DCSEU

Low-Income Decarbonization Pilot Report

January 18, 2023

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Introduction

The District of Columbia is a national leader in combining progressive clean energy and climate policies that reduce energy consumption, increase renewable energy use, create green jobs, and reduce energy burdens among low-income residents. In Fiscal Year 2020 (FY20), the District of Columbia Sustainable Energy Utility (DCSEU) tested an emerging strategy for significantly supporting the achievement of the District's energy and climate goals. The Low Income Decarbonization Pilot (LIDP) investigated the extent to which decarbonizing homes could reduce energy burdens for the District's low-income residents, while meaningfully reducing greenhouse gas (GHG) emissions.

The project resulted in five categories of recommendations for the successful delivery of low-income decarbonization strategies in a future program designed to achieve the outcomes demonstrated in the LIDP. Taken together, the recommendations address communications with contractors, the role of the DCSEU in accelerating project uptake in low-income communities, optimal staffing for a future low-income decarbonization program, appropriate project scoping, and managing the intersection of building decarbonization projects with renewable energy installations.

The Goal: Building Decarbonization for All

Achieving the District's climate goals requires reducing GHG emissions from the buildings sector. Under the District's Building Energy Performance Standards (BEPS), commercial and institutional building owners—including owners of multifamily affordable housing-- must fulfill energy use benchmarking requirements and meet energy performance requirements in the next several years, depending on the size of their buildings. Some building owners are interested in meeting voluntary net-zero-energy building codes for existing buildings and new construction, in anticipation of net-zero-energy (NZE) requirements that will take effect in the next code cycle update. Achieving NZE ahead of the statutory requirement is an ongoing objective of the District and the DCSEU.

In addition to these policies, the District has set one of the most aggressive Renewable Energy Portfolio Standards (RPS) in the country, mandating 100% renewable energy by 2032.[1] As the grid grows cleaner, beneficial electrification (BE)[2] is a key strategy to decarbonize existing buildings that currently rely on fossil fuels such as natural gas. In buildings, the most common consumer end uses that can be electrified today are space heating, water heating, and cooking. Under the Regulatory Assistance Project definition, "for

[1] https://doee.dc.gov/service/clean-energy-dc-act

[2] The Regulatory Assistance Project investigates the long-term economic and environmental sustainability of the power and natural gas sectors, providing technical and policy assistance to policymakers and regulators. https://www.raponline.org/be/

electrification to be considered beneficial, it must meet one or more of the following conditions without adversely affecting the other two":

1. Saves consumers money over the long run;
2. Enables better grid management; and
3. Reduces negative environmental impacts.[3]

One way to apply this framework is to assess whether a proposed BE strategy reduces net lifecycle energy consumption (in million British Thermal Units, or MMBtu), in addition to reducing costs and improving grid management. BE strategies are most effective when they also integrate building and equipment controls that allow building owners to participate in flexible load management opportunities that support grid reliability and resilience.[4]

Low Income Decarbonization Pilot

In FY 2020, the DCSEU operator[5] received funding from the District Department of Energy & Environment (DOEE) to undertake a pilot program investigating the overall costs and other resources needed to install BE in single-family homes that used fossil fuels as the primary source of heating. This report describes the development and results of the Low Income Decarbonization Pilot (LIDP) and offers recommendations for future decarbonization programs targeting low-income customers.

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[3] Farnsworth, David, Jessica Shipley, Jim Lazar, and Nancy Seidman, 2018. "Beneficial Electrification: Ensuring Electrification in the Public Interest." Montpelier, VT: Regulatory Assistance Project.

[4] *Flexible load management* (FLM) refers to strategies involving high-energy-use customers and utilities in jointly controlling energy use during peak load times, resulting in lower energy costs. One criterion of successful FLM is the absence of noticeable disruptions to building operations. For more information, see a VEIC case study at https://www.veic.org/clients-results/case-studies/unlocking-hidden-energy-storage-to-relieve-peak-demand.

[5] The operator of the DCSEU since 2011 is VEIC: https://www.veic.org/.

Background

The District's Single-Family Residential Market Characteristics

Most residential buildings in the District use natural gas for space heating. The nation's capital has an abundance of historical buildings, especially in the Capitol Hill and Georgetown neighborhoods, where many of the buildings were built prior to 1935, as shown in **Figure 1.** By contrast, many multifamily buildings in the downtown and Southeast areas of the District were built after 1980.

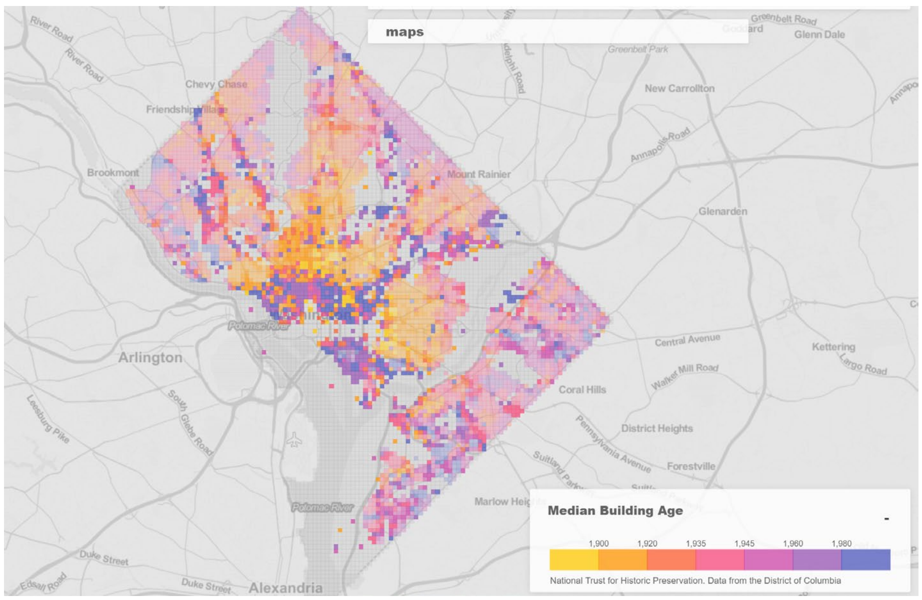

Figure 1. Median building age in the District; yellow, orange, and red-orange areas signify building clusters constructed prior to 1935. Source: National Trust for Historic Preservation.

Single-family homes and multifamily units in buildings containing four or fewer units comprise the third-largest energy user in the District, behind multifamily housing (5+ units) and office buildings.[6] These buildings accounted for 94,232 housing units in 2019.[7] **Table 1** shows the type of energy used for home heating in the District, relative to the U.S. average.

Table 1. % of fuels used in U.S. and DC homes, 2020[8]

	All-electric	Natural Gas
All Homes	26%	60%
District of Columbia	24%	74%

[6] Data for single-family housing are not broken out in terms of single-family detached housing, rowhouses, or duplexes.
[7] Taylor, Yesim Sayin, 2019. "Single-family zoning and neighborhood characteristics in the District of Columbia." Washington, DC: DC Policy Center. https://www.dcpolicycenter.org/publications/single-family-zoning-2019/#:~:text=The%20District%20has%20over%2094%2C000,greatly%20across%20differently%20zoned%20areas.
[8] EIA (Energy Information Administration). 2020. *Highlights for fuels used in U.S. homes by state*. 2020. https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Space%20Heating%20Fuels.pdf

Source: U.S. Energy Information Administration

Pilot Goals

The goal of the LIDP was to obtain data on the total costs, benefits, challenges, resident impact, and cost-effectiveness[9] of BE from installing BE and energy efficiency measures in income-qualified homes on a pilot basis. The DCSEU Pilot Team also sought to derive best practices—from the pilot and from the DCSEU's own substantial experience in delivering services to the low-income residential market—to guide building owners and other interested stakeholders considering beneficial electrification. The Pilot Team also expected the results to help the DCSEU examine consumer pros and cons from switching to BE from fossil fuel sources for heating, ventilation, and air conditioning (HVAC) equipment and appliances.

The pilot's primary strategy was to replace fossil fuel measures with high-efficiency electric equipment and appliances. A secondary objective was to ensure the participating homes became more functional, comfortable, and safe for their occupants. Participants could be either owners or renters of single-family dwellings (detached houses or rowhouses), or renters in low-rise multifamily buildings with four or fewer units.

Low-Income Decarbonization Pilot Design

To achieve the pilot goals, the Team proposed to DOEE that participating homes initially undergo a home energy audit, followed by installation of electrification measures for space heating and cooling, and appliances. The pilot would also ensure each home received weatherization measures where applicable. The DCSEU mandated that permits and inspections be obtained from the Department of Consumer and Regulatory Affairs (DCRA) on relevant mechanical equipment. A second audit by a qualified contractor followed the measure installation. This step was a quality assurance measure, and a way to assess the change in the home's energy performance post-project.

While heat pump equipment that requires lower amperage is on the horizon,[10] this pilot required all but one home to "heavy up" their electric panels to 200-amp capacity to accommodate the electrification measures. Additionally, given the age of the District's housing, many dwellings have insufficient amperage for today's energy needs. The DCSEU residential team also knew from its decade of experience serving residential customers that many homes have hazardous, ungrounded wiring systems. The DCSEU thus planned for each

[9] This pilot was not held to the DCSEU's cost effectiveness standards / testing. However, the analysis was performed and is included in the **LIDP Project Results** section.

[10] Example of equipment: https://www.prnewswire.com/news-releases/rheem-introduces-120-volt-proterra-plug-in-heat-pump-water-heaters-301587523.html

home to receive a new electric panel, with a dedicated electrical circuit and wiring for each new piece of installed equipment.

The DCSEU worked with DOEE to determine the scope and cost assumptions for electrification and efficiency measures for the pilot. **Table 2** presents the initial estimated cost ranges for the pilot measures.

Table 2. Initial measures and budget assumptions for LIDP Pilot, per home

System	Existing furnace or central AC with ductwork		Existing boiler with no ductwork	
Single heat pump	**$7,500**		**$15,000**	
Mini-splits (4 indoor, 1 outdoor)				
Additional measures	Low	High	Low	High
Smart thermostat	$250	$250	$250	$250
Weatherization	$5,000	$6,500	$5,000	$6,500
Doors and windows	$1,000	$3,000	$1,000	$3,000
Electric water heater (regular, heat pump)	$2,200	$5,000	$2,200	$5,000
“Heavy-up” to 200 amps	$2,000	$3,000	$2,000	$3,000
Electric Stove/Oven	$0	$500	$0	$500
Clothes dryer	$0	$500	$0	$500
Lights	$250	$250	$250	$250
Other direct costs				
System design	$2,000	$4,000	$2,000	$4,000
QA / testing of installed measures’ proper operations	$500	$500	$500	$500
Range of costs	$20,700	$31,000	$28,200	$38,500
Estimated total costs	Minimum	Average		Maximum
	$20,700	$29,600		$38,500

LIDP Stakeholder Engagement

The DCSEU hosted a stakeholder session on October 29, 2019, comprising representatives from DOEE and the DCSEU, several Certified Business Enterprise (CBE)[11] contractors, and members of the DC Chapter of the Sierra Club. The DCSEU presented the estimated costs in **Table 2** and the overall program budget. All parties felt that the assumptions were reasonable.

Some of the concerns and potential challenges the stakeholders articulated were:

- Replacement of the gas stove, which many stakeholders believed would be the hardest item for customers to part with or change

[11] Department of Small and Local Business Development: https://dslbd.dc.gov/getcertified

- Overcoming the legacy perception that heat pumps cannot supply the amount of heat needed or expected, compared to traditional radiant heat
- Foreseeable problems when replacing radiant or forced-air heating:
  - In bathrooms that might not have enough wall space available for mounting a mini-split, there could be a lack of sufficient heat, normally provided by a functioning radiator.
  - There might be aesthetic inconsistencies, especially in tight-space, enclosed row houses with radiators. For example, there might be space on the wall, but refrigerant and electric lines would need to run along the ceiling, because walls are shared. Homeowners might not want exposed ductwork.
  - If walls need to be cut into to run wires, then they must be patched and painted; matching existing paint can difficult and increases costs.
  - Costs of restoration and removal of existing radiant or forced-air systems can vary significantly from home to home.
  - Because it is the customer's decision to convert to BE, contractors were hesitant to take on the burden of having to respond to customer callbacks in the event of customer dissatisfaction.
  - Radiant heat distribution feels different from warm air coming from a heat pump, thus necessitating changing homeowner expectations.

The DC Chapter of the Sierra Club reiterated its stance on the necessity of electrification of fossil fuel-powered equipment, and suggested the pilot prioritize homes with older furnace and boiler systems. The Sierra Club reasoned that this practice would ensure the money would be used to replace the most inefficient systems nearing replacement, even without the pilot. They noted that knowledgeable contractors should be selected for the pilot, to ensure that the equipment would be properly sized and installed.

Final Pilot Design

The Team incorporated stakeholder comments and DOEE requests into a final pilot design, which DOEE approved on March 3, 2020. As the pilot was launching, the COVID-19 pandemic created widespread disruption for customers and contractors alike. The DCSEU had to adjust implementation strategies throughout the pilot.

The following measures were offered to LIDP customers:

- Conversion of fossil fuel space heating that had used either forced-air ducted or hydronic non-ducted distribution systems (radiators) and traditional air conditioning equipment (central or window units) to high-efficiency electric air-source heat pump or mini-split systems with smart thermostat(s)
- Weatherization, air sealing, and insulation measures where appropriate and accessible (project costs for shell work not to exceed $6,500)

- Replacement of traditional natural gas-fired domestic hot water heater with a high-efficiency heat pump water heater
- Replacement of gas range or stovetop with an electric range or cooktop where possible, or where residents permitted[12]
- Participation in the Solar for All program, if on-site solar PV could offset the increase (typically 3.5 kW capacity) in electricity demand from the added electric installations; if the roof was not suitable for solar PV, the resident was enrolled in the DOEE Solar for All Community Solar program, offsetting the minimum that would be produced annually on the rooftop from solar PV
- Heavy-up to a 200-amp panel to handle the additional load, as well as new wiring and circuits, as needed

Each project was designed for three phases of work:

1. **Home energy audit**. Auditors assessed building air leaks, potential harmful gas or other type of leaks, and opportunities for home performance and weatherization improvements utilizing blower door test.[13] The home energy audit report was shared with the implementation contractor, thus guiding the contractor in ways to improve the general state of the home.
2. **Energy efficiency and BE measure installation.** To streamline the installation phase and reduce the number of contractors entering residents' homes during the COVID-19 pandemic, one implementation contractor per project was responsible for identifying, designing, and installing high-efficiency heating and cooling equipment, domestic hot water systems, stoves, and weatherizing and insulating the homes.
3. **Quality assurance and quality control (QA / QC) inspection and audit services**. After measure installation (including home insulation; Phase 2), the home energy auditor returned to conduct another audit to record the new state of the home. This QA / QC inspection ensured the measures were installed correctly and that safety measures were addressed. Each project also required a "pass" determination from the DCRA permit inspection.

LIDP Program Implementation

LIDP Contractor Recruitment

The DCSEU issued three types of Request for Qualifications (RFQs) for contractors to align with the phases in the program design: audit, measure installation, and QA / QC. The phased approach enabled streamlined service delivery while enabling efficient verification of results. To keep the quality of work at the highest level

[12] Induction stoves were not offered due to perceived cost concerns and the pilot's focus of HVAC/hot water/weatherization measures.
[13] https://www.energy.gov/energysaver/blower-door-tests. The results of pre- and post- blower door testing were used to estimate energy savings and GHG reductions in section "Estimated change in energy use and GHG emissions"

and to ensure objectivity in reported results, implementation contractors could not apply for both the project work and auditing work.

The Team publicly released the RFQs on March 31, 2020. Three weeks later, the DCSEU received on-time responses from five contractors, three of which responded with bids for both the Home Energy Audit and QA / QC Inspection services. The DCSEU team scored contractor firms on experience, staff capacity, and CBE status. The Team also used its own experience and price lists from other DOEE programs[14] to derive expected costs, with the understanding that the LIDP's fossil fuel conversions would require building modifications that were not included in previous program scopes.

The Team scored all responses before the end of April, choosing two implementation contractors for measure installation and one contractor to conduct the home energy audits and the QA / QC scopes of work. Having that contractor conduct both initial and final audits streamlined the process while reducing the number of people entering residents' homes. The team notified these contractors in May and issued subcontracts in June.

Shortly after the measures were installed and projects completed, the DCSEU staff interviewed participating contractors for feedback on their experience in the measure installation portion of the pilot, capturing challenges, suggestions for improvement, and perceptions about future program success.

LIDP Participant Recruitment

In addition to posting information on its website, the DCSEU conducted outreach by placing sign-up sheets at senior citizen events, and via DOEE's Solar for All Source List, the DCSEU Energy Kit Customer List, DOEE referrals, and participating contractors. The DCSEU provided detailed information to interested customers and answered their questions. The Team received serious interest from 35 customers, and with support from DOEE, the Team verified their incomes. Of these 35 potential participants, 15 were income-qualified as existing LIHEAP recipients. The Team divided the list and sent the respective leads to the implementation contractors; ten completed projects resulted. The cohort comprised six single-family households, and four households occupying a four-unit condominium building.

LIDP qualification requirements

The Team followed standard DCSEU definitions for low-income projects. *Low-income households* are defined as those with annual incomes either (1) equal to or below 80 percent of Area Median Income, or (2) 60 percent of the State Median Income, whichever is higher. *Affordable, low-income housing* is defined as a single home

[14] Primarily the federal Low-Income Home Energy Assistance Program (LIHEAP, administered locally by DOEE), and the Emergency HVAC Program (operated through the DCSEU).

where the owner or occupant meets the definition of *low-income household* or a multifamily building where at least 66 percent of the households meet the definition of *low-income household*.

Additional DCSEU income qualification criteria are:

- Residence in the home, and DC residence
- Within the income guidelines shown in **Table 3.**

Table 3. Household income limits for participation in the pilot, by number of persons occupying the home

Household size	1	2	3	4	5	6	7	8
Maximum annual income	$70,600	$80,650	$90,750	$100,800	$108,900	$116,950	$125,000	$133,100

LIDP Project Results

Study Limitations

It is important to note several factors that influenced the results of the pilot and may limit its application to future low-income decarbonization efforts:

1. This relatively small pilot for a possible future DCSEU low-income building decarbonization program tested customer uptake and other elements of a tailored decarbonization program under a condition in which the DCSEU covered 100 percent of costs. Readers should not interpret the results of this evaluation to be directly applicable to a more comprehensive program solution that contains different financial conditions. That is, a full-scale electrification program or a program for families with higher incomes would need different designs from what this pilot contained.
2. Because this pilot sought information about customer uptake in a specific market segment and because the pilot's results would not be counted in annual energy savings claims, customer projects did not need to meet traditional DCSEU cost-effectiveness tests.
3. The rowhomes chosen in this study represent 0.5 percent of the overall rowhome building type in DC. Therefore, none of the study findings should be used as proxy data for the rowhome building type in general or other building types. Further, the cost information from this report should not be used as a proxy average cost data of building electrification in terms of dollars per square foot of space.
4. More study into the costs to electrify homes should be performed, because many other DC homes are likely to require lower or no incentives; for example, if additional electrical upgrades are not required or the replacement is performed that the end of an equipment's life.

Pilot Homes Overview

Table 4 presents information about the features of the participating households' homes prior to installation of the BE and efficiency measures.

Table 4. Physical characteristics of each participating home in the pilot

Project number	House type, conditioned area, sq. ft.	Year or decade built	Stories above grade	BR	DHW/HVAC	Attic / basement / foundation
1	Single-family, 1,995	1930s	2	2	Gas Furnace Central AC Gas Tank DHW	No insulation, no ventilation
2	End-unit rowhouse, 1,339	1936	2	3	Gas Furnace Central/Window AC Electric DHW	No access, garage has high infiltration rate
3	Enclosed Rowhouse, 2,099	1890s	3	3	Gas Boiler Central/Window AC Gas Tank DHW	Closed crawlspace, high infiltration
4	End-unit rowhouse, 1,424	1940s	3	3	Gas Furnace Central AC Gas Tank DHW	No insulation, no ventilation, open crawlspace
5	End-unit rowhouse, 1,319	1937	2	2	NO Heating Window AC Electric Tank DHW	No insulation, no ventilation
6	End-unit rowhouse, 1,775	1938	2	3	Gas Fired Boiler Electric Resistant Heat Window AC Gas Tank DHW	No insulation, no ventilation
7	Unit 1 in a fourplex, 625	1936	Bottom unit	1	Each unit had an individual gas boiler and hot water heater	No access, open crawlspace, shared with #2
8	Unit 2 in a fourplex, 625		Bottom unit			No access open crawlspace, shared with #1
9	Unit 3 in a fourplex, 625		Top unit			No access
10	Unit 4 in a fourplex, 511		Top unit			Access to attic in this unit

Program Costs and Savings

Estimated vs. actual total project cost

Table 5 shows the range of actual total costs per project. These costs were consistent with those estimated and presented in **Table 2.** The costs do not include Solar for All solar installation or participation in that program's community solar option.

Table 5. Minimum, maximum, and average costs per project

Actual total cost		Project notes
Minimum	$8,900	Only HVAC required replacement. Customer already had electric stove and hot water heater and did not require a "heavy up" of the electric panel. Cost includes removal of existing gas furnace, installation of a new electrical circuit to the air handler of a new 16 SEER 3-ton heat pump, and a programmable thermostat.
Average	$25,518	Typically, each of the homes except 1 received a single heat pump unit
Maximum	$39,150	This home received a 3.5 ton mini-split heat pump and 5 qty. air handling units. Cost includes removal/disposal of gas boiler, replacement of 150A Federal Pacific (recalled) electric panel and upgrade to 200A, a new mini-split 5 zone heat pump and air handlers (each required a new electric circuit), programmable thermostat, removal/disposal of gas hot water heater, new electrical circuit to new 50-gallon heat pump water heater, lift required to place equipment on roof, air sealing and insulation.

Figure 2 breaks down the component costs for each project and each home.

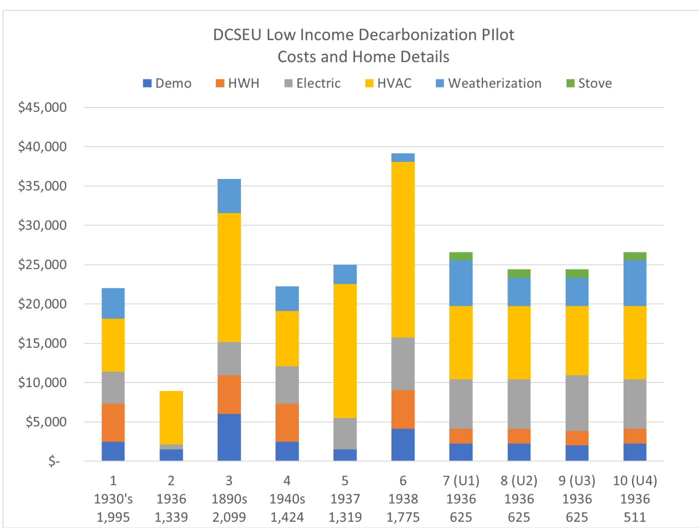

Figure 2. Total costs, broken down by component measures for each of 10 households participating in the pilot.

Total project cost analysis

Figure 3 shows the proportion of costs per component for each project. Heat pump equipment, including installation costs, was nearly 50 percent of the total cost. An additional 19 percent of the cost for the typical project was associated with upgrading the home's electrical system. This cost was less in homes with electric resistance appliances, or where electric service was already adequate to power the existing electric equipment.

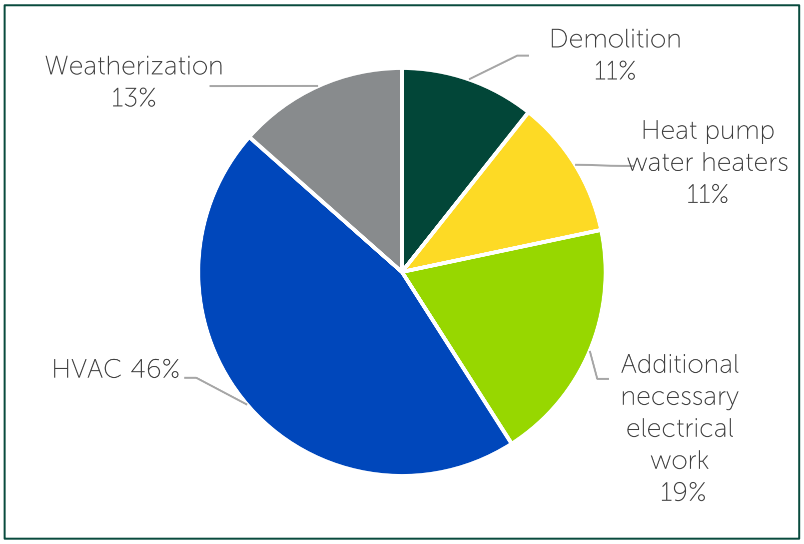

Figure 3. Average percentage of each component of the project, relative to total project cost.

Electrical upgrade costs

Table 6 presents the minimum, average, and maximum costs for the electrical upgrades. To accommodate the increased electrical loads of the equipment and appliances, pilot participation sometimes involved extensive upgrades to existing electrical service in the participant's home. Many of the homes still had Edison fuses, and their electric panels were significantly out of date and unsafe. This scenario is especially common for houses built in DC between 1930 and 1960, when air conditioning was not yet common. Additionally, such panels did not have a ground connection, making them not to code, which now requires a ground fault circuit interrupter (GFCI) for central air conditioning systems. Further, new electric circuits and breakers are required whenever gas appliances are replaced by electric ones. This is due to the fact that gas-fired water heaters typically have power wiring to supply a 2- to 3-amp blower fan. The pilot crews removed the existing circuits and supplied the required wiring to support the increased load of an electric heat pump hot water heater. These upgrades added between $650 and $7,050 to overall project costs and made the projects more disruptive to the participants' homes.

Electrical upgrade costs		Project Notes
Minimum	$650	No heavy up required, hot water heater already electric, only a new circuit to the air handling unit was required.
Average	$4,928	Heavy up to 200 amp ($2,750). Remainder of cost was to add additional circuits required for each piece of equipment (heat pump, hot water heater, air handling unit(s), thermostats), drilling through walls, upgrading Federal Pacific Panel with a new panel capable to handling additional equipment and circuits,
Maximum	$7,050	See above notes on highest total cost project.

*Table 6. Minimum, average, and maximum costs for **electrical** upgrades, per project*

Weatherization and insulation costs

The DCSEU set a per-project limit of $6,500 for weatherization and insulation labor and materials cost. Because of time constraints and some owners' refusals to allow the contractors to expose walls or ceilings to perform the work, the maximum amount spent on this work was $5,825, as shown in **Table 7.**

Table 7. Minimum, average, and maximum costs of weatherization and insulation, per home

Weatherization and Insulation		Project Notes
Minimum	$1,100	Small amount of air sealing and insulation required
Average	$3,760	Air seal attic and crawl space and install blown cellulose insulation in attic
Maximum	$5,825	Air seal attic and crawl space, clean out and install vapor barrier in crawl space, install fiberglass batt insulation in crawl space

Estimated change in energy use and GHG emissions

The DCSEU's Evaluation Measurement & Verification (EM&V) department used pre- and post-audit results (including blower door testing), existing and upgraded equipment specifications, monthly historical gas utility data, as well as known costs and industry assumptions as inputs to standard engineering calculations in order to estimate the change in energy use and the reduction of GHG emissions for each of the homes, as shown in **Table 8**. The following are definitions used in the table:

- **Electric consumption increase** (kWh) from higher electric load caused by the fuel switch from gas-fired boilers or furnaces (therms) and air conditioning units (kWh) to heat pumps or mini-splits (kWh); this value also accounts for expected decreases in energy use for heating and cooling from weatherization / insulation improvements.

- **Solar offset** (kWh) from the reduction in electricity use from either the expected offset by each of the individually installed PV systems or the credit received as a participant in the Solar for All Community Renewable Facility (CREF) program.[15]
- **Gas savings** (therms) from the removal of gas-fired equipment at the site and weatherization / insulation improvements.
- **CO2 emissions reductions** (pounds) were calculated using two methodologies, one based on average GHG emissions rates, and one based on marginal emissions rates**.** Marginal emission rates are typically used to reflect the impact of energy-efficiency and renewable energy programs, since these programs "are not generally assumed to affect baseload power plants that run all the time, but rather marginal power plants that are brought online as necessary to meet demand."[16]

Table 8. Preliminary, estimated values from changes in energy use, by project[17]

#	House type, Area (ft^2)	Electric (Increase) (kWh)	Solar offset (kWh)	Natural gas decrease (therms)	CO2e reduction marginal (pounds)	CO2e reduction average (pounds)	Project Details
1	Single-family, 1,995	(4,491)	5,136	575	7,568	7,211	• Air sealing and insulation improvements • Existing/heat pump AC SEER were equivalent • 3-ton HVAC heat pump installed • 50 gal HPWH installed
2	End-unit rowhouse, 1,339	(5,112)	2,568	524	6,298	6,229	• No air sealing or insulation performed • 3-ton HVAC heat pump installed • Electric water heater remained
3	Enclosed rowhouse, 2,099	(4,111)	7,704	776	13,772	11,786	• Air sealing and insulation improvements • 2 qty. 2-ton HVAC heat pump systems installed • 50 gal HPWH installed
4	End-unit rowhouse, 1,424	(5,374)	6,163	801	10,396	9,960	• Air sealing and insulation improvements • 3-ton HVAC heat pump installed • 50 gal HPWH installed
5	End-unit rowhouse, 1,319	(1,480)	3,595	0.0	2,762	1,593	• Air sealing and insulation improvements • 2-ton HVAC heat pump installed • No existing heating in the home

[15] The DCSEU is also the implementer of the District's Solar for All program under a separate funding mechanism provided by DOEE. Solar for All funded PV systems were installed on each of the six single family homes and the residents of the 4-unit condo building were enrolled to receive credits on their electric utility bill through the Solar for All program.

[16] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

[17] DCSEU assumptions: 1,249 pounds of CO_2e / kWh (marginal); 720 pounds of CO_2e / kWh (average); 117 pounds of CO_2e / MMBtu of natural gas, and a line loss factor of 1.046.

#	House type, Area (ft^2)	Electric (Increase) (kWh)	Solar offset (kWh)	Natural gas decrease (therms)	CO2e reduction marginal (pounds)	CO2e reduction average (pounds)	Project Details
							• Hot water heater was already electric
6	End-unit rowhouse, 1,775	(7,029)	5,650	822	7,820	8,582	• Air sealing performed • 3.5-ton HVAC Mini-split heat pump with 5 air handling units installed • 50 gal HPWH installed
7 8 9 10	4-unit condo building, 2,386	(15,481)	14,380	1980	21,732	22,342	• Attic insulated • 4 qty. 1.5-ton HVAC heat pumps installed • 4 qty. 40 gal HPWH installed

Discussion of energy cost impacts

In Table 8, the "Electric (Increase) (kWh)" and "Solar offset (kWh)" values are not directly related. The electric increase was estimated by analyzing the homes' previous utility data to determine the amount of electricity/gas required to cool/heat the home in its existing state. These values were then used to calculate the equivalent amount of electricity that the installed heat pump would be expected use to provide the same amount of cooling and heating based on its efficiency ratings.[18] The solar offset was based on the actual solar system installed (dependent on the size and characteristics of the roof, homes #1 - #6), or for homes #7 - #10, the standard CREF allocation of 4,200 kWh annually.

The LIDP resulted in the following expected impacts on resident operating costs, after completion of the BE projects. Operating costs indicate how the BE projects affected each household's monthly energy bills on an ongoing basis, not including the cost of measure installation.

- In homes #1, #3, #4, and #5 where the solar offset is greater than the estimated electric increase, gas usage should go to zero and, if behavior did not change (e.g., the resident decided to heat/cool more with the new system), the electric bill should not increase from its historical value, providing an annual total utility cost decrease to the resident.
- In home #2, gas usage decreased but the available space for the solar system was smaller than the typical 3.5 kW PV system, meaning that the solar did not fully offset the increase in electricity usage. As a result, this customer could experience increased total energy bills. To mitigate this risk, this resident could be enrolled in the CREF program to receive an additional "supplement" to get them to the 4,200 kWh offset allowed for all Solar for All participants.
- In homes #6, and #7 - #10 where the estimated electric increase is slightly higher than the solar offset, gas usage should go to zero and, if behavior did not change (e.g., the resident decided to heat/cool

[18] Efficiency ratings for air source heat pumps include Heating seasonal performance factor, HSPF for heating, and Seasonal Energy Efficiency Rating, SEER, for cooling.

more with the new system) the electric bill should show just a slight increase from its historical value and the annual total utility cost should decrease.

Cost effectiveness or project "screening"

The LIDP was not required to meet the DCSEU's standard cost-effectiveness screening requirements, but the DCSEU calculated impact savings and Societal Cost Testing (SCT) results for informational purposes. Results were derived from the DCSEU's SCT screening tool, with current assumptions and inputs as specified in the DCSEU contract after approval by DOEE.[19] The estimates are shown in **Table 9.**

Table 9. Project costs, net present values, marginal emissions, and average emissions, per project[20]

Project costs			Marginal emissions			Average emissions		
#	LIDP Invoice cost	Solar PV cost	Net present value ($)	Annual CO_2e savings (pounds)	CO_2e valuation required for SCT screening ($/short ton)	Net present value ($)	Annual CO_2e savings (pounds)	CO_2e valuation required for SCT screening ($/short ton)
1	$22,000	$13,443	($12,205)	7,568	$279	($12,920)	7,211	$311
2	$8,900	$6,721	($1,007)	6,298	$122	($1,198)	6,229	$127
3	$35,875	$20,164	($14,737)	13,772	$225	($16,579)	11,786	$267
4	$22,250	$16,131	($6,057)	10,395	$167	($6,920)	9,960	$185
5	$25,000	$9,410	($21,730)	2,762	N/A[21]	($22,692)	1,593	N/A[22]
6	$39,150	$14,787	($29,565)	7,820	$539	($29,735)	8,582	$552
7 8 9 10	$102,000	$37,639	($74,948)	21,733	$492	($76,189)	22,342	$526

[19] DCSEU societal cost test (SCT) screening assumptions which are shown for reference and updated and approved of annually by DOEE and 3rd party evaluator can be found in Appendix A - DCSEU FY2020 Societal Cost Screening Assumptions.

[20] The Team derived the results from the DCSEU's FY20 assumption of $100 / short ton of GHG emissions, as the societal cost of CO_2e, and 5 percent non-energy benefit (NEB) adders that are applied during an annual EM&V process. NEBs account for the value of comfort, noise reduction, aesthetics, health and safety, ease of selling / leasing home or building, improved occupant productivity, reduced work absences due to reduced illnesses, ability to stay in home / avoided moves, and macroeconomic benefits. Benefits from reducing environmental externalities (air and water pollution, greenhouse gas emissions, and cooling water use) comprise another 5 percent adder. The DCSEU must be cost effective at the portfolio level, but normally hesitates to support any project that does not screen (NPV < $0).

[21] This home was utilizing small electric space heaters (did not utilize gas heating) prior to participating in the pilot so it is not a true "fuel switch." However, the efficiency of the installed heat pump is greater than the electric space heater so electricity usage for heating should decrease. However, since it was not a true fuel switch, this value was not included in the SCT discussion.

[22] Ibid.

Table 9 shows the carbon dioxide equivalent (CO_2e) values that would be required for each project to pass the SCT, based on both average and marginal emissions.[23] The CO_2e cost would need to range from $122 to $539 per short ton to make the project screen positive from a net present value standpoint. This compares with the $100-per-short-ton cost of CO_2e the DCSEU used for FY20 cost-effectiveness testing.

Cost-effectiveness observations

- The findings indicate that changes to basic screening assumptions included in the SCT used by the DCSEU to evaluate energy efficiency and decarbonization projects may be necessary to aid in the justification of investment in the District's GHG reductions and equity goals.
- An alternative to increasing the CO_2e value could be to increase each of the two non-energy benefit adders in the SCT (currently valued at 5 percent), to improve the ability of future decarbonization projects to screen. LIDP participants themselves spoke about the many benefits of the home improvements, such as comfort and air quality, indicating that a higher non-energy benefit adder might be appropriate (see **Customer Interviews,** below**).**
- If solar was not installed or credits to the utility bill were not considered, the project cost would be reduced, and the cost/benefit ratio of the beneficial electrification project might improve. However:
    - Per industry standards for deep energy retrofits, the SCT requires that all known project costs be included in the analysis, and
    - If solar were not included, customers would have additional utility costs, which would also be considered in the screening of each project and have a negative impact on total energy costs for pilot participants.
- One prominent resource for this discussion is the National Energy Screening Project. The group helps guide jurisdictions in deriving cost-effectiveness tests for benefit-cost analyses specifically for distributed energy resources. Its *National Standard Practice Manual* has become the trusted industry standard for cost-effectiveness testing.[24]

Customer interviews

The first winter after the new equipment was installed, the DCSEU performed a follow-up call with each of the participating residents to seek their initial thoughts on the transition away from fossil-fueled energy use and their perceptions about the installation process. The objectives of the survey were to understand the motivation for participation, and to inform improvements on the implementation process. The surveys were intended to seek information about how the weatherization measures and new mechanical equipment changed the customer's experience of living in the home.

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[23] Alternatively, or together with the cost of carbon dioxide equivalent, the NEB adder value could be adjusted while holding the cost of carbon at $100 to determine a % that would enable the project to screen positive from a net present value standpoint.

[24] National Energy Screening Project, n.d. *The National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources.* https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/.

- All but one participant:[25]
    - Were very satisfied with their overall experience from the program
    - Noticed a remarkable drop in total energy costs over the winter from the previous year
    - Would recommend this new technology to others and would choose the new technology for themselves again
- Four of the six participants who responded said their homes were “somewhat comfortable” before the retrofit, and three reported that their homes were now “very comfortable.”
- Besides the one participant who was not “satisfied” or “very satisfied,” the only (common) complaint from the other participants was the noise from the fan in the outdoor heat pump unit.
- All participants expressed appreciation for the contractors they worked with, noting that they were patient and empathetic.
- In several of the homes, the customer or the customer’s partner ultimately refused the stove conversion and could not be swayed to make the change as they believed the quality of cooking would be affected adversely. In one home, the owner is a baker, and her existing gas stove was professional level including a convection oven. The replacement version offered did not have the convection capability.
- Sample comments:
    - “I am so happy with the program and that I could participate. It has really helped me out!”
    - “Now the heat is spread evenly throughout the house.”
    - “Each room can be given its own comfortable temperature.”
    - “The air quality in my home has improved immensely.”
    - "The insulation added to the back den / extension makes it much warmer than it has been in years, because it is airtight now. My plants are not dying, and my husband and I can now sit comfortably back there in the winter. We can utilize more of our home now.”
    - “Before, I gave up on my oil-fired boiler with radiators and started to use electric radiant heaters throughout the house, especially in the basement to keep pipes from freezing. But this would shoot my electric bill right up over $200 per month. Last month my electric bill was only $90, and the heat flows much more evenly throughout the house. I don’t wake up sweating anymore, either!”
    - “I thoroughly enjoyed the home energy audit. We shared coffee and had conversation. They explained everything to me as they did their work.”
    - “Sometimes I felt like I was asking too many questions, but I needed clarity; they were very responsive to my questions and concerns.”

[25] The unsatisfied participant experienced a faulty fuse shortly after installation. The contractor could not return to fix the issue for approximately 36 hours. The participant also noted that insulation between the first floor and the basement was not installed, and that the first floor continued to be uncomfortable (cold) in the colder weather.

Contractor Interviews

The Team conducted four discussions with participating contractors:

- 1 General Contractor who fully participated in the pilot
- 1 mechanical contractor who participated as a subcontractor to another contractor
- 1 home auditor who fully participated and also performed QA/QC

Each of the participating contractors was an active, longtime vendor for the DCSEU, with proven high-quality work and timely service to customers. They each had reputations for having advanced listening skills, being responsive—especially to people who are unfamiliar with clean energy interventions—and flexible in meeting participant needs. The Team conducted the interviews as conversations, but also prompted the contractors to respond to questions aligned to their respective roles and participation levels in the pilot. Regardless of the participation level, contractors shared many experiences and observations in common.

Electrification experience

Contractors supplying energy efficiency and BE measures knew how to install each piece of equipment individually but were less experienced in completing multiple BE equipment installations at a single site. Further, contractors reported that, prior to LIDP, they had not, or had rarely, been asked to make a comprehensive fuel switch in an existing home that was not undergoing major renovation. Each contractor cited hesitancy in taking on the risk and general liability when customer expectations might have been greater than what could realistically be carried out. This was especially the case with heating equipment installations. In the cases where duct work required some demolition and change to the structure of the home, some previous customers expressed concern about the change in indoor aesthetics.

The auditor for home energy and QA / QC inspection services had extensive experience in evaluating and proposing improvements—typically weatherization and insulation—for a home's energy performance and comfort level. However, the auditor also noted that in her previous experience, she had not had to discuss BE with homeowners or renters. Regardless, the home energy auditor generally agreed that BE is where the future lies and felt that LIDP provided useful insights to inform future efforts.

COVID-influenced decision-making

The COVID-19 pandemic made it difficult for contractors to be staffed at their usual levels. One contractor decided that his firm, which has historically carried out many projects with the DCSEU, could not deliver the same high-quality services for the pilot and withdrew his participation. Another contractor had put a pandemic-related hiring freeze on his business but committed to the pilot by hiring subcontractors to fill labor needs. The third contractor increased staff during COVID-19 to accommodate demand in the local market—demand unrelated to the LIDP pilot.

All three vendors experienced problems in the materials supply chain because of the pandemic. These problems were unrelated to LIDP levels of participation. Further investigation by the DCSEU's Trade Ally Manager found that the shortfalls in the supply chain occurred across several materials supply points, and not predominantly in any specific one. For example, material supplies that typically had a 3- to 4-day turnaround, pre-COVID-19, became 3 to 4 weeks (and in some instances, 2 months or more). In response, the Team authorized the use of alternative brands of equipment that could be sourced for several homes, as pilot deadlines approached. The Team ensured that these materials met the DCSEU's performance specifications.

Contractor observations about customer acceptance

Overall, customer willingness to accept the proposed measures and their flexibility with installation timelines drove contractor success in the LIDP. During the enrollment process, the Team did not choose customers who seemed unsure about their participation in the pilot. One contractor noted specifically, "If the customer is difficult when you are explaining the program on the phone, they will be ten times more difficult when you start working in their home." Contractors also mentioned a need for more comprehensible program literature and customer information about the pilot's purpose. Gas stove conversion to electric, for example, was a significant barrier in the installation process, even after the customer had given initial approval.

When asked an opinion of who would be considered an "ideal customer," the contractors agreed that it was someone who understood the pilot, was open to learning more about it, wanted to know what to expect, and wanted to help the environment. One contractor did not observe a noticeable "ideal customer" demographic in terms of age or gender, whereas another contractor noted that younger people who have learned about climate change in school or in the media were more likely to participate.

Timeline of the pilot

All installation contractors noted that they were concerned about the unusually short timeline for delivering LIDP services. They cited the need for a substantial amount of coordination to fulfill the extensive retrofit scope of the LIDP, and the disruptiveness of the work to the occupants:

- Heavying up the home's amperage
- Air sealing
- Installing insulation
- Drilling and running electrical lines through walls
- Patching or replacing drywall
- Re-painting drywall
- Carpentry
- Installing equipment and appliances
- Considering and accommodating customers' interior aesthetics
- Installing solar PV, if warranted
- DCRA permit inspections

In one case, five different teams were simultaneously in a house on a single day, completing the extensive work against the pilot's deadline.

The delivery time for services per project was under 45 days. This schedule increased the need for installation crews, which created logistical problems. In some instances, the contractors could not deliver the full scope of services. Further, the contractors noted the unavoidable inefficiencies of teams working over each other. Contractors estimated that future comprehensive BE projects should allow for a 5 to 6-month timeframe, to go from initial encounters with customers to project completion and signoffs of the conversions.

The role of effective communication for successful service delivery

The contractors emphasized that high-quality communication practices need to be in place, covering project vetting, information for customers, managing customer expectations. Easily accessible program information and technical talking points about the change from gas to electric equipment would also be helpful in customer communications.

Challenges

COVID-19

The presence of the pandemic was a significant factor in keeping the pilot design from being carried out within the originally specified timeline. The pilot's target start date was July 2020; DCSEU employees shifted to a fully remote work on March 16, 2020, providing only a few months for contractor recruitment, outreach, and other program start-up activities.

The pandemic caused delays in the supply chain, as described in **Contractor Interviews, COVID-influenced decision-making.** It also resulted in an increase in costs to upgrade home HVAC equipment throughout the national market, because of the need for more residential cooling in warmer weather. Contractors reported hearing "no availability" of equipment, beginning in June 2020. Distributors had a three-month supply of stock on hand, but factories were shut down for three months. That meant that supply decreased significantly but began again to increase in November. The shortage of supply and the increase in demand resulted in some distributors' taking advantage of the market and imposing a price hike of up to 14 percent on goods.

Although contractors typically seal project deals through in-person conversations and through site visits, COVID-19 restricted conversations to phone calls, and imposed some uncertainty about project scoping and feasibility. Further, COVID-19 guidelines constrained the LIDP's implementation schedule, which was aligned with the end of the District's Fiscal Year, in September. The easing of supply chain constraints began to occur in November, after the end of the Fiscal Year.

Because of these factors, contractors had to switch to different vendors because of the lack of supply, with different shipping points of origin. Factory shutdowns also curtailed the supply of appliances and caused manufacturers to source parts and services from different regions and specify assembly in different parts of the globe, contributing to supply chain delays.

Despite these challenges, one advantage was that most pilot participants were at home. Thus, it was easier for contractors to schedule customer conversations and the retrofit work. However, several customers were very particular about when contractors could be let into the houses because they had occupants with pre-existing conditions who needed to be moved to another location at those times. Most contractors said customers were open to having them in their homes, if crews wore masks and practiced physical distancing. Project work began in late July; had contractors tried to enter homes several months earlier, customer openness—with ground rules—to contractor entry might not have occurred.

Gas Stoves

In early conversations with customer-candidates for participation in the pilot, the DCSEU found that three-quarters of them were hesitant about or refused to consider the removal of their gas stoves. The DCSEU did not fully disqualify these potential participants on those grounds but continued searching for willing participants who did not have those qualifications about their gas stoves. The Pilot Manager spoke to each of the final participants to confirm their agreement with having their gas appliances replaced, once they entered the pilot. Ultimately, of the ten participants, six did not have their gas stoves replaced. In one home, it was prohibitively intrusive for the contractor to run wiring to the stove. In four houses, the customer or the customer's partner ultimately refused the conversion. The final home's owner is a baker, and her existing gas stove was professional level including a convection oven. The replacement version offered did not have the convection capability.

Split Incentives

Split incentives typically occur in rental units, or in any situation in which a gas or electricity meter is master metered, as is common in a multifamily building. In many master-metered buildings in the District, the occupants bear the cost of their own electricity use, but the building owner is responsible for the gas utility bill. In such a scenario, the owner can install energy-saving measures that reduce the building's gas utility costs and can pass those savings along to the tenant through lower rent. The replacement of gas equipment and appliances with electric ones, however, would raise the tenant's electric utility bills.

The pilot included a fourplex multifamily building with split incentives whose residents were enrolled in the DOEE Solar for All Community Solar offering. If Solar for All covered 100 percent of the increased electric cost, then both the tenant and the owner would benefit from a fuel conversion. However, because the Solar for All Community Solar offering covers about 50 percent of the likely monthly energy use,[26] the tenant's electric bill is anticipated to increase slightly. This cost shift is especially problematic for low-income tenants.

Project Complexity in Existing Homes

One contractor withdrew participation in the LIDP, in part because the firm had other, less complex projects under way. The fewer the complications, the lower the likelihood of customer complaints. The other contractors who stayed with the pilot had trouble arranging for walk-throughs to scope the project work at some homes and were uncertain that they could complete such complex projects on time due to COVID-related delays.

Contractors also noted that it was difficult to remove boiler systems and radiators from participating houses. Thus, the Pilot Team decided to require disabling and removal of gas or oil-fired boilers, but not the removal of the hydronic distribution systems (radiators and supply / return lines) throughout the home.

Recommendations

The LIDP contributed to GHG reduction targets specified in Clean Energy DC Act. However, the pilot's principal desired outcome was to determine the extent to which low-income residents can benefit from beneficial electrification in the DC residential market. The LIDP also sought to determine how to increase contractor capability to support comprehensive BE upgrades, and the extent to which the number of contractors offering heat pumps could be increased. The DCSEU will continue to raise BE technology awareness among distributors, installers, and consumers, and use this experience to inform the support necessary for undertaking and completing fuel conversions in future programming.

The LIDP provided sufficient information to guide a successful future program designed to achieve similar outcomes to this pilot. The Team derived the following recommendations from the contractor

[26] DOEE / and the Solar for All Community Solar program assumes 4,200 kWh per household, which was used in Table 8 Solar offset (kWh).

and participant interviews, its own experience with the pilot, its experience with programs designed for low-income residents, and its knowledge of District policies and requirements relating to the building retrofits.

Contractor Recommendations

See also **Talking points for contractors** at the end of this section.

- Contractor communication skills
    - Empathic, patient contractors can have a significant, positive effect on a pilot's success which affects customer satisfaction and allows for optimum building energy performance and good post-project care of the installed appliances and other measures.
- Program team → customer → contractor interactions
    - Contractors recommended vetting and informing customers about the project before handing them over to the contractors.
        - Some customers appeared to perceive the contractors as "sneaky salespeople," and were wary about receiving free things ("What's the catch?").
    - Sharing important project information with customers—project processes, and requirements for participation, in particular—should be a primary focus of the Team.
        - Customers need to have this information reinforced through friendly reminders during the entire process, especially when installations begin to occur.
    - Training contractors on program details gives them confidence in their ability to respond to customer questions.
    - Contractors recommended the creation of a customer information form for contractors and the DCSEU. This form would contain signed proof by customers that they have received and understood the proper operation and maintenance of their new equipment. It would also ensure that contractor technical crews can train customers in programmable thermostats, for example.
- Communicating what the program is not
    - One contractor said he had to convey to customers that the LIDP was not a "Fixer Upper" television program offering. This observation reinforces the importance of communicating the features of the program—from the perspective of people who might associate home improvements with exposure to popular media.[27]

[27] For example, when the boilers were removed in LIDP homes, contractors left the radiators intact, even though they were no longer functional. Removal would expose two holes in the floor (supply and return water lines). These holes would have to be filled or patched in a way that would require matching of the rest of the floor's materials and colors. Moreover, wall paint behind the radiators was likely unchanged since the radiators were installed many years prior, so the wall would need to be repainted. Matching paint color to adjoining walls that have withstood years of wear and tear would necessitate a significant amount of cosmetic remediation.

- Managing other customer expectations
    - The availability of talking points to share with customers will be an important feature of future programs modeled on the LIDP—particularly regarding the replacement of a familiar and reliable gas stove with an electric one.
    - Contractors knew enough not to approach the customer with statements such as, “Your gas stove is the first thing you need to give up, if you want to receive the other benefits of this program.” However, determining a customer’s level of resistance to the removal of a gas stove, in advance, would help to eliminate customer situations in which they receive other equipment and, in the end, refuse to convert to an electric stove.[28]

DCSEU Recommendations

Customer and contractor communications

- **Right-sizing the communication effort to maximize benefits to contractors and customers**
    - A solid understanding of any future program needs to involve contractors, system designers, and customers. Better communication and coordination in a whole-house delivery of multiple measures are likely to yield deeper decarbonization outcomes.
        - **Recommendation:** Future information materials should be disseminated via several approaches: in-person or webinar workshops for contractors and designers, and customer-centric takeaways and webinars for homeowners, before and after installation.
            - Such materials would address proper installation, operations & maintenance of equipment, best practices, differences between existing system and heat pump system, how efficiency measures lower the cost of home energy, and so on.
- Managing timing expectations for customers
    - The DCSEU learned several lessons about realistic timing for decarbonization work. These lessons can help inform future program design.
        - **Recommendation:** Program designers should build in the following phases for the work plan and allow at least six months to complete projects from start to finish:
            - 1 to 2 months for customer recruitment
            - 1 to 2 months for verifications of home energy audits (analyzing preliminary walkthroughs, evaluating proposed changes, and communicating this information to the resident)
            - 2 to 3 months for installations, depending on the proposed scope of work

[28] Explaining the health impacts that result when gas is combusted in the home can be added to the discussion with customers. See Roberts, David, 2020. “Gas stoves can generate unsafe levels of indoor air pollution.” *Vox*, May 11. https://www.vox.com/energy-and-environment/2020/5/7/21247602/gas-stove-cooking-indoor-air-pollution-health-risks.

        - 1 month for final inspections
- Effects on fuel assistance
    - The LIDP encountered customer concerns about fuel assistance payments being affected by converting from natural gas to electricity.
        - **Recommendation:** Future LIDP programs should clearly communicate the types and extent of effects on customers' federal and other fuel assistance program payments. There may also be opportunities to update LIHEAP and other fuel assistance policies and procedures to better support customers switching from one fuel to another.

Assigning labor / staffing responsibilities for future LIDP initiatives

- Program vs. project coordination
    - The Team assumed that the DCSEU could serve as General Contractor (GC) to coordinate multiple implementation contractors and subcontractors. However, contractors suggested that the DCSEU should not be the GC, because of the high number of project components requiring coordination—a skill well within the scope of a professional GC. Contractors felt that the DCSEU was better suited to serve as a program coordinator than a project coordinator or GC role.
        - **Recommendation:** Future programs supporting comprehensive decarbonization projects, like those completed through LIDP, should plan for an entity to serve as GC. This is a key role in successful program delivery.
- Determining needs for a GC
    - Home auditors are well trained in the details of what remediation steps are necessary for a successful home performance and weatherization efforts.[29] The home audit report should be designed in such a way as to signal the need for a General Contractor on the project when the audit report indicates needs for more than two contracted services--such as carpentry, mechanical work, and electrical equipment installation.
        - **Recommendation:** Future home audits for a decarbonization program should indicate where contractors will need to install insulation and seal visible holes. Because an HVAC contractor might not have the expertise to fully remedy these deficiencies, the role of a GC becomes more important in coordinating the solutions with relevant contracting expertise.
- Weatherization and insulation, and the role of the home energy auditor
    - The home auditor argued that it was more appropriate for a qualified weatherization and insulation contractor with relevant certifications from the Building Performance Institute (BPI) to perform those parts of the scope. The auditor argued that HVAC contractors

[29] Including remediation measures such as proper rim band joint insulation, ventilation, and isolating the attic from the rest of the house.

design and install HVAC systems and are not experts in weatherization and insulation. The auditor further believed better work would have resulted than what the audit firm inspected during the QA / QC portion of the job. The HVAC contractor also might have to subcontract insulation work, which increases program costs.

    - **Recommendation:** Installation of weatherization and insulation measures should be overseen by a BPI-certified professional. Certified home energy auditors should be allowed to undertake weatherization and insulation tasks, provided safeguards are in place to prevent inappropriate practices (up-to-date certification, for example, and passing a QA / QC inspection conducted by a different firm).

Program and project scoping

- Finishing the job for higher benefit to customers
  - The Team suggests serious consideration of how much funding can be put toward aesthetic remediation. Should the scope include new sheetrock, painting, cost-effective miscellaneous repairs, cleaning, plastering, and carpentry? Should it consider exceptions to the scope if special structural circumstances pertain?
    - **Recommendation:** If the answer to either question is ”no,” such exclusions should be communicated clearly to participants prior to the onset of projects—with leads on how customers can obtain the cosmetic remediation services they need. Alternatively, contractors could be set up to provide separate pricing to perform aesthetic work.
    - **Recommendation:** The DCSEU will need to determine the extent to which a lack of support for such remediation will lead to refusals to participate.
- Ventilation and indoor air quality
  - Many older District homes were not constructed with a way to exhaust hot air from the attic in summer. The District’s high summer temperatures create hot air in attics, thus decreasing occupant comfort.
    - **Recommendation:** Scopes for decarbonization projects in climate zones with hot summers should contain the installation of air vents and an appropriately mounted attic fan, to reduce the home’s cooling load and to contribute to a more comfortable and efficient home.
- Economies of scale can improve program performance and drive down costs
  - Because of the small size of the pilot, it was not possible for contractors to achieve benefits from bulk purchases of HVAC equipment and appliances, or to make new insurance requirements cost effective for their businesses.
    - **Recommendation:** Future low-income decarbonization programs should be sufficiently funded to (1) achieve economies of scale, (2) increase the program’s

reach to low-income residents, (3) decrease GHG emissions on a larger scale, and (4) support CBE and other enterprises with predictable workloads.

Assessing resident bill impacts and solar offsets

- **Assessing and managing resident bill impacts**
  - With current electricity and gas prices, some customers could experience increases in overall energy bills after electrifying. Incorporating energy efficiency and solar into projects is a key strategy to mitigate potential bill increases. In the LIDP, solar offsets and efficiency measures were sufficient to result in reduced total energy bills for all but one customer.
    - **Recommendation:** Future low-income BE programs should assess potential bill impacts for each retrofit project, ensure that bill assistance program interactions deliver the customer a reduction in total energy costs[30] after fuel conversions, and build in safeguards for those benefits. Low-income customers should not be put in a position in which they must pay more for home heating, electric power, and cooking than they did before the whole-building project.
- Right-sizing solar PV and electricity bill offsets
  - In the LIDP, solar could not always be sized to meet the full need. For example, in one case the roof size limited the amount of on-site PV capacity that could be installed, resulting in less electricity generation than the home required after BE.
    - **Recommendation:** BE programs should ensure that customers receive offsets on the electricity bill that are greater than the expected additional energy usage after BE. For example, the customer with limited roof space could be enrolled in Solar for All to further offset electricity costs.
- Ensuring participant savings from solar installations
  - Participation in the Solar for All program's community solar offering is designed to cover 50 percent of a customer's electricity use based on the District of Columbia's average residential electric bills for 2016, which equates to a reduction of 4,200 kWh per year. This offset was not always sufficient to result in lower electricity costs for LIDP customers after BE, although in most cases total energy costs went down due to the reductions in natural gas usage.
    - **Recommendation:** Solar for All should work with DOEE and LIHEAP to coordinate utility bill offsets with future LIDP initiatives. The outcome of this coordination should be a written commitment to decrease total energy costs for participants, by an appropriate strategy such as covering extra electricity costs. This

[30] For example, if the loss of a LIHEAP gas benefit is not fully offset by a higher LIHEAP electricity benefit, a net increase in the portion of utility bill that household has to cover after accounting for LIHEAP assistance will result.

recommendation is consistent with the Regulatory Assistance Project's BE criterion for reducing net lifecycle costs for consumers.

Talking points for contractors

The contractors cited a need for talking points to help lessen the concern of customers who might be skeptical about the change from gas to electric equipment.

- Heat pumps
  - It is widely acknowledged that there is a different "feel" in the heat produced by a heat pump versus that of a furnace / radiator. Some customers might also recall historical inadequacies of heat pumps produced 30 years ago and be skeptical about how well they might heat the home.
    - **Talking point:** Today's heat pumps, when operating correctly, do not leave the occupant feeling cold. Many improvements have been made in the past 5+ years to make this form of space heating superior to older heat pumps and to traditional systems involving radiators and boilers.
- Radiators
  - Mini-splits can accommodate different comfort needs of a house's occupants.
    - **Talking point:** Hydronic radiators are not easily shut off and are designed to heat the whole house at a constant temperature. Mini-splits make it possible for two rooms to be at different temperatures, to satisfy the comfort needs of different people at the same time.
- Hot water heaters
  - Existing gas units typically cycle on and off continuously, regardless of the need for hot water—even if the occupant is away from the house for an extended period.
    - **Talking point:** The resident is paying for a lot of unused hot water. A heat pump water heater reclaims all the heat it produces. Over the life of the unit, this feature can result in over $3,000 in energy savings and a reduction of GHG emissions, making the home no longer a source for those emissions. To date, heat pump water heaters appear to be lasting longer than traditional gas units.
- Combustion
  - Any gas-burning equipment (furnace, boiler, or water heater) uses air from the home in the combustion process, which can depressurize the house. Depressurization sends conditioned air up the chimney, which results in a drafty house. Gas stoves also emit indoor air pollution that can have negative health effects[31].
    - **Talking point:** Removing gas-fired equipment reduces indoor air pollution and decreases the amount of cold and hot air coming into the home and improves

[31] https://www.health.harvard.edu/blog/have-a-gas-stove-how-to-reduce-pollution-that-may-harm-health-202209072811

comfort levels. Gas-fired equipment also creates potential fire and carbon monoxide hazards.

Appendix A

DCSEU FY2020 Societal Cost Test Screening Assumptions

Documentation for DCSEU FY2020 Screening Assumptions

This document outlines the societal screening assumptions and sources for values used for FY2020 DCSEU measures screening purposes.

The following assumptions are valid for the 2020 fiscal year, effective 10/1/2019 through 9/30/2020. All dollar values are 2020$. Where necessary, the FY2020 future inflation rate was used to bring all dollar values to 2020$. Note: values presented in this document may be rounded for readability. For full, exact values, supporting spreadsheets should be referenced.

Future Inflation Rate

Source/Notes:

Calculated using the past 10 years of consumer price index data published by the U.S. Labor Department for the months of August.

Reference Spreadsheet: Future Inflation Rate

Value: 1.740%

Real Discount Rate

Source/Notes:

10-year treasury rate posted in the Wall Street Journal on the first business day of October 2019 (1.638%) plus 2% (as specified in the DC SEU contract no. DOEE-2016-C-0002).

Reference Spreadsheet: Real Discount Rate

Value: 3.638%

Line Loss Factors

Source/Notes:

Published PEPCO Zone Capacity and Transmission Peak Load Calculations for Year 2018 are used as a basis to establish weighted line loss factors for both electric energy and demand. Individual load profile line loss factors are weighted against system total transmission peak load and summed to produce a single representative line loss factor for both energy and capacity. Note: line loss factors are applied (multiplied) by delivered energy and capacity to establish the required input on the generation side.

Reference Spreadsheet: Line Loss Factors

Reference Document(s): 2018_PEPCO_PLC Capacity and Transmission Report_Web.pdf
DCRateCodeLossFactorMatrix-2-26-18.pdf

Value: Energy: 1.045992, Demand: 1.077076

Natural Gas Capacity Adder

Source/Notes:

Per Section C.40.10.3 of contract DOEE-2016-C-0002.

Reference Spreadsheet: Not applicable

Value: 5%

Risk Adder

Source/Notes:

Per Section C.40.10.3 of contract DOEE-2016-C-0002.

Reference Spreadsheet: Not applicable

Value: 5%

NEB Adder

Source/Notes:

Per Section C.40.10.3 of contract DOEE-2016-C-0002.

Reference Spreadsheet: Not applicable

Value: 5%

Transmission and Distribution Cost

Source/Notes:

Transmission rate based on Potomac Electric Power Company (“Pepco”), Docket No. ER09-1159 Informational Filing of 2019 Formula Rate Annual Update to the Federal Energy Regulatory Commission

(FERC). Distribution rate deduced from the 2017 filing of Pepco's Application for Authority to Increase Existing Retail Rates and Charges for Electric Distribution Service and Supporting Testimony and Exhibits, Formal Case No. 1150 and the subsequent DC Public Commission Order No. 19433.

Reference Spreadsheet: Transmission & Distribution

Reference Document(s): pepco-2019-annual-update.pdf

FC-1150-2017-E-1.pdf

FC-1150-2018-E-95.pdf

Value: Transmission: $31.75/kW-yr

Distribution: $64.02/kW-yr

Total T&D: $95.77/kW-yr Total T&D, **including demand line losses**: $103.15/kW-yr

Fuel Externalities

Source/Notes:

Fuel emissions coefficients published by the U.S. Energy Information Agency are valuated using $100/short ton CO_2 (2018$), as published in Avoided Energy Supply Components in New England: 2018 Report.

Reference Spreadsheet: Fuel Externalities

Reference Document(s): AESC-2018-17-080.pdf

Value:

($/MMBtu)			
Distillate	Propane	Natural Gas	Kerosene
$8.07	$6.95	$5.85	$7.97

Electric Externalities

Source/Notes:

Based on the methodology recommended in the NMR Team FY2017 Evaluation. PJM's 2014-2018 CO2, SO2, and NOx Emissions Rate Report, published April 5, 2019 was referenced for 2018 monthly marginal CO2 emission rates, which were then averaged based on the four loadshape periods. Carbon valuation is based on $100/short ton CO_2 (2020$), consistent with Fuel Externalities and Avoided Energy Supply Components in New England: 2018 Report.

Reference Spreadsheet: Electric Externalities

Reference Document(s): 2018-emissions-report.pdf

Value:

****Including energy line losses****

Year	$/kWh			
	Summer Off-Peak	Summer On-Peak	Winter Off-Peak	Winter On-Peak
2017-2065 (values held constant)	0.066485857	0.072840258	0.065139143	0.06845363

Electric Energy Cost

Source/Notes:

Based on NMR Team FY2017 Evaluation recommendations. Hourly real-time locational marginal prices (LMPs) for PEPCO zone from January 2015 to May 2018 are used in conjunction with hourly load data for PEPCO zone for the same period to calculate load-weighted marginal price by energy period. This establishes the 2017 value. Price escalation over the remainder of the forecast horizon (2018-2050) is calculated by averaging growth projections from a series of EIA Annual Energy Outlook forecasts for the Mid-Atlantic region.

Reference Spreadsheet: Energy (kWh)

Reference Document(s): NMR Team Evaluation Recommendations.xlsx

Value: ****Including energy line losses****

Year	$/kWh			
	Winter Peak	Winter Off-Peak	Summer Peak	Summer Off-Peak
2017	0.047951054	0.041751981	0.046621926	0.031486103
2018	0.048200253	0.041968964	0.046864217	0.031649734
2019	0.048309904	0.04206444	0.04697083	0.031721735
2020	0.050775631	0.044211399	0.04936821	0.033340805
2021	0.050625244	0.044080455	0.049221992	0.033242057
2022	0.050930711	0.044346431	0.049518992	0.033442635
2023	0.051298858	0.044666984	0.049876934	0.033684371
2024	0.051931851	0.045218144	0.050492381	0.034100014
2025	0.053126699	0.046258523	0.05165411	0.034884587
2026	0.053178059	0.046303243	0.051704046	0.034918311
2027	0.053827334	0.04686858	0.052335324	0.035344645
2028	0.054125381	0.047128097	0.052625111	0.035540352
2029	0.054227851	0.047217319	0.05272474	0.035607636

2030	0.054390856	0.047359251	0.052883227	0.03571467
2031	0.054498267	0.047452776	0.05298766	0.0357852
2032	0.054431277	0.047394446	0.052922527	0.035741212
2033	0.054495036	0.047449963	0.052984519	0.035783078
2034	0.054513453	0.047465999	0.053002425	0.035795171
2035	0.054535761	0.047485423	0.053024115	0.035809819
2036	0.054804833	0.04771971	0.053285729	0.0359865
2037	0.054891617	0.047795274	0.053370107	0.036043485
2038	0.055050384	0.047933516	0.053524474	0.036147736
2039	0.055247346	0.048105015	0.053715976	0.036277067
2040	0.055371459	0.048213083	0.053836649	0.036358564
2041	0.055503784	0.048328301	0.053965306	0.036445452
2042	0.055441414	0.048273994	0.053904665	0.036404498
2043	0.055562155	0.048379125	0.054022059	0.03648378
2044	0.055561073	0.048378184	0.054021007	0.03648307
2045	0.055479439	0.048307103	0.053941636	0.036429467
2046	0.055208258	0.04807098	0.053677972	0.036251401
2047	0.055169824	0.048037515	0.053640603	0.036226164
2048	0.055347763	0.04819245	0.053813609	0.036343004
2049	0.055348599	0.048193178	0.053814423	0.036343553
2050	0.055245133	0.048103087	0.053713824	0.036275614

Values beyond 2050 held constant at 2050 values.

Capacity Cost

Source/Notes:

Based on NMR Team FY2017 Evaluation recommendations. Base Residual Auction clearing prices for all PJM delivery years where the auction has occurred was compiled and established as the avoided cost of generation capacity for the DCSEU fiscal years where the auction has occurred (FY2017 through FY2022). The remaining years of the avoided cost horizon are established using the average clearing price for the 15 delivery years PJM has held capacity auctions.

Reference Spreadsheet: Capacity (kW)

Reference Document(s): NMR Team Evaluation Recommendations.xlsx

Value:

****Including demand line losses****

Year	$/kW-yr
2020	39.31327804

2021	33.24665267
2022	53.17210173
2023	67.82166058

Values beyond 2023 held constant at 2023 value.

Natural Gas Cost

Source/Notes:

Based on the U.S. Energy Information Administration Annual Energy Outlook 2019. Projected prices for the industrial sector (Mid-Atlantic region) are adopted. Note: cost includes **Natural Gas Capacity Adder**, as outlined previously.

Reference Spreadsheet: Natural Gas

Reference Document(s): Energy_Prices_by_Sector_and_Source.xlsx

Value:

Year	$/MMBtu
2017	5.333229095
2018	5.401750051
2019	5.468065773
2020	5.452753032
2021	5.313375462
2022	5.299654968
2023	5.398196026
2024	5.523128168
2025	5.708518954
2026	5.744164632
2027	5.741220334
2028	5.786828152
2029	5.774098872
2030	5.805222135
2031	5.792933033
2032	5.925004744
2033	5.98621332
2034	6.008409132
2035	6.045568804
2036	6.115286391

2037	6.150507108
2038	6.146945474
2039	6.169401045
2040	6.228554373
2041	6.231408462
2042	6.269886492
2043	6.330294054
2044	6.39870089
2045	6.473715822
2046	6.532114871
2047	6.593621246
2048	6.707437005
2049	6.813602372
2050	6.896125318

Values beyond 2050 held constant at 2050 value.

Other Fuels Cost

Source/Notes:

Projected prices for the industrial sector (Mid-Atlantic region) (where possible - transportation sector used as a substitute for kerosene cost) are adopted from the EIA Annual Energy Outlook 2019 supporting tables for energy price by sector and source.

Reference Spreadsheet: Other Fuels

Reference Document(s): Energy_Prices_by_Sector_and_Source.xlsx

Value:

Year	$/MMBtu		
	Propane	Distillate Fuel Oil	Kerosene
2017	13.57871866	19.58771401	13.04493016
2018	14.39897406	23.40772438	17.06813142
2019	14.98523289	24.01729915	16.80398316
2020	14.89750854	23.63389947	18.09150504
2021	15.22587671	23.01065213	17.83427468
2022	15.82146508	22.29824399	17.58596104
2023	16.19715386	21.96538428	17.8459832
2024	16.75647089	22.10545365	18.12354918

2025	17.33500092	22.69137864	18.43276754
2026	17.7599017	23.13529865	18.83050852
2027	18.03873984	23.87754151	19.37715238
2028	18.2332615	24.08993976	19.7754989
2029	18.291049	24.57571893	20.4456477
2030	18.33768402	24.80128532	20.57525649
2031	18.37651127	25.03959965	20.84188378
2032	18.5664266	25.36422927	21.25900416
2033	18.78234542	25.70584667	21.47231336
2034	18.97504203	25.78916164	21.66506578
2035	19.13342189	26.0380566	21.95206871
2036	19.31416882	26.42280953	22.27805159
2037	19.42046273	26.32852322	22.35143991
2038	19.49725366	26.50878256	22.56615923
2039	19.58755288	26.6749365	22.76740397
2040	19.67092999	26.86093531	22.89303936
2041	19.70277088	26.89799122	23.01392416
2042	19.77871827	27.07123366	23.23760231
2043	19.86252925	27.08171846	23.3615938
2044	19.93638937	26.98645802	23.33446665
2045	19.97112	27.04785454	23.50906761
2046	19.97717541	26.92277624	23.49252846
2047	19.97687211	26.79831823	23.556166
2048	19.97376648	26.84042276	23.70851467
2049	19.92010402	26.77294873	23.66991069
2050	19.81957907	26.74518128	23.6610361

Values beyond 2050 held constant at 2050 value.

Water

Source/Notes:

DC Water distributes drinking water and collects and treats wastewater for the District of Columbia. DC Water also provides wholesale wastewater treatment services for neighboring Arlington County and Fairfax Water territories. The Washington Aqueduct, managed by the U.S. Army Corps of Engineers (USACE), provides wholesale water treatment services to DC Water. DC Water purchases water from the Aqueduct and is responsible for maintaining the distribution system that delivers drinking water to customers. DC Water

Approved FY2018 Budgets and an independent engineering assessment of District of Columbia Water and Sewer Authority's (DC Water's or the Authority's) wastewater and water systems are used to estimate the marginal costs associate with water supply from the Washington Aqueduct and wastewater treatment for DC Water's wholesale customers. The two values taken in sum represent the wholesale price of supply and subsequent wastewater treatment for the District.

Reference Spreadsheet: Water

Reference Document(s): approved_fy_2018_operating_and_capital_budgets_final.pdf

2017 Engineering Feasibility Report WATER.pdf

Value: $3.071277613/CCF

Low Income Adder for Solar Measures

Source/Notes:

When applicable, solar projects serving low-income people (as defined by contract DOEE-2016-C-0002) will account for the Non-Energy Benefits associated with serving the Low-Income demographic, by way of an additional 15% adder (to the adders outlined in section C.40.10 of the SEU contract) in the screening. This adder is modeled on a regulatory order (State of Vermont Public Service Board "ORDER RE COST-EFFECTIVENESS SCREENING OF HEATING AND PROCESS-FUEL EFFICIENCY MEASURES AND MODIFICATIONS TO STATE COST-EFFECTIVENESS SCREENING TOOL," 2/7/2012) that intended to capture the broader impacts of alleviating fuel poverty that include improved thermal comfort, decreased morbidity and mortality, and improved educational outcomes, among others.

Reference Spreadsheet: Not applicable

Value: 15%

Avoided Cost of Solar Alternative Compliance Payment

Source/Notes:

The Renewable Portfolio Standard (RPS) in effect for the District of Columbia mandates that a certain percentage of electricity generated annually be sourced from solar sources, putting a premium price on energy generated from solar technologies. Each MWh of solar energy (electric or thermal) qualifies as one Solar Renewable Energy Certificate (or Credit), which can be traded on the DC SREC market. Electricity suppliers must acquire, on an annual basis, the appropriate number of SRECs as required by the RPS, or make Solar Alternative Compliance Payments (SACP) for any SREC not acquired. The SACP price is set at $500 through 2023.

It is reasonable to assume that every SREC created eliminates the need for one SACP purchase. Therefore, the avoided costs attributable to renewable measures will include the value of the SREC creation (the difference between SACP price and SREC price), to be added to the standard avoided costs. For solar electric measures (or thermal measures that reduce electricity consumption), the difference in SACP and SREC price will be added to the standard avoided costs of electric energy. For solar thermal measures that reduce fossil fuel consumption, the difference in SACP and SREC price will be added to the standard avoided fossil fuel costs.

The latest year's average SREC trading price for the DC market is used to establish the SREC value for the subsequent program year. For FY2020, the weighted average SREC price from November 26, 2018 through November 18, 2019 ($390.41) is used as a basis to calculate the value of avoided compliance payments. In 2024, the SACP begins an annual decline and therefore the SREC price is taken to be 78.08% of the SACP (ratio of $390.41 to $500) until the RPS expires at year's end in 2032. Beginning 2033, standard avoided costs of electric generation are used.

<u>Reference Spreadsheet:</u> Solar Adder

<u>Value:</u>

Year	Energy (kWh) Adder ($/kWh)	Natural Gas Adder ($/MMBtu)
2019	$0.10959	$32.11817
2020	$0.10959	$32.11817
2021	$0.10959	$32.11817
2022	$0.10959	$32.11817
2023	$0.10959	$32.11817
2024	$0.08767	$25.69453
2025	$0.08767	$25.69453
2026	$0.08767	$25.69453
2027	$0.08767	$25.69453
2028	$0.08767	$25.69453
2029	$0.06576	$19.27090
2030	$0.06576	$19.27090
2031	$0.06576	$19.27090
2032	$0.06576	$19.27090

No adder applied beyond 2032.