9% of the total cost of the Plan.
- **Category 3: Did Not Model.** Some programs from the 5-year Action Plan are not included in the analysis, for one or more of the following reasons: (1) the program is a pilot or demonstration project; (2) Pepco DC determined that the program is a baseline infrastructure investment needed to safely and reliably enable distributed and clean energy applications; and/or (3) Pepco DC determined that the program's budget has already received (or is pending) regulatory approval and therefore does not require further cost-effectiveness analysis. 15 programs are excluded from the BCA entirely, accounting for around 28% of the total 5-year Action Plan budget estimate. Our analysis is limited to Pepco DC's proposed programs within the 5-Year Action Plan and does not include any other ongoing programs or investments, such as the necessary investments to maintain system performance and reliability.

The four tables below summarize the 5-Year Action Plan programs by portfolio, including the target size of the programs as specified in the 5-year Action Plan, and their treatment in the BCA.

TABLE 2: ELECTRIFYING TRANSPORTATION PORTFOLIO PROGRAM SUMMARY

	Name	Description	5-Year Target Size	In BCA?
3.1 Connect Transportation Initiative				
3.1.1	**Key Corridors Charging**	Incentives for public DC fast chargers	40–60 ports	Yes
3.1.2	**Residential Charging**	Incentives for L2 chargers in homes	2,000 ports	Yes
3.1.3	**Multi-Unit Dwelling (MUD) Charging**	Incentives for L2 chargers in MUDs	500 ports	Yes
3.1.4	**EV-Ready System Design & Engineering**	Support for charging infrastructure and streamlined interconnection	20–30 M/HDV fleet assessments over 10 years	Cost only
3.1.5	**Vehicle-to-Grid Demonstration**	Pilot to demonstrate V2G capability	N/A (pilot)	No
3.1.6	**Food Truck Service Electrification**	Incentives for chargers the support electrification of food trucks	50 L2 or DCFC	Cost only
3.1.7	**Destination Charging**	Incentives for L2 chargers in commercial facilities	2,000 ports	Yes
3.1.8	**Rideshare & Taxi Charging Hubs**	Incentives for charging to support rideshare/taxi fleets	100 L2 or DCFC	Yes
3.1.9	**Transit Bus Charging**	Incentives for DCFC to support public bus fleets	12 transit buses	Yes
3.2 Smart Rates Transportation Initiative				
3.2.1	**Residential EV Charging TOU**	EV-specific residential TOU for customers with L2 chargers	1,000–5,000 participants	Yes
3.2.2	**Demand Charge Solution**	Reduced demand charge for DCFC	N/A	Cost only
3.2.3	**Transit Bus Rate Solutions**	Rates to optimize public bus fleet solutions	N/A	Cost only

Note: Program names and numbering convention consistent with Pepco DC's Climate Solutions 5-year Action Plan filing. The total number of programs listed in Tables 2-5 does not add up to 62 (as identified elsewhere in this report) because 20 programs are included within program category 4.1 ("DC Energy Efficiency Programs Initiative"), and program 4.2.8 ("DSM Expansion") is divided into three entries for the purposes of this table. "N/A" indicates that information on program target size was not applicable or otherwise not provided in the 5-year Action Plan report. Appendix B provides further detail on our approach to estimating the magnitude of impacts of the programs.

TABLE 3: DECARBONIZING BUILDINGS PORTFOLIO PROGRAM SUMMARY

	Name	Description	5-Year Target Size	In BCA?
4.1 DC Energy Efficiency Programs Initiative		2-Year extension of 20 programs originally proposed in Pepco's FC1160 filing. First 3 years of program deployment are excluded from BCA.	199,197 MWh of energy savings in 2026	Yes
4.2 Connect Homes and Buildings Initiative				
4.2.1	**Appliance Electrification**	Rebates for heat pumps and other electric appliances (residential and commercial)	20–600 participants	Yes
4.2.2	**Distribution System Power-Up Rebate**	Reduce commercial customer front-of-meter upgrade costs to support electrification	160–700 participants	Cost only
4.2.3	**Rebates for BTM Heavy-Up**	Rebates for residential BTM (including meter) electrical upgrades to support electrification	100–1,000 participants	Cost only
4.2.4	**Urban Heat Island Reduction**	Strategic tree planting to reduce A/C use	2,200 trees per year for 5 years	Cost only
4.2.5	**Dedicated LMI Electrification (Owner-Occupied)**	Rebates to support electrification adoption by LMI customers in owner-occupied residences	10–250 pieces of equipment in various categories	Yes
4.2.6	**Dedicated LMI Electrification (Renter-Occupied)**	Rebates to support electrification adoption by LMI customers in renter-occupied residences	10–250 pieces of equipment in various categories	Yes
4.2.7	**Commercial Building EE Financing Package**	Finance EE investments through property tax assessment	N/A	Cost only
4.2.8a	**DSM Expansion – Battery Storage**	Residential BYOD battery program with direct control of customer-owned battery	60–140 participants	Yes
4.2.8b	**DSM Expansion – EV Charger**	Direct control of residential home EV charging	390–920 participants	Yes
4.2.8c	**DSM Expansion – Smart Thermostat**	Frequent management of residential smart thermostat	1,000–3,000 participants	Yes
4.2.9	**Income Eligible Multifamily**	Incentives for deep retrofits and technical assistance	10,000 households	No
4.3 Smart Rates: Buildings Initiative				
4.3.1	**Residential TOU Pilot**	Whole home residential TOU rate	835 participants	Yes
4.3.2	**All-Electric Rate Study**	Study to investigate the re-introduction of a reduced rate for "all electric" customers	N/A	Costs only
4.3.3	**Expand R-PIV to all Residential SOS Customers**	Extend EV TOU eligibility to all residential customers	N/A	Yes
4.3.4	**Dynamic Pricing**	Residential Critical Peak Rebate (CPR)	25,000 participants	Yes

TABLE 4: ACTIVATING THE LOCAL ENERGY ECOSYSTEM PORTFOLIO PROGRAM SUMMARY

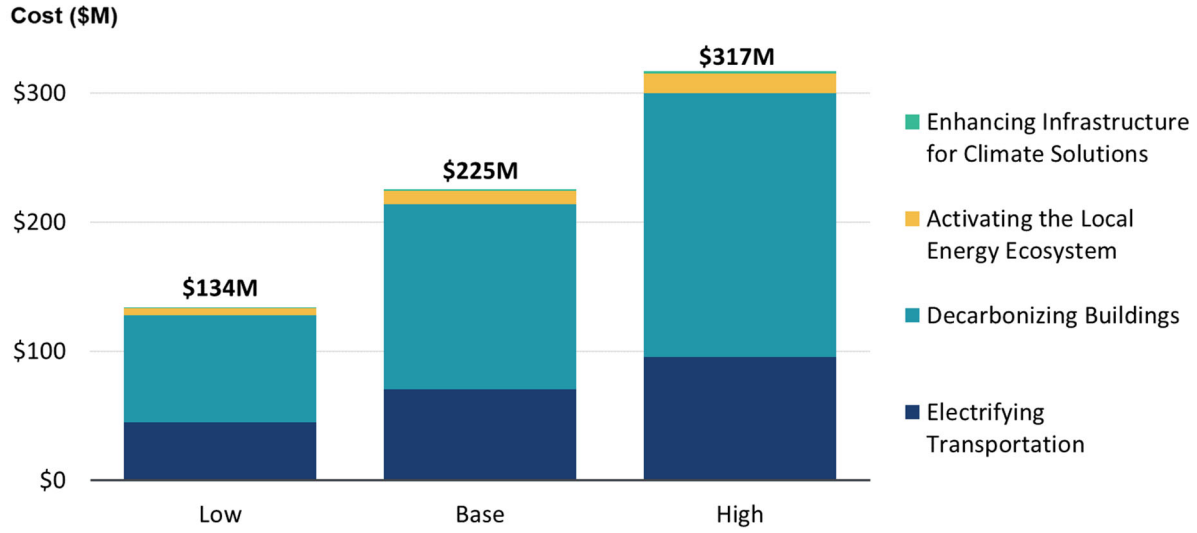
	Name	Description	5-Year Target Size	In BCA?
5.1 Connect DER Initiative				
5.1.1	**Virtual Power Plant Demonstration**	Control of BTM batteries (residential and commercial)	100–200 participants	No
5.1.2	**Interconnection Design and Process Streamlining**	Automated approval of small DER project interconnection; assistance for large projects	N/A	Cost only
5.1.3	**DER Hosting Capacity Maps**	Enhanced DER and hosting capacity maps	N/A	No
5.1.4	**Community Solar Automation**	Automation of payment processes for Community Renewable Energy Facility program	N/A	Cost only
5.1.5	**Virtual Community Renewable Energy Facility Automation Program**	Establishes billing system to allow Pepco to offer BTM community solar projects	N/A	No
5.2 Connect Communities Initiative				
5.2.1	**Resilience Center**	On-site solar and storage to promote resilience for specific communities (i.e. microgrids)	5 projects with 50 kW solar PV and 50 kW / 50 kWh battery	Yes
5.2.2	**Mt. Vernon Connected Community Roadmap and Demonstration Project**	Develop Roadmap for pursuing NWA at Mt. Vernon substation	N/A	No
5.3 Accelerating Renewables Initiative				
5.3.1	**Green Rider Expansion Program**	Extends eligibility for 100% green pricing program from EV customers to all residential customers	N/A	Yes
5.3.2	**Standard Offer Service Contracting Program**	Pepco signs long term PPAs for SOS load (5% in 2024, growing to 100% in 2032)	N/A	No

TABLE 5: ENHANCING INFRASTRUCTURE FOR CLIMATE SOLUTIONS PORTFOLIO PROGRAM SUMMARY

	Name	Description	5-Year Target Size	In BCA?
6.1 Connect Data Initiative				
6.1.1	**Advanced Distribution Management System**	Establishes ADMS to support distribution control, management and optimization capabilities	N/A	No
6.1.2	**Advanced DER Analytics Program**	Creates analytics platforms to centrally process DER data for load forecasting and DER-impact analyses	N/A	No
6.1.3	**Planning and Forecasting System Program**	Forecasts DERs at granular temporal and spatial scale using historical and forecasted data	N/A	No
6.1.4	**Geographic Information Systems (GIS) and Data Digitization and Optimization Program**	Standardization throughout GIS systems	N/A	No
6.2 Connect Infrastructure Initiative				
6.2.1	**Radial Hosting Capacity Improvements Program**	Invest in radial system to allow for increased DER installations	N/A	Costs only
6.2.2	**Mt. Vernon Substation Battery NWS Demonstration Program**	Battery at substation to defer investment of fourth substation	1 MW to 3 MW battery	No
6.2.3	**Distribution System Planning/Non-Wires Alternatives (DSP/NWA) Process**	Process to solicit third-party non-wires solutions to address capacity constraints	N/A	No
6.2.4	**Ward 8 Investment Deferral Program**	Microgrid and battery projects to defer substation	1 MW to 3 MW battery	No

Pepco DC estimates the total program costs of all programs analyzed in the BCA to be $225 million.[17] Pepco DC provided base cost estimates, as well as low and high estimates for the sensitivity analysis, which are discussed later in this report. **FIGURE 2** summarizes the breakdown of costs across the four portfolios in the 5-year Action Plan.

FIGURE 2: 5-YEAR ACTION PLAN PROGRAM COST BREAKDOWN



Source: Program cost data provided by Pepco DC.

[17] This total includes all programs analyzed in the BCA, as described above. We assume project costs are incurred at the beginning of the deployment period as a simplifying modeling assumption; this assumption should be refined as Pepco continues to develop the programs. In contrast, our estimates of benefits assume a 5-year deployment schedule and are discounted back to a present value. In this regard, our analysis overstates costs relative to benefits, and therefore understates the cost-effectiveness of the 5-year Action Plan.

III. Key Findings

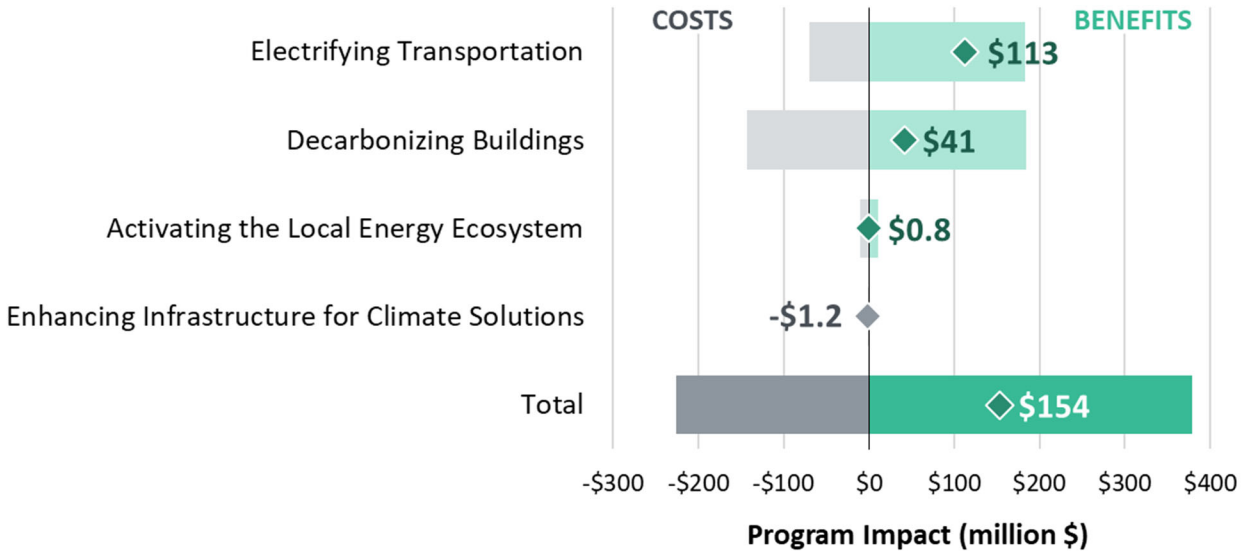
Chapter III summarizes the key findings of the 5-Year Action Plan cost effectiveness analysis, including the results for the 5-year Action Plan in its entirety as well as for each of its four portfolios. Key findings include the net present value (NPV) of the 5-year Action Plan, as well as energy system and emissions impacts. We report results for a variety of sensitivity cases. The chapter concludes with discussion of additional potential benefits that were not included quantitatively in the analysis.

Quantified Benefits and Costs

OVERALL 5-YEAR ACTION PLAN

The 5-Year Action Plan programs in our analysis have a positive net present value of $154 million, indicating that the present value of the plan's benefits ($379 million) is larger than the estimated total program costs ($225 million). Presented as a benefit-cost ratio, the 5-Year Action Plan has a ratio of 1.68. In other words, every $1 Pepco DC spends on the programs in the Plan will produce $1.68 of quantified net benefits. The Electrifying Transportation and Decarbonizing Buildings portfolios account for the vast majority of quantified benefits and costs of the overall 5-Year Action Plan. **FIGURE 3** summarizes the 20-year NPV of the 5-Year Action Plan in total and by portfolio.

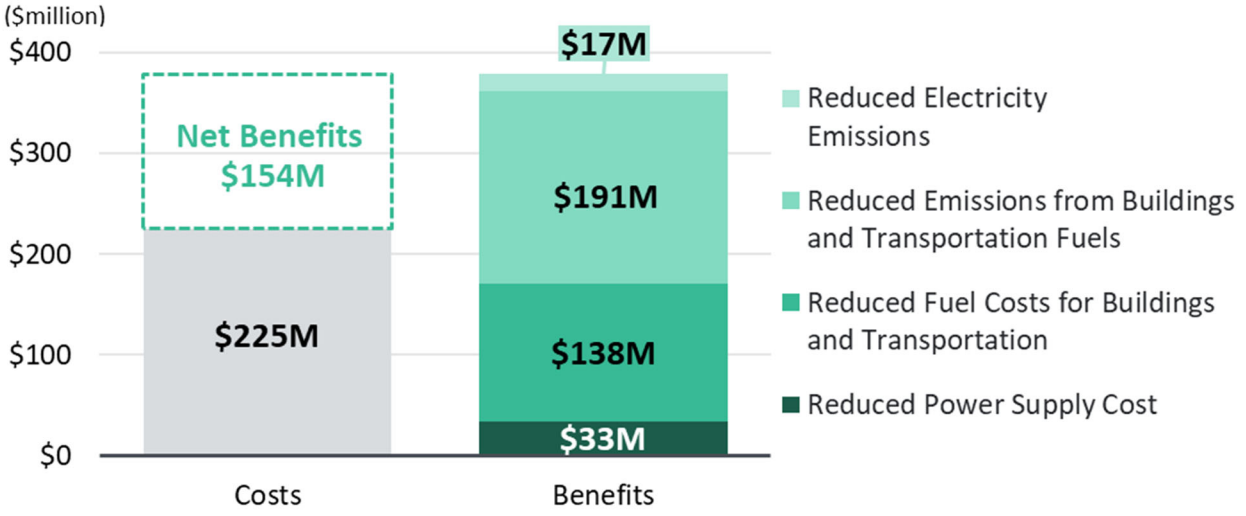
FIGURE 3: BENEFIT COST ANALYSIS OF THE 5-YEAR ACTION PLAN PORTFOLIOS



Note: Diamond sign represents net benefits of portfolio. The "Enhancing Infrastructure" portfolio is modeled entirely as a cost with no quantified benefits, because the portfolio provides support for other decarbonization initiatives rather than providing directly attributable benefits under our study framework.

For the overall 5-Year Action Plan, the key drivers of net benefits are avoided power supply costs, avoided transportation fuel costs, and reductions in GHG emissions. **FIGURE 4**: summarizes the total 5-Year Action Plan cost and the value of each of the plan's system impacts.

FIGURE 4: TOTAL 5-YEAR ACTION PLAN BENEFITS AND COSTS (PRESENT VALUE)



Notes:
"Reduced Power Supply Cost" reflects net savings from reduced costs associated with electricity generation, capacity, distribution, and RECs. "Reduced Fuel Costs for Buildings and Transportation" reflects savings from reduced costs associated with gasoline, diesel, natural gas, heating oil and propane use. "Reduced Emissions from Buildings and Transportation Fuels" reflects savings from reduced GHG emissions and criteria air pollutant (i.e., NOx, SOx, PM2.5) emissions associated with gasoline, diesel, natural gas, heating oil and propane use. "Reduced Electricity Emissions" reflects net savings from reduced GHG and criteria air pollutant emissions associated with electricity generation, as well as savings from Pepco's Green Rider program. We use Pepco DC's after-tax WACC of 6.49% to discount all benefits and costs that are not "societal." To discount "societal" benefits and costs (i.e., those associated with changes in carbon emission and criteria air pollutants), we use the same discount rate used to calculate the social cost of carbon (2% in the Base Case). Program costs shown are "base case" cost estimates.

ELECTRIFYING TRANSPORTATION

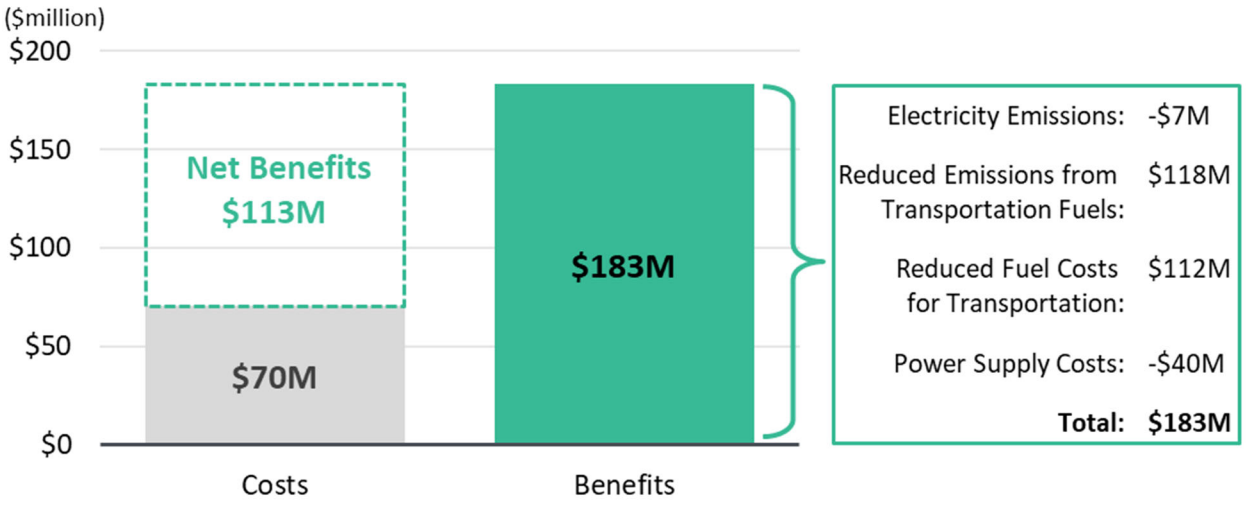
Pepco DC's Electrifying Transportation portfolio has a 20-year NPV of $113 million. The primary benefit of the Electrifying Transportation portfolio is avoided gasoline costs and associated GHG emissions. While there is an increase in costs associated with additional electricity demand, the additional costs only offset 23% of the gasoline fuel cost savings.

The societal benefits of reduced GHG emissions are also a major driver of the results and outweigh the GHG emissions associated with additional electricity usage by a factor of 19x.[18]

[18] The net present value of the societal benefits of reduced GHG emissions from transportation fuel use are $109.9 million, while the net present value of the net societal costs of GHG emissions from increased electricity use is $5.9 million.

These net GHG emissions reductions highlight the benefits of transportation electrification in a jurisdiction with strong RPS requirements such as the District. **FIGURE 5** summarizes the present value of benefits and costs associated with the Electrifying Transportation portfolio.

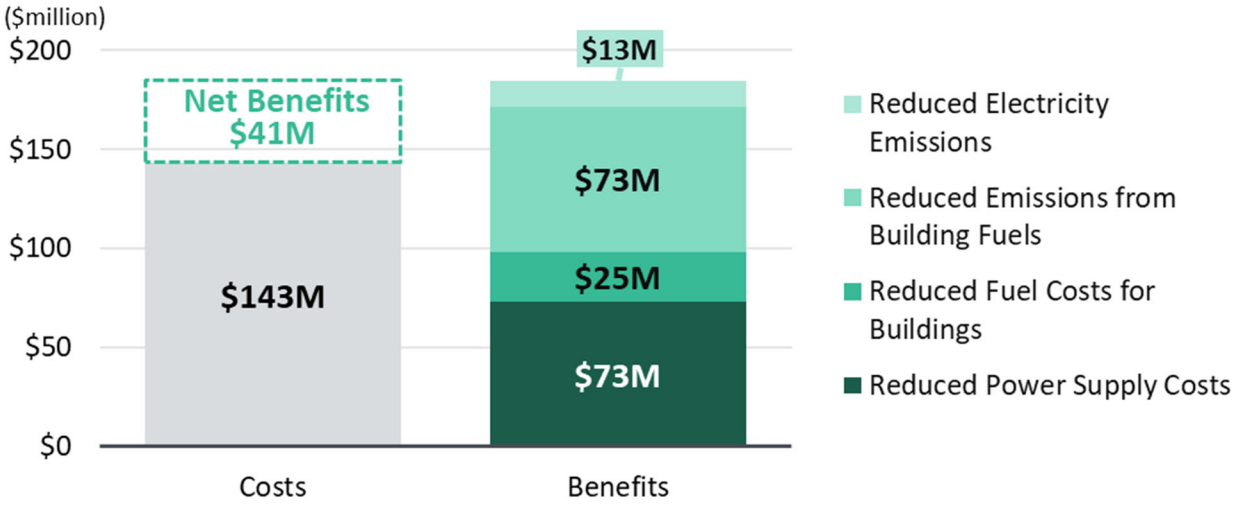
FIGURE 5: ELECTRIFYING TRANSPORTATION PORTFOLIO BENEFITS AND COSTS (PRESENT VALUE)



DECARBONIZING BUILDINGS

Pepco DC's Decarbonizing Buildings portfolio has a 20-year NPV of $41 million. The positive NPV is driven by a significant net reduction in electricity-related costs, including power supply costs and emissions. The driver of these benefits is Pepco DC's two-year extension of the energy efficiency programs proposed in the company's recent filing in FC 1160. The reduction in power supply costs associated with those energy efficiency programs outweighs an increase in costs associated with serving the additional electricity demand from Pepco DC's proposed building electrification programs. **FIGURE 6** summarizes the present value of benefits and costs associated with the Decarbonizing Buildings portfolio.

FIGURE 6: DECARBONIZING BUILDINGS PORTFOLIO BENEFITS AND COSTS (PRESENT VALUE)



ACTIVATING THE LOCAL ENERGY ECOSYSTEM AND ENHANCING INFRASTRUCTURE

The Activating the Local Energy Ecosystem and Enhancing Infrastructure for Climate Solutions portfolios are partially included in our analysis. Many of the programs in these two portfolios provide support for other decarbonization initiatives, rather than providing directly attributable benefits under our study framework. For example, the Community Solar Automation program will involve automated processes necessary to manage community solar programs. Ultimately, this improvement should facilitate a better customer experience with the program and increase participation, but there is no empirical basis for directly attributing the benefits of increased community solar participation to this program. For those reasons, we modeled only its costs in our analysis. Similarly, Pepco DC's Resilience Centers will primarily provide resilience benefits to resource-challenged communities through on-site solar and storage installations.[19] However, resilience is not quantified as a benefit in this analysis, so only the avoided electricity costs associated with the solar and storage deployments are considered.

The limited scope of benefits considered for these portfolios results in the combined portfolio effectively breaking even. Quantified benefits are attributable to the environmental value of the RECs purchased through Pepco DC's Green Rider Expansion program and to the power system cost and emissions savings associated with the solar and storage facilities in the Resilience Center projects. Combined, the Activating the Local Energy Ecosystem and Enhancing Infrastructure for Climate Solutions portfolios have a program cost of $11.5 million and benefits of $11.2 million, resulting in an NPV of -$0.3 million.

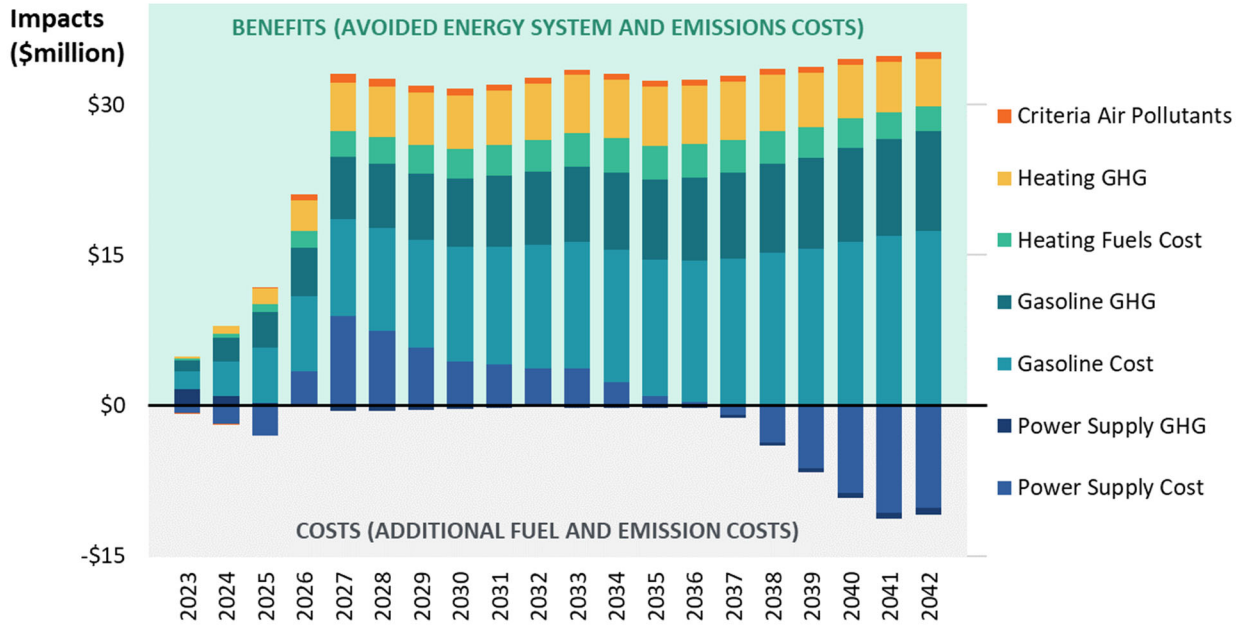
[19] In prior reports, Pepco DC used the term "Resilience Hubs."

Annual Quantified Benefits

The annual benefits of the 5-Year Action Plan will ramp up considerably during the initial 5-year deployment period, from $4 million in 2023 to $33 million in 2027. From 2028 to 2042, the benefits gradually decline to $24 million in 2042 as certain equipment installed due to the 5-Year Action Plan reaches the end of its useful life (*e.g.*, energy efficiency measures and heating electrification appliances).[20]

FIGURE 7: summarizes the quantified benefits of the changes in system and emissions costs in each year of the study horizon. In the first decade of the study period, the 5-Year Action Plan benefits include avoided power supply costs (energy, capacity, and distribution), primarily due to the energy savings of Pepco DC's proposed energy efficiency programs. As the energy efficient equipment reaches the end of its useful life, the fuel cost and emissions reduction benefits of the Electrifying Transportation portfolio account for a growing share of the total plan benefits in the later years of the horizon.

FIGURE 7: ANNUAL QUANTIFIED BENEFITS OF 5-YEAR ACTION PLAN (NOMINAL DOLLARS)



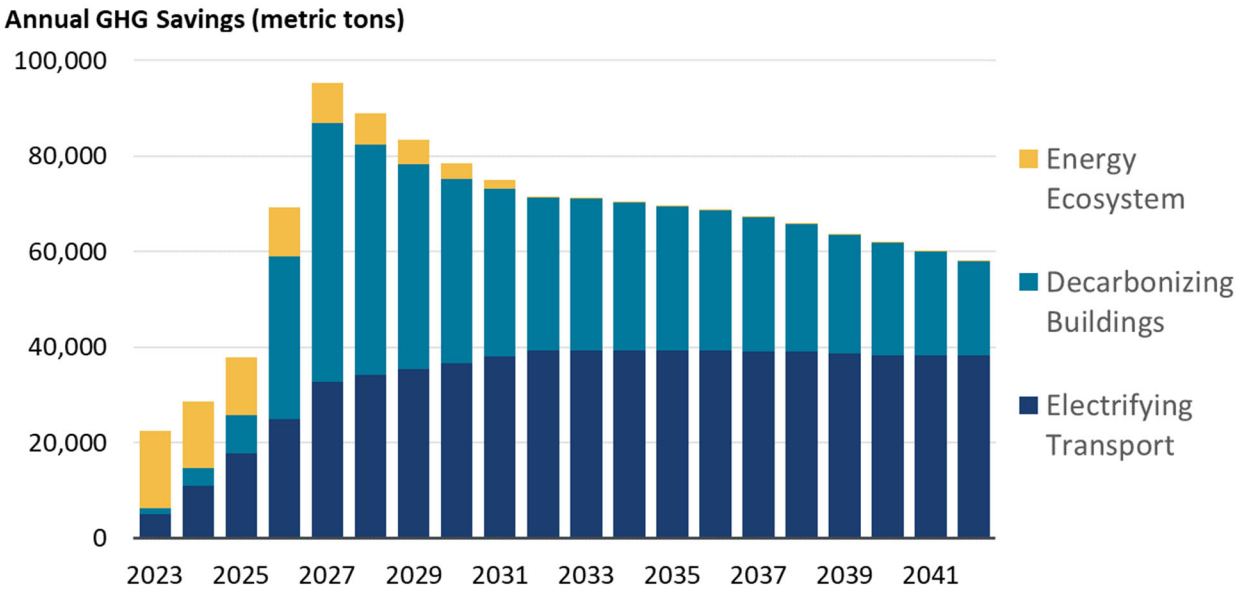
Note: Any costs shown represent a net increase in the associated cost category in that year.

The 5-Year Action Plan will cut future GHG emissions both by reducing total energy use and by facilitating the use of cleaner fuel sources. In 2027, the first year in which all of the programs

[20] Following the initial deployment of EV chargers in the first five years of the 5-year Action Plan, the benefits of EV charger deployments and the associated EV adoption remain steady throughout the 20-year study period because the make ready infrastructure installed through the 5-year Action Plan is likely to remain in operation for at least 20 years, similar to other distribution system facilities.

will have been fully deployed, the 5-Year Action Plan will reduce District GHG emissions by 95,000 metric tons. Of course, Pepco DC and other entities will need to introduce additional initiatives beyond the 5-year Action Plan to sustain or improve upon this annual impact. **FIGURE 8** summarizes the cumulative annual GHG emissions reduction attributable to the 5-Year Action Plan.

FIGURE 8: ANNUAL GHG EMISSIONS REDUCTIONS OF 5-YEAR ACTION PLAN



The 5-Year Action Plan will reduce electricity use, electricity peak demand, natural gas use in buildings, and gasoline use for transportation. In other words, in addition to environmental benefits and cost savings, the 5-year Action Plan will reduce the overall resource needs of the District. **TABLE 6** summarizes these key energy system impacts of the 5-year Action Plan once it has been fully deployed in 2027.

TABLE 6: ENERGY DEMAND AND EMISSIONS REDUCTIONS OF THE 5-YEAR ACTION PLAN IN 2027

SYSTEM METRIC	NET IMPACT OF THE 5-YEAR ACTION PLAN IN 2027
Electricity Consumption	**105 GWh reduction,** or 1.1% of 2020 Pepco DC system-wide electricity sales.
Electricity Peak Demand	**35 MW reduction**, or 1.8% of 2020 Pepco DC system-wide peak demand.
Natural Gas Consumption	**571,000 MMBtu reduction**, the equivalent annual consumption of over 1,000 average-sized commercial buildings.[21]
Gasoline Consumption	**5 million gallon reduction**, the equivalent annual consumption of over 15,000 light duty vehicles.[22]
GHG Emissions	**95,000 metric tons reduction**, the equivalent GHG footprint of over 11,000 residential homes.[23]

Sensitivity Analysis

To determine the sensitivity of our findings to key modeling assumptions, we re-estimated the NPV of the 5-Year Action Plan for a plausible range of key modeling inputs. Specifically, we identified all modeling assumptions that are likely to be key drivers of the results and established a plausible high and low sensitivity value for each. The NPV of the 5-Year Action Plan is then recalculated for each sensitivity assumption individually. **TABLE 7** below shows the high- and low- sensitivity assumptions tested. The "High-Value Case" assumptions are all designed to reflect upside uncertainty in the NPV of the 5-Year Action Plan, whereas the "Low-Value Case" assumptions are designed to represent downside uncertainty.

[21] Average natural gas consumption per 16,000 sq. ft. commercial building in the South Atlantic region is 566 MMBtu according to EIA 2018 CBECS Survey, Tables B1 and C28.

[22] Based on LDV gasoline efficiency assumptions from EIA Annual Energy Outlook 2021, Table 7. Transportation Sector Key Indicators and Delivered Energy Consumption.

[23] Estimated using the EPA's GHG Equivalencies Calculator.

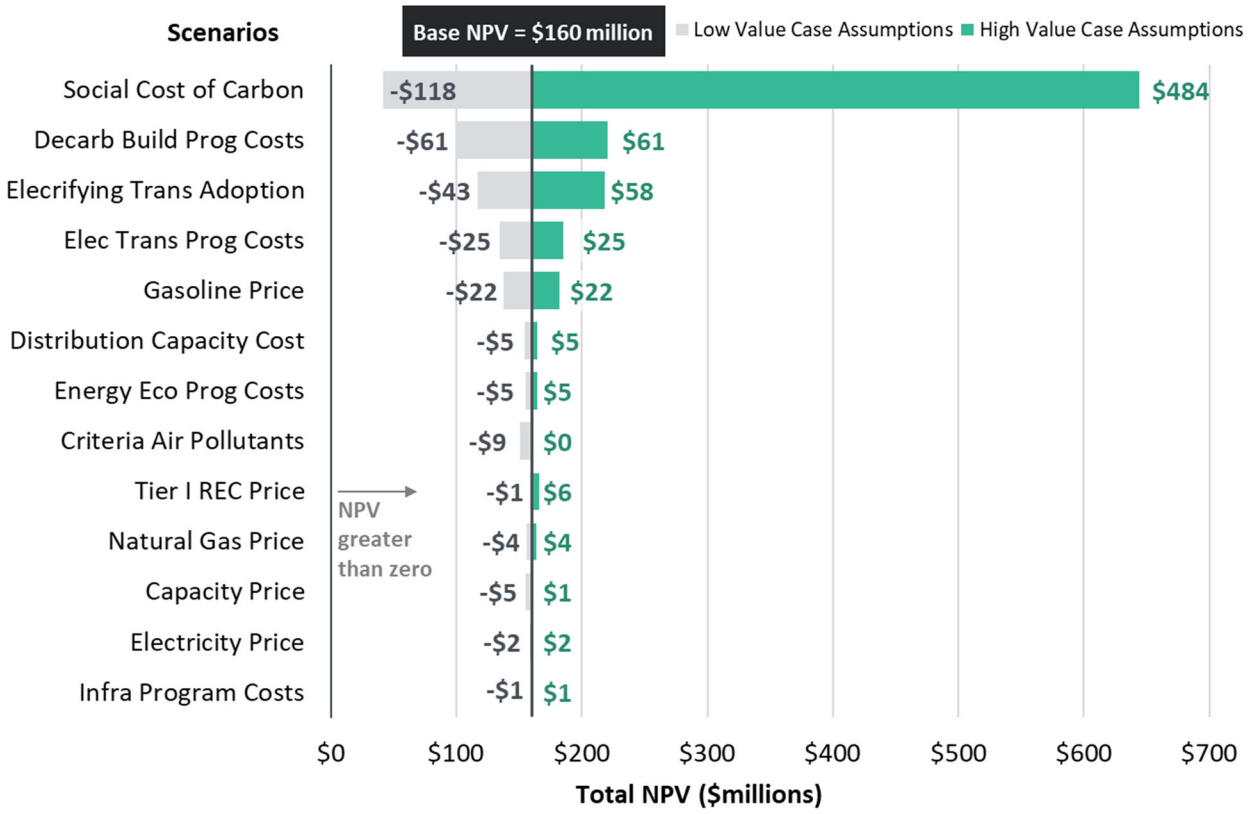
TABLE 7: SENSITIVITY ANALYSIS ASSUMPTIONS

	Base Case Assumption	Low-Value Sensitivity Case Assumption	High-Value Sensitivity Case Assumption
MARGINAL COSTS AND EMISSIONS			
Social Cost of Carbon	SCC @ 2% discount rate	SCC @ 3% discount rate	SCC @ 1% discount rate
Electricity Price	Combination of PJM market prices and Cambium projections	Base electricity prices minus 20% in all years	Base electricity prices plus 20% in all years
Gasoline Price	EIA Annual Energy Outlook forecast	Base gasoline prices minus 20% in all years	Base gasoline prices plus 20% in all years
Natural Gas Price	EIA Annual Energy Outlook forecast	Base natural gas prices minus 20% in all years	Base natural gas prices plus 20% in all years
Capacity Price	Combination of PJM market prices and Cambium projections	5-yr historical average PJM capacity price ($117/kW-yr)	Highest price forecast from Cambium scenarios
Distribution Capacity Cost	$26/kW-yr, based on analysis of Pepco system data	Zero, reflecting a case where the net impact of the CSP is not large enough to trigger meaningful incremental changes in Pepco's distribution plan	$50/kW-yr, which is within the higher end of the range of assumptions used in other utility studies
Tier I REC Price	$10/MWh, based on review of recent market prices	$15-20/MWh, declining to $0 by 2032, based on Brattle analysis (see Appendix A for description)	$45/MWh in all years, based on high end of range of recent historical prices
Criteria Air Pollutants	See Appendix A	Zero, to test a case where this benefit is excluded entirely from the analysis due to data uncertainty	N/A
PROGRAM ASSUMPTIONS			
Transportation Electrification Program Costs	Pepco base cost estimate	Pepco high cost estimate	Pepco low cost estimate
Decarbonizing Buildings Program Costs	Pepco base cost estimate	Pepco high cost estimate	Pepco low cost estimate
Activating the Local Energy Ecosystem Program Costs	Pepco base cost estimate	Pepco high cost estimate	Pepco low cost estimate
Enhancing Infrastructure for Climate Solutions Program Costs	Pepco base cost estimate	Pepco high cost estimate	Pepco low cost estimate
Transportation Electrification Adoption	13,000 light duty EVs adopted due to Pepco charging infrastructure programs	9,000 light duty EVs adopted due to Pepco charging infrastructure programs (see Appendix B)	19,000 light duty EVs adopted due to Pepco charging infrastructure programs (see Appendix B)

FIGURE 9 summarizes the results of the sensitivity analysis. The black vertical line in the middle of the figure represents the NPV of the total 5-Year Action Plan under our base case assumptions. Each horizontal bar indicates the deviation from base case NPV, positive or negative, associated with the High-Value Case and Low-Value Case assumptions for each

assumption. For example, the Low-Value Case assumption for the social cost of carbon (calculated at a 3% discount rate) reduces the Base Case NPV by $118 million, to $36 million, whereas the High-Value Case assumption for the social cost of carbon (calculated at a 1% discount rate) increases the Base Case NPV by $484 million to $638 million.

FIGURE 9: CHANGE IN BASE CASE NPV DUE TO SENSITIVITY CASE ASSUMPTIONS



Note: The impact of each sensitivity case shown should be considered in isolation. The sensitivity cases were defined such that the impacts of individual cases are not additive.

The order in which the sensitivity cases appear in **FIGURE 9** indicates their overall impact on the NPV, with the most impactful sensitivity cases appearing at the top. The Base Case NPV result is most sensitive to the range of plausible assumptions regarding the social cost of carbon, Decarbonizing Buildings program costs, and EV adoption attributable to Pepco DC's charging infrastructure programs. Uncertainty related to marginal energy system costs (*e.g.*, electricity, capacity, natural gas) and costs related to the Activating the Local Energy Ecosystem and Enhancing Infrastructure for Climate Solutions portfolios has very limited impact on the NPV of the 5-Year Action Plan.

The sensitivity analysis also shows that there is significant upside potential associated with the modeling uncertainty. In particular, if one believes that 1% is the appropriate discount rate to

use when calculating the social cost of carbon, the 5-year Action Plan NPV is be roughly four times higher than our Base Case estimate. Further, none of the Low-Value Case assumptions result in a negative NPV. The largest downside results from calculating the social cost of carbon using a 3% discount rate. In that case, the NPV decreases by roughly 75% but still results in net benefits of the 5-year Action Plan of $36 million.

It is important to note that the bars in **FIGURE 9** are not additive. In other words, it is not an appropriate use of this information to construct a "low value scenario" by adding up all of the negative values to represent an aggregate NPV impact. Each of the Low Value Case and High Value Case assumptions are plausible but relatively unlikely to occur. To assume that all of these unlikely assumptions would materialize together, in a single scenario, is improbable. For example, if the Decarbonizing Buildings portfolio costs turn out to be at the high end of the modeled range, it is similarly probable that the Electrifying Transportation portfolio costs could turn out to be at the low end of the cost range. The offsetting impact of generally uncorrelated modeling variables needs to be considered when constructing scenarios based on the information in the sensitivity analysis figure.

Non-Quantified Benefits

In addition to the benefits quantified in the BCA, the 5-Year Action Plan could provide several other benefits. While we do not include an estimate of the monetary value of these benefits in the NPV estimates, they are still important to consider when evaluating the value of the Plan.

- **Improved resilience:** Certain programs in the Plan provide incremental improvements to reliability beyond the baseline levels of Pepco DC's standard service. For example, the Resilience Center program provides on-site solar PV and battery storage which can act as a form of backup power during outages for resource constrained communities. Studies have found that customers significantly value avoiding power interruptions.[24]
- **Indoor air quality:** Converting from gas appliances to electric appliances—such as stoves—can significantly improve indoor air quality and provide associated health benefits. According to a study by the Environmental Protection Agency (EPA), homes with gas stoves can have NO_x concentrations that are 50 to 400 percent higher than homes with electric stoves.[25] In our study, our estimates of the social benefits of reduced criteria air pollutants do not include reductions in indoor emissions due to a lack of relevant data. We estimate

[24] The U.S. DOE and Lawrence Berkeley National Lab have developed the Interruption Cost Estimate (ICE) calculator, which relies on survey data to provide an estimate of the "value of lost load," or the amount customers would be willing to pay to avoid an outage. https://www.icecalculator.com/home.

[25] U.S. EPA. Integrated Science Assessment (ISA) for Oxides of Nitrogen – Health Criteria (Final Report, Jan 2016). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/068, 2016.

that the 5-Year Action Plan would reduce natural gas consumption in buildings by 8.8 million MMBtu over the 20-year study horizon.

- **Natural gas distribution infrastructure cost:** If future natural gas consumption is significantly reduced through the electrification of building heating or through energy efficiency, this could reduce the need for future investments in natural gas distribution infrastructure that otherwise would be required to accommodate at least a portion of that natural gas demand. We developed an estimate of changes in *electricity* distribution costs in the BCA with Pepco DC, but data limitations prevented us from including comparable changes in natural gas distribution costs.

  To provide an order-of-magnitude estimate of the potential value of these natural gas distribution cost savings, we rely on EIA cost forecasts from the Annual Energy Outlook.[26] Specifically, we multiply the annual reduction in natural gas consumption estimated for the 5-Year Action Plan with the difference between wholesale and retail natural gas prices reported in the Annual Energy Outlook for the South Atlantic census region. The NPV over 20 years equals $49 million in avoided gas distribution costs.

- **Transmission cost:** Analysis of demand-side programs often includes an estimate of the avoided transmission investment associated with reductions in electricity demand. The 5-Year Action Plan is expected to produce a relatively modest reduction in electricity demand due to the offsetting impact of electrification and energy efficiency programs. As a result, the impacts of the Plan may not be large enough to defer transmission-scale projects (though they could incrementally contribute to investment deferral if combined with other parallel initiatives that reach the necessary scale). For this reason, transmission benefits are excluded from the analysis. The NPV could modestly increase with the inclusion of transmission benefits; based on our survey of avoided T&D cost assumptions in other utility jurisdictions, transmission benefits often are approximately 25% of the magnitude of the distribution benefit estimate, which would increase net benefits of the 5-year Action Plan by about $1.3 million.[27]

- **Other impacts:** Other potential impacts excluded from the BCA due to low impact, speculative nature, or otherwise being outside the scope of this study's cost-effectiveness

---

[26] While we do not include the gas infrastructure costs in our analysis due to lack of reliable data, we reviewed the incremental difference between wholesale and retail gas costs as a proxy for the gas infrastructure costs. This approach, while imperfect, is consistent with Washington Gas's assessment of similar gas infrastructure costs in its recent Climate Business Plan filing. See ICF, "Opportunities for Evolving the Natural Gas Distribution Business to Support the District of Columbia's Climate Goals" prepared on behalf of AltaGas, 2020.

[27] See Appendix A for Brattle's survey of avoided T&D costs from other utility jurisdictions.

framework include changes in water use, vehicle maintenance costs, property value, jobs, and customer comfort.

IV. Conclusion

This study set out to determine the cost effectiveness of Pepco DC's 5-Year Action Plan by comparing the energy system and environmental benefits that will result from full implementation of the plan to Pepco DC's costs of deploying the programs. Given the diverse programs included in the 5-year Action Plan, we employed a robust bottom-up modeling methodology to account for a comprehensive range of relevant impacts across the District's energy ecosystem.

The energy system cost savings and environmental benefits of the 5-Year Action Plan significantly outweigh the plan's program costs. The net present value of the 5-Year Action Plan is $154 million over the 20-year study period. Every $1 spent by Pepco DC on the 5-Year Action Plan programs is expected to result in roughly $1.68 of quantified benefits.

The 5-Year Action Plan will achieve these benefits partly by reducing the District's energy use, and partly by facilitating the transition from burning fossil fuels to utilizing decarbonized electricity to heat buildings and power transportation. Notably, the 5-year Action Plan is expected to reduce the overall use of every energy source included in this analysis: electricity, gasoline and diesel for transportation and natural gas and other fuels for heating.

Our finding that the 5-Year Action Plan has a positive NPV is robust across a range of alternative assumptions about the system impacts, benefits, and costs of the programs. Further, the analysis likely understates the overall net benefit of the Plan, as there are several additional sources of value that are not quantitatively included in the analysis, such as improved resilience and indoor air quality.

These findings highlight the important role that Pepco DC's 5-year Action Plan will play in facilitating the cost-effective achievement of the District's decarbonization goals. The Plan is a critical first step down the path to the District's goal of net zero economy-wide carbon emissions and will establish a dynamic and adaptable platform for future decarbonization program development.

V. References

1. Alternative Fuels Data Center. *Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite* webtool page. https://afdc.energy.gov/evi-pro-lite

2. California Public Utilities Commission. "California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects." October 2001. cpuc-standardpractice-manual-2001-10.pdf (raponline.org)

3. Council of the District of Columbia. "CleanEnergy DC Omnibus Amendment Act of 2018." D.C. Law 22-257, effective March 22, 2019. https://code.dccouncil.us/us/dc/council/laws/22-257

4. District Department of Transportation. "DC Circulator Battery-Electric Bus Pilot Report." August 2021. https://www.dccirculator.com/wp-content/uploads/2021/09/Final-Electric-Bus-Pilot-Report-v3_8.25.21.pdf

5. District of Columbia Department of Energy and Environment. "Transportation Electrification Roadmap: EV Service Equipment Strategy." June 24, 2021, Powerpoint Presentation. https://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/2021.06.24_DC-TER_SEFG-EV-EVSE-strategy-webinar-slides_final.pdf

6. District of Columbia Public Service Commission. "Renewable Energy Portfolio Standard Report" informational page. https://dcpsc.org/Orders-and-Regulations/PSC-Reports-to-the-DC-Council/Renewable-Energy-Portfolio-Standard.aspx

7. Doll, Scooter. "Current EV registrations in the US: How does your state stack up?" Electrek, August 24, 2021. https://electrek.co/2021/08/24/current-ev-registrations-in-the-us-how-does-your-state-stack-up/

8. EPA. "Technical Bulletin: Nitrogen Oxides (NOx), Why and How They Are Controlled." Prepared by the Clean Air Technology Center, EPA-456/F-99-006R, November 1999. https://www3.epa.gov/ttncatc1/dir1/fnoxdoc.pdf

9. EPRI. "The Impact of Incentives on Electric Vehicle Adoption: National Average Results (2019 Technical Report)." Prepared by The Brattle Group, December 2019. https://www.epri.com/research/products/000000003002017549

10. Hledik, Ryan, Sanem Sergici, Michael Hagerty, and Julia Olszewski. “An Assessment of Electrification Impacts on the Pepco DC System.” prepared by The Brattle Group for Pepco, August 2021. https://www.pepco.com/Documents/1167%20%20Pepco%27s%20Electrification%20Study%20%20082721.pdf

11. ICF. “Opportunities for Evolving the Natural Gas Distribution Business to Support the District of Columbia’s Climate Goals.” Prepared on behalf of AltaGas, April 2020. https://sustainability.wglholdings.com/wp-content/uploads/Technical-Study-Report-Opportunities-for-Evolving-the-Natural-Gas-Distribution-Business-to-Support-DCs-Climate-Goals-April-2020.pdf

12. *In the Matter of the Implementation of Electric and Natural Gas Climate Change Proposals*. Formal Case No. 1167, Order No. 20754 (Public Service Commission of the District of Columbia, June 4, 2021). https://edocket.dcpsc.org/apis/api/Filing/download?attachId=125555&guidFileName=a43e32dd-d6d5-4145-bb8c-e06a8f929775.pdf

13. Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. “Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990.” February 2021. https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

14. Jenn, Alan. “Emissions Benefits of Electric Vehicles in Uber and Lyft Services.” UC Davis: Institute of Transportation Studies, August 1, 2019. https://ncst.ucdavis.edu/research-product/emissions-benefits-electric-vehicles-uber-and-lyft-services

15. National Highway Traffic Safety Administration. *Corporate Average Fuel Economy* informational webpage. https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy

16. National Renewable Energy Laboratory. ‘Standard Scenarios’ informational page. https://www.nrel.gov/analysis/standard-scenarios.html

17. National Renewable Energy Laboratory. *Cambium 2020 dataset*. https://www.nrel.gov/analysis/cambium.html

18. National Transit Database Tables. American Public Transportation Association, 2018. https://www.apta.com/research-technical-resources/transit-statistics/ntd-data-tables/

19. NC Clean Energy Technology Center. *Renewable Portfolio Standard* Program Overview and informational page, Database of State Incentives for Renewables & Efficiency (DSIRE), North Carolina State University, last updated May 21, 2021. https://programs.dsireusa.org/system/program/detail/303

20. New York Department of Environmental Conservation. *Establishing a Value of Carbon: Guidelines for Use by State Agencies*. October 2021. https://www.dec.ny.gov/docs/administration_pdf/vocguidrev.pdf

21. New York Department of Environmental Conservation. *Establishing a Value of Carbon: Guidelines for Use by State Agencies*, "Appendix: Value of Carbon." October 2021. https://www.dec.ny.gov/docs/administration_pdf/vocapprev.pdf

22. New York State Energy Research and Development Authority and Resources for the Future. "Estimating the Value of Carbon: Two Approaches." Revised April 2021. https://media.rff.org/documents/RFF_NYSERDA_Valuing_Carbon_Synthesis_Memo.pdf

23. Nicholas, Michael, Peter Slowik, and Nic Lutsey. "Charging Infrastructure Requirements to Support Electric Ride-Hailing in U.S. Cities." Working Paper 2020-09, 2020 International Council on Clean Transportation, March 2020. https://theicct.org/wp-content/uploads/2021/06/Charging_infrastructure_ride_hailing_US_03242020.pdf

24. Pepco. "Climate Solutions Plan, Pepco's Blueprint to Support the District of Columbia's Climate and Clean Energy Goals." Formal Case No. 1167, June 20, 2021. https://edocket.dcpsc.org/apis/api/Filing/download?attachId=126283&guidFileName=c8e06843-892f-413c-b260-bcbe969be456.pdf

25. PJM Capacity Market ("Reliable Pricing Model") webpage. https://www.pjm.com/markets-and-operations/rpm.aspx

26. PJM. "2016–2020 CO2, SO2 and NOX Emission Rates," PDF. April 9, 2021. https://www.pjm.com/-/media/library/reports-notices/special-reports/2020/2020-emissions-report.ashx

27. PJM. "2023-2024 RPM Base Residual Auction Planning Parameters," Excel Spreadsheet document. November 30, 2021. https://www.pjm.com/-/media/markets-ops/rpm/rpm-auction-info/2023-2024/2023-2024-planning-period-parameters-for-base-residual-auction.ashx

28. Seel, Joachim and Andrew Mills. *Integrating Cambium Marginal Costs into Electric-Sector Decisions*. Berkeley Lab ETA Publications, November 2021, Powerpoint presentation. https://eta-publications.lbl.gov/sites/default/files/berkeley_lab_2021.11-_integrating_cambium_prices_into_electric-sector_decisions.pdf

29. Smart Electric Power Alliance. "Residential Electric Vehicle Time-Varying Rates That Work: Attributes That Increase Enrollment." SEPAPower, November 2019. https://sepapower.org/resource/residential-electric-vehicle-time-varying-rates-that-work-attributes-that-increase-enrollment/

30. The National Energy Screening Project. "National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources." August 2020. https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/.

31. Sergici, Sanem, Ryan Hledik, Michael Hagerty, Ahmad Faruqui, and Kate Peters. "The Customer Action Pathway to National Decarbonization." Prepared by The Brattle Group for Oracle, September 2021. https://www.oracle.com/industries/utilities/opower-energy-efficiency/decarb-report/

32. U.S. Department of Energy. "A National Roadmap for Grid-Interactive Efficient Buildings." Prepared by LBNL, The Brattle Group, Energy Solutions, and Wedgemere Group, May 2021. https://gebroadmap.lbl.gov/.

33. U.S Energy Information Administration. *Annual Energy Outlook 2021*, "Table 57. Components of Selected Petroleum Product Prices." https://www.eia.gov/outlooks/aeo/data/browser/#/?id=70-AEO2021&region=1-5&cases=ref2021&start=2019&end=2050&f=A&linechart=ref2021-d113020a.3-70-AEO2021.1-5~ref2021-d113020a.20-70-AEO2021.1-5&map=ref2021-d113020a.4-70-AEO2021.1-5&ctype=linechart&sourcekey=0

34. U.S Energy Information Administration. *Annual Energy Outlook 2021*, "Table 13. Natural Gas Supply, Disposition, and Prices." https://www.eia.gov/outlooks/aeo/data/browser/#/?id=13-AEO2021&region=0-0&cases=ref2021&start=2019&end=2050&f=A&linechart=~ref2021-d113020a.60-13-AEO2021&map=&ctype=linechart&sourcekey=0

35. U.S Energy Information Administration. *Annual Energy Outlook 2021*, "Table 3. Energy Prices by Sector and Source." https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2021&region=1-5&cases=ref2021&start=2019&end=2050&f=A&linechart=~~ref2021-d113020a.70-3-AEO2021.1-5~ref2021-d113020a.71-3-AEO2021.1-5&map=ref2021-d113020a.4-3-AEO2021.1-5&ctype=linechart&sourcekey=0

36. U.S Energy Information Administration. *Annual Energy Outlook 2021*, "Table 7. Transportation Sector Key Indicators and Delivered Energy Consumption." https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2021&cases=ref2021&sourcekey=0U.S. Energy Information Administration. *Commercial Buildings Energy Consumption Survey (CBECS) 2018*, "Table B1. Summary table: total and means of floorspace, number of workers, and hours of operation, 2012." Energy Information Administration (EIA)- Commercial Buildings Energy Consumption Survey (CBECS) Data.

37. U.S. Energy Information Administration. *Commercial Buildings Energy Consumption Survey (CBECS) 2018*, "Table C28. Natural gas consumption and conditional energy intensity by Census division (part 2), 2012." Energy Information Administration (EIA)- Commercial Buildings Energy Consumption Survey (CBECS) Data.

38. U.S. DOE. *National Plug-In Electric Vehicle Infrastructure Analysis*, "Appendix C: Central Scenario PEV/EVSE Estimates by State." Prepared by the National Renewable Energy Laboratory, September 2017. https://www.nrel.gov/docs/fy17osti/69031.pdf

39. U.S. DOE and Lawrence Berkeley National Lab. "The Interruption Cost Estimate (ICE) Calculator." https://www.icecalculator.com/home.

40. U.S. Energy Information Administration. *Carbon Dioxide Emissions Coefficients* webpage. Last accessed on November 18, 2021. https://www.eia.gov/environment/emissions/co2_vol_mass.php

41. U.S. Environmental Protection Agency. *Light Duty Vehicle Emissions* webpage. Accessed January 12, 2022. https://www.epa.gov/greenvehicles/light-duty-vehicle-emissions

42. U.S. Environmental Protection Agency. Integrated Science Assessment (ISA) for Oxides of Nitrogen – Health Criteria (Final Report, Jan 2016). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/068, 2016. Accessed January 28, 2022.

Appendix A: System Costs and Emissions Detail

Appendix A contains further detail on the methodology and data sources used to develop the forecast of marginal energy system costs and emissions rates used in this study.

Electric Sector Detailed Projections

We rely on the National Renewable Energy Laboratory (NREL) 2020 Cambium data for several of the long-term forecasts of power sector costs and emissions rates used in this study.[28] Specifically, we use the Cambium data sets that contain hourly projections of CO_2 emissions, operating costs, and power system operations by balancing area across the U.S. electric sector. NREL developed the Cambium data sets to supplement their Standard Scenarios forecasts, which have been published annually for several years to provide industry analysts with detailed hourly data on a range of possible future power system outcomes.[29] NREL develops the long-term Standard Scenarios forecasts using ReEDS, a capacity expansion model, and then performs detailed dispatch modeling using Plexos to create the hourly data granularity in the Cambium data sets. We use NREL's Mid-Case as the basis for our assumptions.

We select the NREL projections as the source for this analysis because they are produced by an independent and credible third party. All data is publicly-available and well documented. The Cambium data has been vetted by the national labs and utilized by industry analysts. Recently, Lawrence Berkeley National Lab (LBNL) published a report validating the Cambium output using other data sources.[30] The U.S. DOE relied on Cambium datasets in its *National Roadmap for Grid-Interactive Efficient Buildings*.[31] Additionally, based on our review of other potential sources of long-term forecasts, such as the EIA's Annual Energy Outlook, the NREL Cambium data sets include the most comprehensive and granular set of forecasts that are relevant to our analysis, which allows for internal consistency across the various value streams that are considered in the analysis.

---

[28] The Standard Scenario Cambium data sets are available here: https://www.nrel.gov/analysis/cambium.html. NREL released its 2021 Cambium dataset as we were concluding our analysis for this study. Documentation on the 2021 data was not yet released, so we continued to rely on the 2020 data.

[29] National Renewable Energy Laboratory. 'Standard Scenarios' informational page. https://www.nrel.gov/analysis/standard-scenarios.html

[30] Seel, Joachim and Andrew Mills. Integrating Cambium Marginal Costs into Electric-Sector Decisions. Berkeley Lab ETA Publications, November 2021, Powerpoint presentation. https://eta-publications.lbl.gov/sites/default/files/berkeley_lab_2021.11-_integrating_cambium_prices_into_electric-sector_decisions.pdf

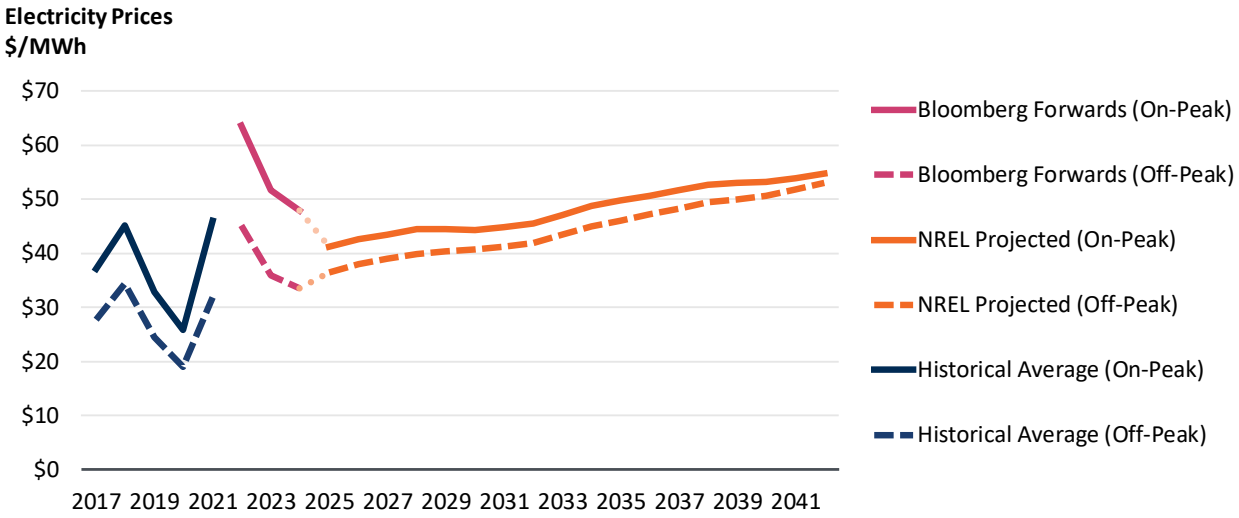
[31] U.S. Department of Energy. "A National Roadmap for Grid-Interactive Efficient Buildings," prepared by LBNL, The Brattle Group, Energy Solutions, and Wedgemere Group (2021). https://gebroadmap.lbl.gov/.

Electricity Generation Costs

To estimate the impact of changes in electricity demand on the cost of generating electricity (fuel, variable O&M), we develop projections of marginal wholesale electricity generation costs based on near-term energy future prices in PJM and long-term projections of wholesale prices from the NREL Cambium data sets.

For the first two years of the study horizon (2023 and 2024), we use monthly PJM on- and off-peak forward prices for the Pepco Zone reported by Bloomberg. To convert the on-peak and off-peak forwards into an hourly price series, we scale the Cambium hourly electricity price forecast for 2023 and 2024 by the average price ratio between monthly average peak and off-peak prices in Cambium and the forward prices. Starting in 2025, we rely directly on the Cambium hourly forecast for the Pepco DC balancing area. **Figure A-1** summarizes the resulting price forecast for all years in the study horizon.

FIGURE A-1: FORECASTED WHOLESALE ELECTRICITY GENERATION PRICES IN PEPCO DC ZONE



Note: Prices are in nominal dollars.

The figure shows that near-term forward prices are significantly higher than recent historical market prices and long-term projections of electricity prices. This disconnect is likely due to the expectation that a recent increase in natural gas prices will increase electricity prices for the next few years compared to recent historical prices. In the longer term, the price trajectory indicates prices will steadily rise, despite an increasingly decarbonized power supply.

Renewable Energy Credit (REC) Costs

To estimate the impact of changes in electricity demand on the costs of achieving the District's Renewable Portfolio Standards (RPS), we develop projections of REC prices based on our analysis of historical REC prices in the District and neighboring states and the projected REC price necessary to attract additional renewables, using NREL Annual Technology Baseline cost projections and energy and capacity market prices from the Cambium data set.

Our review of recent historical Tier 1 REC prices in the District and neighboring states in PJM with RPS requirements, including New Jersey, Delaware, and Maryland indicates that since 2016, Tier 1 REC prices in the District have averaged $4 per MWh, which is $5 per MWh lower than surrounding states that have averaged $9 per MWh. The difference in REC prices reflects the qualification requirements in the respective jurisdictions; all RECs used for compliance in surrounding states must be generated within the PJM market footprint, while Tier 1 RECs to satisfy the DC RPS can be procured from a broader set of locations. However, beginning in 2029, all future Tier 1 RECs in DC must be generated within PJM similar to other states, such that we expect future DC Tier 1 REC prices to more closely align with the prices for neighboring states. We also note that REC prices tend to be very volatile, reflecting changes in state policies concerning future RPS requirements that impact REC demand and renewable energy procurements that impact REC supply, more so than changes in renewable energy costs and market value. For example, Tier 1 REC prices recently rose from 2020 to 2021 by $8–10 per MWh, despite ongoing reductions in the levelized costs of renewable energy resources.

In addition, we develop a forward-looking projection of Tier 1 REC prices necessary to support entry starting with the assumption that the current REC prices in neighboring states are sufficient to support entry of onshore wind and solar generation resources. We estimate future capital cost declines for the renewable resources based on the NREL Annual Technology Baseline and the projected energy and capacity revenues for renewables from the NREL Cambium data sets. Based on these assumptions, Tier 1 REC prices could decrease over the next decade from their current prices to near $0/MWh in the early 2030s.

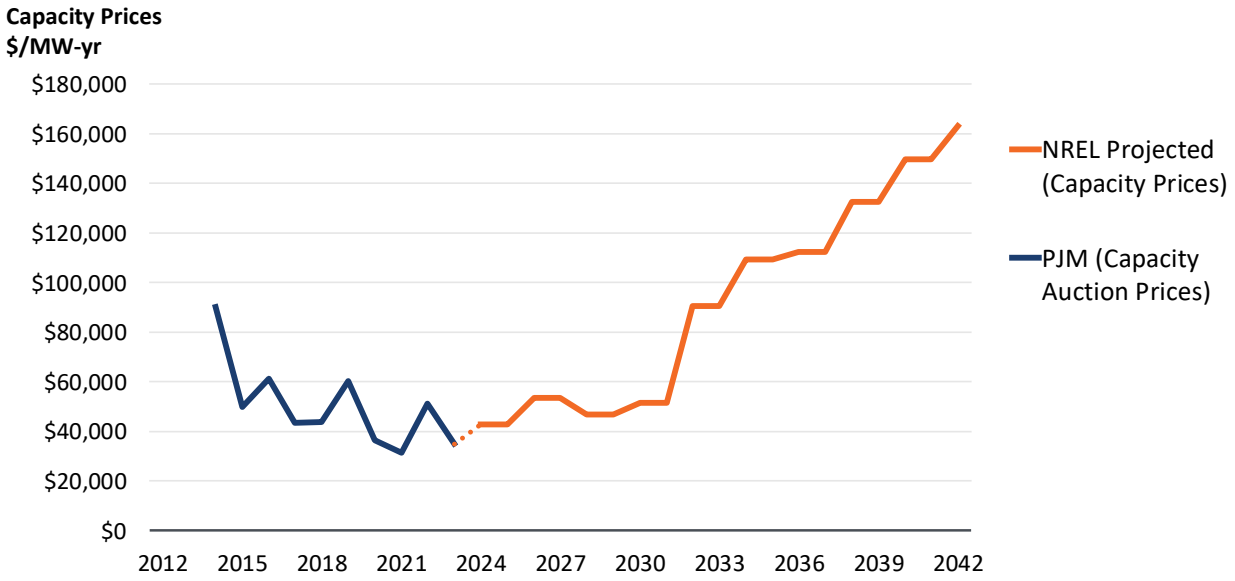
Given the recent trends in historical REC prices and the projected decline in renewable energy resource costs, we assume REC prices over the 20-year timeframe to be on average about $10/MWh (in nominal terms). This REC price is lower than current market prices but higher than the long-term projected price due to the consideration of other factors, including the projected increase in REC demand, rising interconnection costs, and the need to use less desirable locations for development.

We assume that 2.5% of Pepco DC's RECs are met by District-sourced solar resources in the first year of our analysis, and that this share increases to 5% by 2032, in accordance with the Renewable Portfolio Standard Expansion Act of 2016.[32] Locally-sourced SRECs are significantly more expensive than Tier 1 RECs; our price assumptions follow the schedule for the alternative compliance payment for SRECs detailed by the Public Service Commission of the District of Columbia (Commission) in its 2021 Renewable Energy Portfolio Standards Report, which starts at $500/MWh in 2023, ramping down linearly to $100/MWh in 2042.[33]

Generation Capacity Costs

To estimate the impact of changes in electricity peak demand on the costs of generation capacity to maintain system reliability, we develop projections of PJM capacity market prices based on near-term prices from PJM's base residual auction through 2023 for the Pepco DC Locational Deliverability Area and long-term projections from the NREL Cambium data sets starting in 2024.[34] The resulting price forecast is shown in **FIGURE A-2**.

FIGURE A-2: FORECASTED GENERATION CAPACITY PRICES IN PJM



Note: Prices are in nominal dollars.

[32] NC Clean Energy Technology Center. Renewable Portfolio Standard Program Overview and informational page, Database of State Incentives for Renewables & Efficiency (DSIRE), North Carolina State University, last updated May 21, 2021. https://programs.dsireusa.org/system/program/detail/303

[33] District of Columbia Public Service Commission. "Renewable Energy Portfolio Standard Report" informational page. https://dcpsc.org/Orders-and-Regulations/PSC-Reports-to-the-DC-Council/Renewable-Energy-Portfolio-Standard.aspx

[34] PJM BRA results available here: https://www.pjm.com/markets-and-operations/rpm.aspx

Through the early 2030s, the capacity price forecast remains in line with historical PJM capacity auction results. Thereafter, the capacity price rises to a value that reflects the net cost of new entry (Net CONE) in the PJM market. Economic theory supports this view that, in the long run, the capacity market will reach an equilibrium state where the capacity price covers the cost of the last market entrant that is required to ensure system reliability requirements are met (minus the generator's energy and ancillary services value). The projected Net CONE for new gas plants increases over time as the addition of renewable generation greatly reduces the gas plants' energy and ancillary service value. Using the NREL Cambium price forecast provides internal consistency with the electricity generation price forecast. However, recognizing the possibility that capacity market prices may not rise to Net CONE in the future, as noted in Chapter III, we analyze an alternative case that assumes the capacity price remains at historical price levels in real terms.

The capacity reserve margin is assumed to be 8.63%, consistent with PJM's published 2023/2024 base residual auction ICAP forecast pool requirement.[35]

Distribution Capacity Costs

To estimate the impact of changes in electricity peak demand on distribution system capacity costs to maintain system reliability, we develop projections of marginal distribution costs by analyzing projected costs of distribution projects in the District relative to the amount of load growth, with input from Pepco DC.

Changes in electricity peak demand due to the 5-Year Action Plan could increase or decrease the need for investment in electric distribution system capacity. The cost—or avoided cost—of this investment is difficult to estimate for a few reasons. First, the distribution system may not peak at the same time as the bulk system. Different substations may peak at different times, and the impact of the 5-Year Action Plan programs on individual substation load can vary depending on location. In Pepco DC's case, we verified that the peak load contribution days/hours of individual substations are largely consistent with the timing of peak demand on the generation and transmission systems, and that transmission and distribution systems typically peak around the same times. This provides support for using the system peak window for calculating the effect of the 5-Year Action Plan on distribution capacity costs.

Second, marginal distribution costs are typically estimated in a comprehensive marginal cost study that determines the level of investment that is required to meet one increment of growth (load or customer). Pepco DC has not conducted a marginal cost study; therefore, we develop

[35] PJM, 2023-24 Base Residual Auction Planning Parameters.

an estimated value by working with Pepco DC, while applying the core principles of a marginal cost study. The steps in our methodology are summarized below:

1. Pepco DC identified capital projects driven by load growth in the 2022–2026 timeframe. Pepco DC estimates the cost of these projects to be roughly $78 million.

2. Next, Pepco DC identified the substations that drove these load growth-related capital expenditures. We estimate that the load in these three substations would grow by 49.5 MW over the same timeframe as the identified upgrades.

3. These projections imply that the $78 million would be spent to accommodate 49.5 MW additional load in the system, or alternatively $1.6 million/MW.

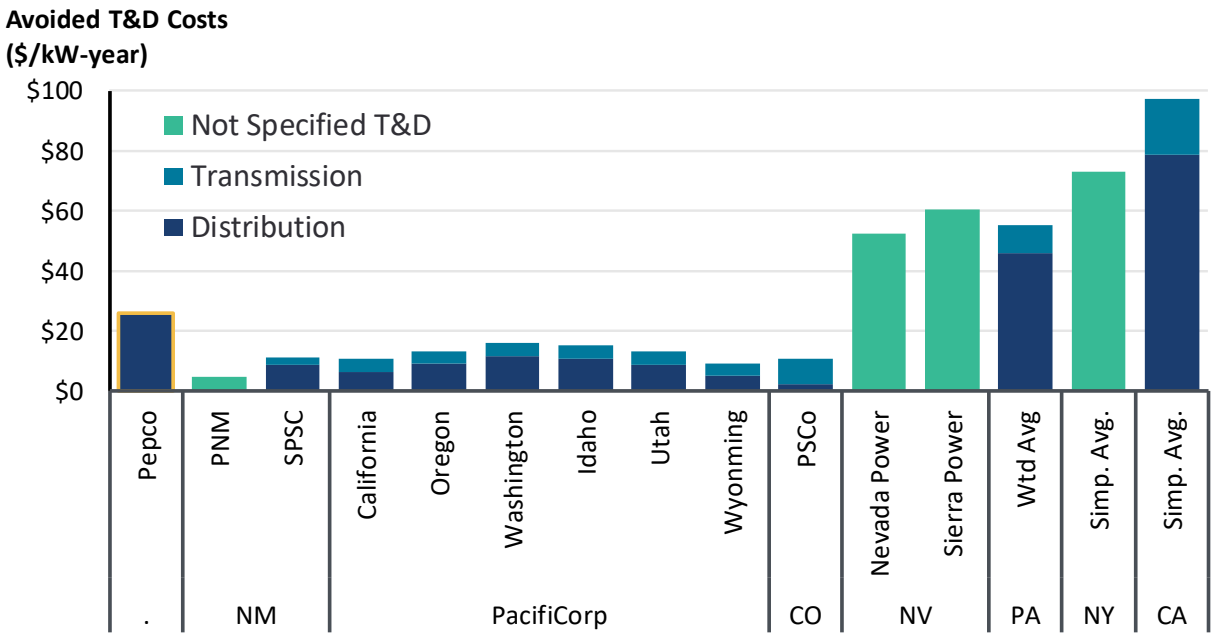
4. Next, we apply Pepco DC's carrying charge of 9% to convert this overnight estimate to an annualized marginal cost estimate, which results in $142,107/MW-year, or $142/kW-year.

5. While $142/kW-year represents the marginal distribution costs in substations experiencing load growth (representing 19% of the load), the rest of the system (81% of the load) is expected to have sufficient capacity to accommodate the load growth and is assigned $0 marginal costs.

6. Since our BCA analysis is for the Pepco DC system as a whole, we calculate the average load-weighted marginal distribution cost of the system as $26/kW-year.

We benchmarked our estimate relative to publicly-available estimates of marginal distribution capacity costs for utilities in other jurisdictions. As shown in **FIGURE A-3**, Pepco DC's marginal distribution cost estimate is within the range estimated in other jurisdictions.

FIGURE A-3: SURVEY OF AVOIDED T&D COSTS FROM OTHER JURISDICTIONS



Transportation and Buildings Fuel Prices

To estimate the avoided costs of reduced transportation and building fuel demand, we rely on projections from the EIA's Annual Energy Outlook for the South Atlantic region (which includes the District) for gasoline, natural gas, heating oil, and propane prices.

For gasoline prices, we use the EIA's projected wholesale motor gasoline price, which excludes distribution costs and federal and local taxes. This is consistent with our use of the wholesale price for electricity used for valuing changes in electricity demand.[36] For natural gas prices, we similarly use the EIA's projected wholesale Henry Hub spot price.[37] For heating oil and propane price forecasts, we rely upon the relevant residential fuel price forecasts by the EIA.[38]

Power Sector Emissions Rate

To estimate changes in power sector air emissions from the 5-Year Action Plan, we rely on recent historical emissions rates reported by PJM in their annual Air Emissions Report, and long-term projections of emissions rates from the Cambium data sets. We describe our

[36] U.S Energy Information Administration, Table 57 of the Annual Energy Outlook 2021.

[37] U.S Energy Information Administration, Table 13 of the Annual Energy Outlook 2021.

[38] U.S Energy Information Administration, Table 3 of the Annual Energy Outlook 2021.

approach to estimating non-power sector emissions in the next section, followed by our description of the assumed societal value of reduced emissions.

Our approach for developing power sector emission rates includes two steps:

STEP 1	Adjust NREL's projected short-run emissions rates to be consistent with recent historical emissions rates reported by PJM
STEP 2	Calculate long-run emissions rates by accounting for the impacts of incremental renewable energy resources added to the system due to the District's RPS requirements.

To develop our approach for estimating power sector emissions, we consider that power sector emissions rates can be measured in at least three ways. The *average emissions rate* represents the average emissions across all generators producing electricity over the relevant time period. The *short-run marginal emissions rate* represents the emissions rate of the marginal generation resource that must operate to meet the historical or forecasted system conditions based on the available resources at any particular time (*i.e.*, the emissions rate of the generator that would be turned up or down in response to a change in load). Finally, the *long-run marginal emissions rate* accounts not only for the emissions rate of the marginal generator in a given hour, but also the emissions rate of new generation capacity that would be added or retired over time due to changes in load and policies.

Conceptually, the long-run marginal emissions rate accounts for the impact of changes in electricity demand over the longer-term. Changes in demand due to the 5-Year Action Plan will occur over the 20-year time period of our analysis and impact the amount of total renewable and conventional resource capacity available to meet future demand. The new resources added to the system to serve growing demand are likely to be cleaner than the existing marginal supply resource due to clean energy policies such as the District's RPS mandates. However, NREL has indicated that its reported long-run marginal emissions estimates in the Cambium data sets are still a work-in-progress. Therefore, to estimate changes in power sector emissions rates, we rely in part on estimates of short-run marginal emissions rates from historical PJM data and from NREL's projections to account for the projected marginal resources. We also account for the incremental impact of the 5-Year Action Plan on renewable energy generation resources via the RPS.

To account for the impact of increasing REC purchases, we assume the District's annual RPS requirement will be fully met through REC purchases, and analyze the extent to which the

hourly generation profile of REC-tied generation aligns with the hourly load impact profile of the proposed programs. For this reason, while Pepco DC is required to achieve a 100% RPS by 2032, REC purchases in 2032 and beyond will not necessarily result in zero power sector GHG emissions.

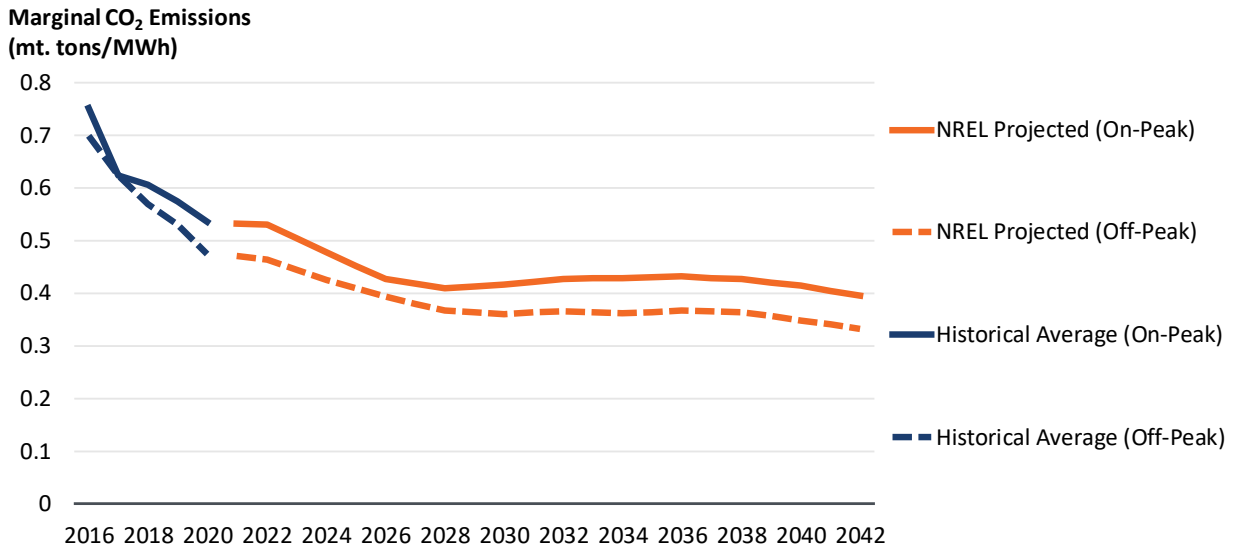
Specifically, we implement the following steps to develop the GHG emissions rates associated with changes in Pepco DC electricity demand:

- **Step 1**: To develop the PJM short-run marginal GHG emissions rate forecast, we first identify recent historical PJM-wide GHG emissions rates based on the 2020 Air Emission report.[39] Using these historical 2020 emissions rates for peak and off-peak periods as the starting point ensures that the emissions forecasts are consistent with actual market data. We then scale the hourly projected short-run marginal GHG emissions rates in the NREL Cambium forecasts to the Pepco DC balancing area to ensure consistency with the recent historical marginal emissions data.[40] The result is an hourly marginal emissions rate forecast for Pepco DC's service territory that is consistent with recent historical data and captures the long-term impacts of an evolving power supply mix forecasted by NREL. **FIGURE A-4** shows the annual emissions rates from PJM's historical data, as well as the scaled forecasted values used in this study.

[39] PJM. "2016–2020 CO2, SO2 and NOX Emission Rates," PDF. April 9, 2021. https://www.pjm.com/-/media/library/reports-notices/special-reports/2020/2020-emissions-report.ashx

[40] A comparison of annual emissions trajectories across several balancing areas within PJM indicated that locational differences are modest in the Cambium forecasts.

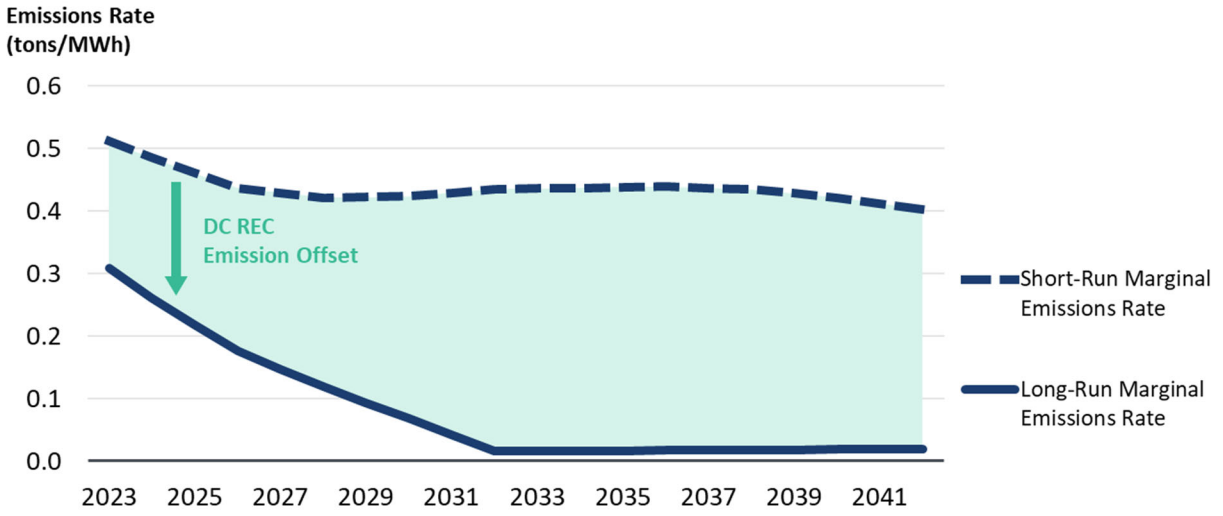
FIGURE A-4: POWER SECTOR SHORT-RUN MARGINAL GHG EMISSIONS RATE



- **Step 2**: To account for the effect of the incremental renewable generation due to the RPS on emissions, we calculate the change in renewable energy generation due to the RPS based on the annual RPS requirements (*e.g.*, 100% in 2032) and the projected change in electricity demand. We assume the renewable generation is equally split between solar and onshore wind for Tier 1 RECs, using renewable generation profiles for each resource from the NREL Cambium data sets. On an hourly basis, we calculate the net change in GHG emissions caused by the combination of the incremental demand and incremental renewable energy generation using the projected hourly short-run marginal emissions rates developed in Step 1. The long-run marginal emissions rate is the net change in emissions divided by the incremental demand. Because of differences in the hourly demand patterns for each portfolio in the 5-Year Action Plan, the calculated long-run emissions rate will differ slightly by portfolio.

Our estimate of the power sector long-run marginal emissions rate is illustrated in **FIGURE A-5**. The figure shows that the long-run marginal emissions rate in 2023 is 40% lower than the short-run marginal emissions rate, which aligns with the DC RPS of 41.25%. The long-run marginal emissions rate decreases as the RPS ramps up to 100% by 2032. From 2032 on, the long-run marginal GHG emissions rate remains slightly positive despite achieving 100% RPS requirements as the incremental renewable energy generation offsets less GHG emissions than the change in electricity demand.

FIGURE A-5: POWER SECTOR PROJECTED MARGINAL GHG EMISSIONS RATES



Note: Long-run marginal emissions rates shown are based on Electrifying Transportation portfolio demand profiles.

We use a similar approach for estimating marginal emissions rates for criteria air pollutants. We rely on recent historical SO_2 and NOx short-run marginal emissions rates estimated by PJM, which were 0.48 lbs per MWh for SO_2 and 0.60 lbs per MWh for NOx.[41] We then develop long-run marginal emissions rates for each pollutant using the trend for GHG emissions shown in the figure above as a proxy, because the NREL Cambium data sets do not include hourly emissions rates for criteria air pollutants.

Transportation and Buildings Fuel Emissions Rate

To estimate the avoided GHG emissions from a reduction of the use of fossil fuels, we rely on the GHG emissions rates for gasoline, natural gas, diesel, and other fuels reported by the EIA.[42] We assume an emission rate of 116.65 lbs/MMBtu for natural gas, 18.74 lbs/gallon of gasoline, 22.46 lbs/gallon of diesel, 138.63 lbs/MMBtu of propane, and 163.45 lbs/MMBtu for heating oil.

To derive criteria air pollutant emissions rates for transportation fuels, we use the EPA's emissions standards for new vehicles of 0.03 grams/mile for NOx and 0.003 grams/mile for PM2.5.[43] We convert these values to pounds per gallon using AEO's 2023 vehicle efficiency

[41] PJM. "2016–2020 CO2, SO2 and NOX Emission Rates," PDF. April 9, 2021. https://www.pjm.com/-/media/library/reports-notices/special-reports/2020/2020-emissions-report.ashx

[42] EIA, Carbon Dioxide Emissions Coefficients, November 18, 2021.

[43] EPA, Light Duty Vehicle Emissions, accessed January 12, 2022.

forecast of 33.3 miles per gallon for LDVs,[44] arriving at 0.0022 lbs/gallon of NOx and 0.00022 lbs/gallon of PM2.5.

We did not estimate the avoided criteria air pollutants for programs in the Decarbonizing Buildings Portfolio. The avoided fuel demand from these programs is significantly smaller than those in the Electrifying Transportation portfolio (roughly 60% lower). Additionally, estimates of the criteria air pollutant emission rates for avoided fuel consumption from these programs vary widely based on the fuel type and the end use (e.g., natural gas for commercial heating versus gasoline for hedge trimmers) and there is considerable uncertainty in the value of avoided emissions from these end uses due to the highly specific and localized health benefits from avoided criteria air pollutant emissions.

Cost of GHG Emissions

The District has set aggressive goals to reduce GHG emissions and mitigate the impacts of climate change and has identified several key pathways to reducing emissions, so this analysis is not intended to assess the cost effectiveness of one pathway over another. Instead, the analysis demonstrates how the portfolio of programs will reduce GHG emissions and thus support the District's efforts to achieving internationally recognized goals to reduce the costs of climate change. For this reason, we value the reduction of GHG emissions at the societal cost of carbon (SCC).

We rely on a recently updated analysis of the SCC by Resources for the Future (RFF) for valuing the change in GHG emissions due to the 5-Year Action Plan programs.[45] The values were recently adopted by the New York Department of Environmental Conservation (DEC) for estimating the costs of changes in GHG emissions.[46] The RFF study uses the results from the same models for estimating the damages caused by climate change as the U.S. Interagency Working Group in the most recent report released in February 2021,[47] but assumes a lower discount rate of 2% based on updated analysis of available market data and reports the values

[44] U.S. Energy Information Administration - EIA - Independent Statistics and Analysis, AEO 2021, Table 7.

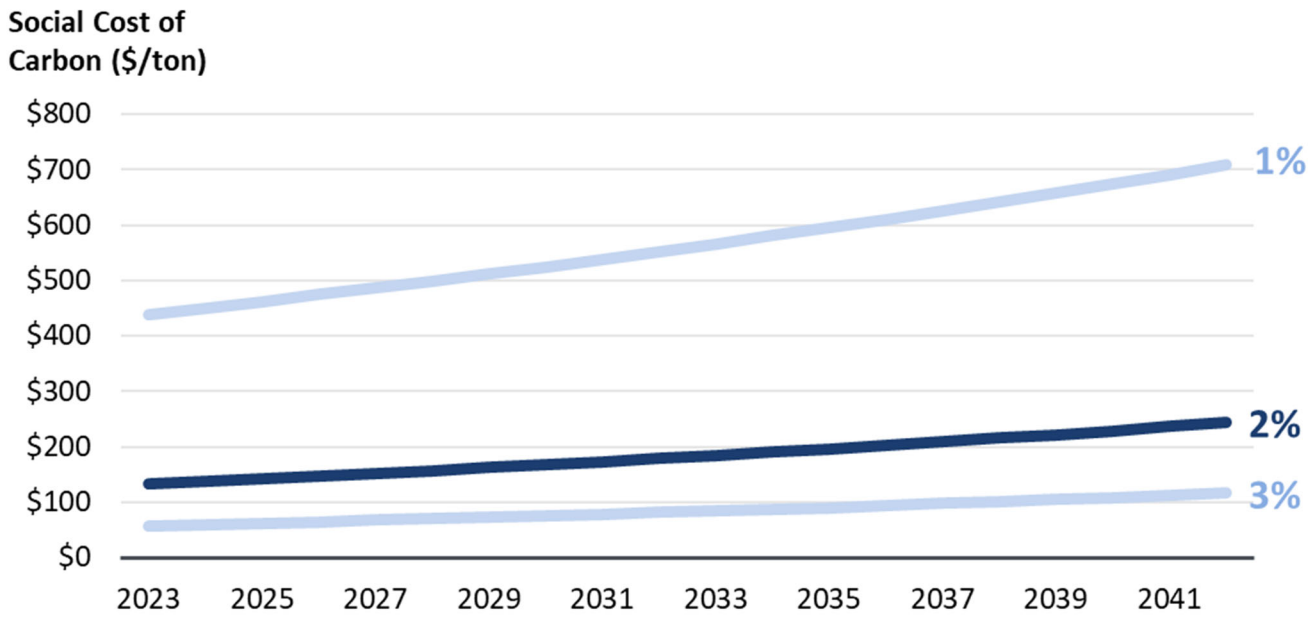
[45] New York State Energy Research and Development Authority and Resources for the Future. "Estimating the Value of Carbon: Two Approaches." Revised April 2021. https://media.rff.org/documents/RFF_NYSERDA_Valuing_Carbon_Synthesis_Memo.pdf

[46] New York Department of Environmental Conservation, Establishing a Value of Carbon: Guidelines for Use by State Agencies, October 2021. The projected social cost of carbon is available here: https://www.dec.ny.gov/docs/administration_pdf/vocapprev.pdf

[47] Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990." February 2021. https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

in 2020 dollars. As **FIGURE A-6** shows, the updated values assuming a 2% discount rate estimate a social cost of carbon of $167/metric ton in 2030.

FIGURE A-6: PROJECTED SOCIAL COST OF CARBON



Notes: Values shown in nominal dollars. Percentages indicate discount rate assumed when calculating the costs.

Cost of Criteria Air Pollutant Emissions

The literature on the value of reducing criteria air pollutants identifies a wide range of potential estimates. The societal costs of criteria air pollutants vary depending on many factors, including the source and location of the emissions. For consistency across sources, we identify estimates for several pollutants and sources in regulatory filings by the National Highway Traffic Safety Administration (NHTSA) in its proceedings related to the updated Corporate Average Fuel Efficiency (CAFE) standards.[48] As there is a significant range in the societal costs of criteria air pollutants, we use the lower end of the range for estimating the benefits of the 5-Year Action Plan, which result in a conservative estimate of benefits from reduced criteria air pollutants.

[48] National Highway Traffic Safety Administration. Corporate Average Fuel Economy informational webpage. https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy

FIGURE A-7: SOCIETAL COSTS OF EMISSIONS

	Power Sector Costs ($/ton)			Transportation Costs ($/ton)	
	NOx	**SOx**		**NOx**	**PM2.5**
NHTSA Low (2025)	$7,100	$44,000	NHTSA Low (2025)	$7,500	$740,000
NHTSA High (2025)	$16,000	$110,000	NHTSA High (2025)	$17,000	$1,700,000
Assumed Value	**$7,100**	**$44,000**	**Assumed Value**	**$7,500**	**$740,000**

Appendix B: Program Impacts Modeling Detail

Appendix B provides a description of key assumptions for modeling the system impacts of each of the portfolio programs for which we estimate benefits. We combine these estimated changes in the consumption of electricity, gasoline, natural gas, or other fuels with the marginal system costs and emissions described in Appendix A to produce an estimate of the net benefits of each 5-Year Action Plan portfolio.

Electrifying Transportation Programs

Charger Deployment Programs

We develop an annual forecast of EV adoption by assuming EV adoption will increase linearly through 2030 to reach the DOEE's goal of 75,000 EVs on the road by 2030. The DOEE's goal for EV adoption represents about 15% of the total cars in DC in 2030, [49] which is consistent with a recent forecast we developed of aggressive but achievable EV adoption by 2030 for Oracle Utilities.[50]

A key assumption in our analysis of the Electrifying Transportation impacts is the relationship between charger deployment and the incremental adoption of EVs due to that charger deployment. As EV adoption increases, multiple types of chargers will be necessary at locations across the District. The EV charger programs in the 5-Year Action Plan reflect the various types and locations of chargers necessary to support EV adoption, targeting charging infrastructure at residences (both single family homes and multi unit dwellings), work places, and key corridors. In our evaluation of the impacts of charger programs on EV adoption, we primarily focus on the deployment of public and workplace chargers to estimate the incremental impact of District-wide EV adoption. The other types and locations for EV chargers are also critical investments to support EV adoption, but target a specific subset of charging needs that are less likely to drive the overall EV adoption. For example, the Residential and MUD charger programs will support certain customers within that group to charge at home, and thus ensure a broader set of customers can participate in reducing GHG emissions.

To estimate the system impacts of the programs that target charger deployment, we use three different approaches to project the amount of incremental EV adoption that could be

[49] We forecasted total vehicle registrations to 2030 (sourced from DC's Department of Motor Vehicles), using the 3% CAGR experienced between 2010 and 2019. Adoption values are calibrated using DOEE's goal of 75,000 ZEV registrations by 2030, and AFDC estimate of 2,360 EVs currently on the road in DC.

[50] The Customer Action Pathway to National Decarbonization (2021). Prepared by The Brattle Group for Oracle. https://www.oracle.com/industries/utilities/opower-energy-efficiency/decarb-report/

attributed to the Plan's proposed charger deployment, leveraging diverse methodologies and data sources. The approaches result in an estimate of an additional 13,000 to 19,000 EVs by 2027 due to the deployment of EV chargers.

- **Approach 1:** The first approach relies on our independent estimate of the role that public chargers will have on increasing EV adoption. We first estimate that the scale of public Level 2 chargers necessary to support EV adoption in the District is 38 public and workplace L2 charger ports for every 1,000 EVs, based on projections from EVI Pro-Lite.[51] As the Destination Charging Program aims to deploy 2,000 L2 charger ports, we calculate that this scale of EV charger deployment will support about 53,000 EVs. Knowing that the amount of public charging infrastructure is only one of several key factors that will drive EV adoption, we estimate based on internal EV adoption modeling that 25% of incremental EV adoption in the future can be attributed to the buildout of public chargers. Applying 25% to 53,000 EVs results in a projection of 13,000 incremental EVs due to the charger programs.
- **Approach 2:** As the purpose of the 5-Year Action Plan is to facilitate the achievement of the climate policy goals by the District, we also assess the extent to which the buildout of public EV charging infrastructure by the Plan would achieve the amount of chargers projected to be necessary by 2030 by the DC Department of Energy & Environment (DOEE). To support their goal of 75,000 EVs on the road in 2030, the DOEE projects the District will need 4,535 L2 and 542 DCFC ports.[52] As noted above, the Destination Charging Program supports 2,000 L2 ports, which is 40% of L2 need, and the Key Corridors Charging Program supports 40–60 DCFCs, or about 10% of DCFC need. On average, the Pepco DC programs will support about 25% of the 2030 public charging needs, assuming both types of chargers are equally necessary to drive EV adoption. Applying 25% to the 75,000 EV goal by 2030 results in a projection of supporting 19,000 EVs in the District.
- **Approach 3:** We rely on the results of a 2019 study for EPRI, in which consumers were surveyed about their preferences and the key drivers of purchasing an EV.[53] The study finds that the addition of one charging station per 10,000 households increases the baseline market share of EV sales by around 2.5%. Our analysis of the findings results in an

---

[51] Alternative Fuels Data Center Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite. https://afdc.energy.gov/evi-pro-lite

[52] District of Columbia Department of Energy and Environment. "Transportation Electrification Roadmap: EV Service Equipment Strategy." June 24, 2021. https://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/2021.06.24_DC-TER_SEFG-EV-EVSE-strategy-webinar-slides_final.pdf

[53] The Impact of Incentives on Electric Vehicle Adoption: National Average Results (2019 Technical Report). Prepared by The Brattle Group for the Electric Power Research Institute. https://www.epri.com/research/products/000000003002017549

approximate estimate of 5 to 10 new EVs adopted for every new public charging port deployed. Given Pepco DC's proposal to deploy 2,000 L2 public and workplace charger ports, the result is an estimate of around 15,000 EVs (10,000 to 20,000 EVs based on the full range) adopted in the District due to Pepco DC's charging infrastructure deployment programs.

Recognizing uncertainty in these estimates, when estimating the benefits of the portfolio of charger programs we rely on the more conservative estimate that the Pepco DC charger programs in the 5-year plan will increase adoption by 13,000 EVs.

We also tested the impact of higher and lower values through sensitivity analysis. We derive a lower adoption sensitivity of 9,000 EVs by increasing our charger to EV ratio from 38 to 55 L2 chargers per 1,000 EVs in the first approach described above. This new ratio represents the average L2 charger to EV ratio across 9 U.S. cities with high EV penetration.[54] We apply the higher ratio to the Destination Charging program's deployment goal of 2,000 L2 chargers and the 25% de-rate to the resulting adoption level. For the higher adoption sensitivity, we use 19,000 vehicles adopted by 2027, the value on the high end of the range we estimated.

We assume the adoption of EVs occurs linearly over the five years of the program and that the chargers will operate throughout the 20 year life of the BCA. We also assume that the incremental EVs adopted due to the charger deployment will be replaced by new EVs, such that the chargers deployed through the 5-Year Action Plan will continue to support about 13,000 EVs for 20 years.

We then estimate the system impacts of the incremental adoption of EVs based on the following assumptions:

- **Vehicle Types:** We assume a mix of EV models (sedans vs. SUVs), types (fully electric Battery Electric Vehicles, or BEVs, and partially electric Plug-In Hybrid Electric Vehicles, or PHEVs), and electric-drive ranges. The most common vehicles are BEV sedans (41% of all EVs) and BEV SUVs (29%), with the remaining 30% being a mix of PHEVs.
- **Annual Mileage:** We estimate an annual average vehicle miles traveled (VMT) of about 10,000 miles per vehicle.[55] We distribute this annual VMT across quarters and weekdays/weekends according to historical LDV driving patterns. We assume battery

[54] National Plug-In EV Infrastructure Analysis (2017). NREL, Appendix C.

[55] Based on forecasts of District-wide VMTs and FHWA 2019 data detailing the number of passenger cars and light trucks in the District

electric vehicles drive 100% electric miles, while PHEV Sedans and SUVs drive between 37% and 55% electric miles annually.

- **Vehicle Efficiency:** We assume an average efficiency of 3 miles per kWh and adjust the efficiency by quarter to account for the impact of temperature.[56] For calculating the avoided gasoline usage, we use the projected efficiency of internal combustion engine light duty vehicles of 32.5 miles per gallon from the AEO 2020 Reference Case.
- **Charger Load Profiles:** We develop an average 24-hour load profile for both EVs and PHEVs by charger type based on daily charging patterns from EVI Pro-Lite. We re-distribute the demand based on DC-specific considerations, assuming about 55% of charging occurs at home with the remaining demand split between workplace and public charging. We then scale up demand by 10% for L2 chargers and 16% for DCFC chargers to account for wall-to-charger losses.

Rideshare & Taxi Charging Hubs

- **EV Adoption:** We estimate that 508 electric rideshare vehicles or taxis could be supported by the 5-Year Action Plan's proposal to deploy 100 dedicated rideshare chargers, based on the estimated level of charging infrastructure requirements needed to support electric ride-hailing.[57]
- **Annual Mileage:** We scale our daily average kWh per day estimate for non-rideshare LDVs by a factor of 6 to reflect the greater miles travelled by taxis compared to personal vehicles. Rideshare vehicles drive between 5 and 7 times more miles per day than non-rideshare vehicles.[58]
- **Charger Load Profiles:** We create a daily charging profile based on charging patterns observed in San Francisco that is slightly flatter than non-rideshare vehicles, with more

[56] Our efficiency assumptions are sourced from EVI Pro-Lite, an NREL tool that provides location-specific demand profiles for LDVs. https://afdc.energy.gov/evi-pro-lite

[57] Nicholas, Slowik, & Lutsey (2020). Charging Infrastructure Requirements to Support Electric Ride-Hailing in U.S. Cities. 2020 International Council on Clean Transportation.

[58] Jenn, Alan (2019). Emissions Benefits of Electric Vehicles in Uber and Lyft Services. UC Davis Institute of Transportation Studies. The study compiles charging frequency figures at the 10-minute level for rideshare and non-rideshare vehicles for three cities in California; we use the San Francisco figure as our proxy for DC and extract out a daily rideshare load profile.

charging occurring in the morning hours and late at night.[59] We assume rideshare driving patterns are consistent across weekdays and weekends.

- **Efficiency:** We assume the same efficiency as non-rideshare LDVs.

Transit Bus Charging

- **Participation:** Based on the program size estimate developed by Pepco for the 5-year Action Plan, we assume that 12 buses will be electrified, with a linear ramp-up in participation over the 5-year program deployment period.
- **Daily Mileage:** We assume 75 miles per day per bus based on DC-specific mileage of the WMATA and DDOT bus fleets in 2018.[60]
- **Efficiency:** We assume an efficiency of 1.75 miles per kWh in the summer and 1.51 miles per kWh in the winter.[61] We estimate avoided diesel fuel consumptions based on the efficiency of diesel-fueled buses reported in the AEO 2020 reference case.
- **Charging profiles:** We develop a charging profile with higher charging levels between 6 pm and 9 pm, with lower levels of charging overnight based on reported charging profiles from SCE's Quarterly Charge Ready Pilot Report from 2020.

Residential EV Charging TOU program

- The 5-Year Action Plan includes a new EV time-of-use (TOU) tariff specifically tailored to EV load as opposed to the whole house load (as it is the case with the R-PIV tariff). The TOU structure will be applicable to just the generation component of the tariff. EV owners with smart L2 chargers will be eligible for this rate.
- There were 2,360 Light Duty EVs registered in DC in 2021.[62] Given that the DOEE has set a target of 75,000 EVs on the road by 2030, we assume a linear projection between 2021 and 2030 to reach that goal.

---

[59] Jenn, Alan (2019). Emissions Benefits of Electric Vehicles in Uber and Lyft Services. UC Davis Institute of Transportation Studies.

[60] National Transit Database Tables. American Public Transportation Association, 2018. National Transit Database Tables - American Public Transportation Association (apta.com)

[61] DC Circulator Battery-Electric Bus Pilot Report. District Department of Transportation, August 2021. Microsoft Word - Final Electric Bus Pilot Report v3_8.25.21.docx (dccirculator.com). We assumed a Proterra Catalyst 40-foot electric bus, as a proxy for electric bus efficiencies in the District. We model a 14% decline in efficiency in the winter months, consistent with findings from a 2021 DDOT Battery Electric Bus Pilot Report.

[62] Doll, Scooter. "Current EV registrations in the US: How does your state stack up?" Electrek, August 24, 2021. https://electrek.co/2021/08/24/current-ev-registrations-in-the-us-how-does-your-state-stack-up/

- Next, we project the share of the total EVs on the road from 2021 through 2030 with access to Level 2 chargers. We start at 5% in 2023 and ramp up to 75% by 2030. Of the EV customers with L2 chargers, we assume that 5% of the customers will sign up on the EV TOU rate, ramping up to 40% by 2030.[63]
- We use the R-PIV peak window (12–8 pm) and estimate that EV TOU participants would shift 85% of their peak EV charging load to the off-peak period.[64]
- The program is assumed to provide capacity, energy, and distribution cost savings as a result of daily load shifting from peak to off-peak periods.

Decarbonizing Buildings Programs

Energy Efficiency

The 5-Year Action Plan includes a suite of 20 energy efficiency programs proposed in Formal Case 1160 (FC 1160) to support residential and commercial energy efficiency and demand response initiatives. As noted elsewhere in this report, our study analyzes only the impacts, costs, and benefits of a two-year extension of those programs. We do not analyze the first three years of program deployment, due to those being under consideration in a separate ongoing regulatory proceeding.

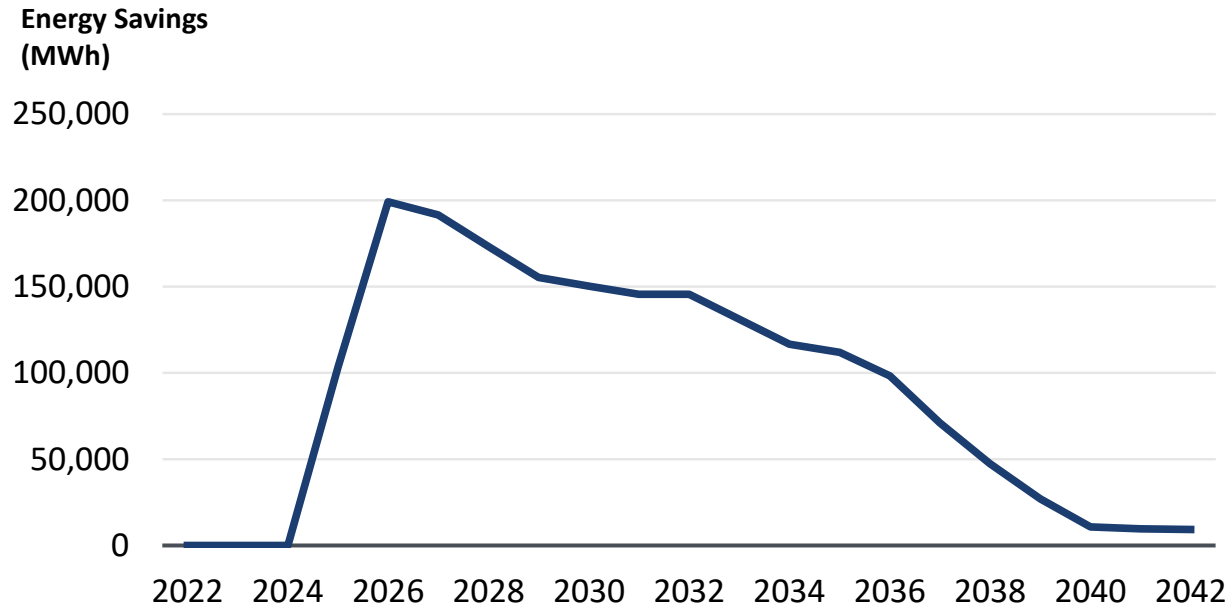
Pepco DC provided seasonal (winter/summer) peak and off-peak energy savings, system peak demand savings, and natural gas savings for each of the energy efficiency and demand response programs. We multiply these energy and peak demand savings by the marginal costs and emissions forecasts to estimate total program benefits.[65] **Figure B-1** illustrates the annual electricity savings attributable to the portfolio with the decline over time being due to the assumption that the equipment will not be replaced upon expiration.

[63] Based on a recent SEPA survey, average EV TOU participation rate is 20% for utilities that actively market these rates, in some cases reaching 70%. See for more information: https://sepapower.org/resource/residential-electric-vehicle-time-varying-rates-that-work-attributes-that-increase-enrollment/

[64] This was modeled based on SDG&E's EV pricing pilot that found that the customers with 2: 1 ratio shifting 73% of their usage to off-peak and those with 3.8:1 ratio shifting 84% of their peak usage to off-peak.

[65] Note that this analysis uses different marginal costs and emissions forecasts than were used in the FC 1160 filing, so the two studies will produce different benefit-cost ratios (though both studies conclude that the portfolio is cost-effective).

FIGURE B-1: MODELED ANNUAL ELECTRICITY SAVINGS OF 2-YEAR EXTENSION OF PEPCO DC'S ENERGY EFFICIENCY INITIATIVE



Appliance Electrification

The 5-Year Action Plan includes three programs to electrify end-use applications in residential and commercial buildings that currently rely on direct use of fossil fuels: Appliance Electrification Program, Dedicated LMI Electrification (Owner-Occupied) Program, and Dedicated LMI Electrification (Rental Properties) Program. In addition, the plan includes two programs to develop the necessary infrastructure to support building electrification: Distribution System Power-Up Rebate Program and Rebates for Behind-the-Meter Heavy Up Program.

For analyzing the system impacts of these programs, Pepco DC provided a projection of the level of adoption, avoided fuel demand, and additional electricity demand for each program.[66] The programs include the electrification of nearly 9,000 electrified appliances by residential customers and about 400 by commercial customers. The majority of the avoided fuel usage is from the electrification of space heating (68%) and water heating (17%), with additional electrification from cooking appliances (ovens, ranges, steam cookers, and griddles) and other appliances (fireplaces, string trimmers, *etc.*). Nearly all of the avoided fuel is from reduced demand for natural gas (95%) with more limited reductions in heating oil (3%), propane (1%), and gasoline (0.2%).

[66] The program impacts were provided by Pepco DC.

TABLE B-1: BUILDING ELECTRIFICATION PARTICIPATION BY 2026

End Use	Participants			Fuel Savings			Savings per Participant		
	Residential	Commercial	Total	Residential	Commercial	Total	Residential	Commercial	Total
	#	#	#	MMBtu	MMBtu	MMBtu	MMBtu	MMBtu	MMBtu
Space Heating	2,237	36	2,273	357,912	3,367	361,280	160	94	254
Water Heating	1,703	146	1,849	83,578	5,286	88,864	49	36	85
Cooking	1,557	90	1,646	62,665	439	63,104	40	5	45
Other	3,400	142	3,542	16,516	362	16,878	5	3	7
Total	**8,897**	**413**	**9,310**	**520,671**	**9,454**	**530,126**	**254**	**138**	**392**

Pepco DC also provided the total annual electricity demand (in kWh) and summer/winter peak demand (in kW) across all of new electrification demand. We estimate the electric power system impacts of the incremental electrification demand by developing hourly demand profiles based on our recent analysis of historical energy demand patterns in the District and daily demand shapes from EPRI.[67]

DSM Expansion

The DSM Expansion program consists of three sub-programs: Battery Storage, EV Charger, and the Smart Thermostat Flexible Load Management (FLM) Pilot.[68]

Battery Storage Sub-Program

- The Battery Storage Sub-Program allows Pepco DC to manage behind-the-meter batteries during a limited number of events per year in order to reduce system costs and/or improve reliability.
- We assume 100 participants at steady state enrollment based on Pepco DC's projected range of 60 to 140 in the 5-year Action Plan. We assume 5-year linear growth from the program's introduction to this steady state enrollment level, a 10-year battery life, and no equipment replacement costs or further benefits upon expiration.
- Battery capacity is similar to that of a Tesla Powerwall (7 kW / 13.5 kWh) with two batteries installed for each participant. We assume 20% of the battery's capacity is reserved for customer use during DR events.
- The 1.9-hour duration battery has an effective load carrying capability (ELCC) of 48%, assuming that 4 hours would be needed to earn full capacity credit in the PJM capacity

[67] See Ryan Hledik, Sanem Sergici, Michael Hagerty, and Julia Olszewski, "An Assessment of Electrification Impacts on the Pepco DC System," prepared for Pepco, August 2021.

[68] While the smart thermostat program is a pilot and therefore not subject to cost-effectiveness analysis, we have included it in the study because it is part of the broader full-scale DSM Expansion program.

market. Combined with the 20% reduction noted above, the batteries installed at each participant site have a total capacity credit of 5.4 kW.

- Only capacity value is estimated for the Battery Storage sub-program. DR events are anticipated to be infrequent, so the program will have minimal impact on electricity costs or emissions.

EV Charger Sub-Program

- The EV Charger Sub-Program allows Pepco DC to manage the EV charging of participants during demand response events.
- We assume 600 participants based on Pepco DC's projected range of 390 to 920 in the 5-year Action Plan. We assume 5-year linear growth from the program's introduction to this steady state enrollment level, 20-year equipment life, and no equipment replacement costs or further benefits upon expiration.
- There are 67 demand response events per year that occur when the load reductions are expected to provide the largest capacity and energy benefits (3 pm to 11 pm on weekdays primarily in the summer).
- During each DR event, 90% of available participating charging load is curtailed, assuming 10% participant override. The curtailment window lasts 8 hours, consistent with the duration of the peak period of Pepco DC's proposed EV TOU rate. All curtailed load is shifted to the 6-hour period in the middle of the night when average energy prices are lowest (midnight to 6 am). On other days of the year, there is no change in charging load attributable to the EV Charger Sub-Program.
- The program is assumed to provide capacity, energy, and distribution cost savings.

Smart Thermostat FLM Sub-Program

- The Smart Thermostat FLM Sub-Program allows Pepco DC to make subtle but frequent changes to the set point in participant's smart thermostat settings to provide a variety of grid benefits.
- We assume 2,000 participants based on Pepco DC's projected range of 1,000 to 3,000 in the 5-year Action Plan. We assume 5-year linear growth from the program's introduction to this steady state enrollment level, a 10-year thermostat life, and no equipment replacement costs or further benefits upon expiration.
- There are 200 DR events per year. Each event is assumed to be 4-hours long, which is a typical duration for a DR event. Events are called on the days of the year that provide the

most value. In the case of the Smart Thermostat FLM Sub-Program, that is 5 pm to 9 pm in the summer (6 pm to 10 pm in the winter) on weekdays, primarily in August, July, and January.

- Over each 4-hour DR event, each participant provides 25% of the impact that could be expected from a participant in a conventional thermostat-based DR program with a limited number of events per year. This is because, as stated in the 5-year Action Plan filing, participants may only be controlled for 15-minutes per hour. The result is an assumed 0.2 kW demand reduction per participant per event.
- The Smart Thermostat FLM Sub-Program is assumed to provide capacity, energy, and distribution capacity savings as a result of the frequent load curtailment events.

Dynamic Pricing Program

- Pepco DC's proposed dynamic pricing program is a Critical Peak Rebate (CPR) program in which participants are paid rebates for reducing their usage below a calculated baseline on a number of system critical event days.
- Residential customers with AMI meters and enrolled in the Company's Energy Wise Rewards (EWR) direct load control program are eligible for participation, while customers choosing to participate in a third-party curtailment service provider's demand response program that earns revenues in the PJM market are not eligible for participation. There are 25,000 eligible customers participating in the EWR program, on average delivering 0.75 kW savings.
- Using the average projected capacity price for 2022–2026 and assuming 20% derate for DR availability, we calculate the capacity value of CPR impacts to be $33.6/kW-year. Assuming that there will be five events in each summer season, each lasting 5 hours, we derive the critical peak rebate value of $1.22/kWh.
- Given that Pepco DC's all-in rate is approximately $0.12/kWh, this rebate value implies a peak/off peak price ratio of 11.2. Based on our database of dynamic pricing programs and peak impacts, we estimate the expected peak reduction will be 26%, based on programs that paired dynamic pricing with enabling technologies.
- When applied to the peak load contribution of an average residential customer with central air conditioning (3.97 kW), we estimate the combined impact of CPR and EWR programs to be 1.04 kW per participating customer and the incremental impact of the CPR program is 0.29 kW (1.04 kW minus 0.75 kW) per participant.

- We expect 85–90% of the EWR customers to actively participate in the program during the first five years, leading to approximately 6.5 MW peak demand reduction at the system level.
- The program is assumed to provide capacity and distribution cost savings as a result of five simulated critical event days.
- We use the R-PIV peak window (12–8 pm) and estimate that EV TOU participants would shift 75% of their peak EV charging load to the off-peak period.[69]

Expanded RPIV Rate to all SOS residential customers

- The 5-year Action Plan proposes to expand the R-PIV time-of-use rate currently offered to the EV customers (on a whole-house basis) to all residential standard offer service (SOS) customers on an opt-in basis.
- In 2021, Pepco DC served 259,083 SOS customers; we apply the residential customer growth rate of 2.3% to forecast the SOS customers for the first five years of the 5-year Action Plan. We assume 2% participation in the RPIV rate in year one reaching to 12% at year five of the Plan.
- The current R-PIV rate has a summer peak to off-peak ratio of 2.4 and winter peak to off-peak ratio of 3.0. These ratios respectively imply peak demand reductions of 5.8% and 7.3%, on a per customer basis, based on our database of time-varying programs and peak demand reduction impacts.
- The program is assumed to provide capacity, energy, and distribution cost savings as a result of daily load shifting from peak to off-peak periods

Activating the Local Energy Ecosystem Programs

Green Rider Expansion

- The 5-Year Action Plan proposes to expand the eligibility for participation in the Green Rider program to all residential SOS customers. Participating customers will pay a surcharge in addition to their SOS rates to procure 100% renewable energy. The Green Rider Expansion program is designed to be entirely incremental to any RECs that Pepco DC would otherwise purchase to fulfill RPS requirements.

[69] This was modeled based on SDG&E's EV pricing pilot that found that the customers with 2: 1 ratio shifting 73% of their usage to off-peak and those with 3.8:1 ratio shifting 84% of their peak usage to off-peak.

- We assume 0.5% of the residential SOS customers participate in the program in year one, increasing to 2.5% by year five. For each year, we calculate the total electricity demand that will be netting additional emissions through the green rider program participation.
- Next, we project the amount of RECs that would need to be procured for each Green Rider participating customer by subtracting that year's RPS requirement from 100%. We multiply the resulting percentage with the total load in each year and calculate the total emissions impact.

Resilience Center

- The Resilience Center program provides resource-constrained communities with distributed solar generation and battery storage that can be used as backup power during outages. For the BCA, we estimate only the power system and environmental benefits that would be provided by the solar and storage projects. The projects are assumed to be operational by the third year of the study horizon (2025).
- Consistent with Pepco DC's 5-year Action Plan, we assume that five projects will be deployed adding 250 kW/250 kWh of battery storage and 250 kW of solar PV, consistent with Pepco DC's Maycroft project.
- The batteries charge during the lowest priced daytime hour (when it would be charging from on-site solar PV), and discharge during the highest priced hour of each day. We use hourly prices, averaged across the 20-year study horizon to determine the minimum and maximum priced hour for every day. Charging typically occurs around 2 am each day, and discharging occurs around 8 pm. The battery is allowed to cycle once per day (365 days per year), with a roundtrip efficiency of 90%.
- In addition to providing energy value from this daily dispatch pattern, the battery provides capacity value. The capacity has an ELCC of 25%, based on its 1-hour duration and an assumed 4-hour window required for full capacity credit in PJM.
- We estimate the solar PV impacts using the same hourly solar generation profile and ELCC assumption that was used in the REC analysis described in Appendix A.
- Finally, we combine the hourly generation profile of the solar PV facilities and the hourly dispatch profile of the batteries to produce an overall system impact profile for the Resilience Center projects.

NOTICE

This report was prepared for Potomac Electric Power Company (Pepco DC), in accordance with The Brattle Group's engagement terms and is intended to be read and used as a whole and not in parts.

The report reflects the analyses and opinions of the authors and does not necessarily reflect those of The Brattle Group's clients or other consultants.

While the analyses presented may assist Pepco DC in rendering informed decisions, it is not meant to be a substitute for the exercise of Pepco DC's own business judgment. Neither we nor Brattle will accept any liability under any theory for losses suffered, whether direct or consequential, arising from the reliance on the analyses presented, and cannot be held responsible if any conclusions drawn from this presentation should prove to be inaccurate.

There are no third-party beneficiaries with respect to this report, and The Brattle Group does not accept any liability to any third party in respect of the contents of this report or any actions taken or decisions made as a consequence of the information set forth herein.

ABOUT THE AUTHORS

Ryan Hledik | Principal | San Francisco
Ryan's consulting practice is focused on regulatory and planning matters related to emerging energy technologies and policies. His research on the "grid edge" has been cited in federal and state regulatory decisions, as well as by Forbes, National Geographic, The New York Times, Vox, and The Washington Post. Ryan received his M.S. in Management Science and Engineering from Stanford University, with a concentration in Energy Economics and Policy. He received his B.S. in Applied Science from the University of Pennsylvania, with minors in Economics and Mathematics.

Sanem Sergici | Principal | Boston
Sanem's practice focuses on regulatory and planning services related to innovative rate design, electrification, distributed energy resources, and grid modernization. Sanem led numerous studies in these areas that were instrumental in regulatory approvals of grid modernization investments and integrated resource plans. She received her PhD in Applied Economics from Northeastern University in the fields of applied econometrics and industrial organization. She received her M.A. in Economics from Northeastern University, and B.S. in Economics from Middle East Technical University (METU), Ankara, Turkey.

J. Michael Hagerty | Senior Associate | Washington, DC
Michael specializes in the economic analysis of new technologies and resources across the power sector supply chain, including transportation and heating electrification, distributed solar resources, and transmission system upgrades. He assists electric utilities, renewable developers, transmission developers, and RTOs in understanding and preparing for a shifting market and policy landscape. Michael received his M.S. in Technology and Policy at Massachusetts Institute of Technology, and B.S. in Chemical Engineering from the University of Notre Dame.

Matt Witkin | Lead Analyst | Boston
Matt's research is focused on decarbonization throughout the power and transportation sectors. He leads analyses for utilities to enable decarbonization through adoption of electric vehicles, community solar, and innovative rate designs. He also supports market operators with wholesale market design. He received his B.A. in Environmental Studies with a focus in Economics from Middlebury College.

Julia Olszewski | Research Analyst | Washington, D.C.
Julia's analysis centers on the role of distributed energy resources and innovative rate design in the transition to a decarbonized power sector. She received her B.A. in Economics and English from Tufts University.

Sharan Ganjam | Research Analyst | Boston
Sharan focuses on modeling wholesale electricity markets, as well as electrification, rate design, and electricity market litigation. He received his B.A. in Economics and B.A. in Physics from Carleton College.

CERTIFICATE OF SERVICE

I hereby certify that a copy of Potomac Electric Power Company's Climate Solutions Plan BCA Report has been served this January 31, 2022 to:

Ms. Brinda Westbrook-Sedgwick
Commission Secretary
Public Service Commission
of the District of Columbia
1325 G Street, N.W.
Suite 800
Washington, DC 20005
bwestbrook@psc.dc.gov

Sandra Mattavous-Frye, Esq.
People's Counsel
Office of the People's Counsel
1133 15th Street, NW, Suite 500
Washington, DC 20005
smfrye@opc-dc.gov

Erin Murphy
Environmental Defense Fund
1875 Connecticut Ave., N.W.
Suite 600
Washington, DC 20009
emurphy@edf.org

Angela Parsons
Public Service Commission
of the District of Columbia
1325 G Street, N.W.
Suite 800
Washington, DC 20005
aparsons@psc.dc.gov

Christopher Lipscombe, Esq.
Attorney Advisor
Public Service Commission
of the District of Columbia
1325 G Street, N.W.
Suite 800
Washington, DC 20005
clipscombe@psc.dc.gov

Frann G. Francis, Esq.
Senior Vice President and General Counsel
AOBA
1025 Connecticut Avenue, NW
Suite 1005
Washington, DC 20036
ffrancis@aoba-metro.org

Brian Caldwell, Esq.
Assistant Attorney General
DC Government
441 4th Street, NW
Suite 600-S
Washington, DC 20001
Brian.caldwell@dc.gov

Moxila Upadhyaya
Venable LLP on behalf of AltaGas Ltd.
600 Massachusetts Ave, NW
Washington, DC 20001
MAUpadhyaya@Venable.com

Nina Dodge
DC Climate Action
6004 34th Place, NW
Washington, DC 20015
Ndodge432@gmail.com

Cathy Thurston-Seignious, Esq.
Supervisor, Administrative & Associate General Counsel
Washington Gas
1000 Maine Avenue, SW, Suite 700
Washington, DC 20024
Cthurston-seignious@washgas.com

Susan Miller
Earthjustice
1625 Massachusetts Ave., NW
Suite 702
Washington, DC 20036
smiller@earthjustice.org

Larry Martin
DC Consumer Utility Board
1631 Newton Street, NW
Washington, DC 20010
lmartindc@gmail.com
eugene.imhoff@gmail.com
larisa.dobriansky@gmail.com

/s/ *Andrea Harper*
Andrea Harper