Future of Solar PV in the District of Columbia

Feasibility, Projections, and Rate Impacts of the District's Expanded RPS

Prepared for the District of Columbia Office of the People's Counsel

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1. EXECUTIVE SUMMARY

The Office of the People's Counsel for the District of Columbia ("OPC") in collaboration with the National Renewable Energy Laboratory (NREL) of the Federal Department of Energy and the Clean Energy States Alliance (CESA) completed "The future of Solar Study for the District of Columbia." Synapse Energy Economics, Inc., contracted to undertake the study for OPC.[1] The objectives of OPC's solar study were:

(i) Assessment of the possibility of meeting the 100% renewable portfolio standard (RPS) by 2032 and the solar carve-out provision of the RPS requiring that 10% of renewable energy be sourced from solar inside the District of Columbia by 2041, pursuant to the Clean Energy DC Omnibus Amendment Act of 2018; and

(ii) Assessment of the technical and economic potential of solar by ward and type of deployment (rooftop vs. parking lot canopy, private vs. community) including estimates of the price of solar energy credits and the presence of cost shifting between solar and non-solar owners.

The scope of the study is limited due to budget and time constraints. These limitations include the following issues:

a) The study did not assess the cost of meeting the RPS and its impact on ratepayers, relative to an alternative without an RPS statute.

b) The study did not specifically determine how hosting capacity constraints, permitting barriers, rooftop conditions, and other factors inhibit the development of solar in the District.

c) The study did not assess the performance of the Solar for All program with respect to evaluating whether it will achieve its goals, how program design might be optimized to deliver the greatest benefit to the District, or its impact on meeting the solar carve-out.[2]

d) The study estimated the rate and bill impacts of solar development but did not conduct a value-of-solar analysis to account for all the benefits that solar provides to the grid and

1 OPC thanks NREL for its initial funding and its guidance and technical support, and CESA, as well as the Department of Energy and Environment for DC for its valuable comments on various sections of the study.

2 While this study did not explicitly estimate solar deployment due to the Solar for All program, the contribution of this program toward overall District carve-out achievement is believed to be reflected in the medium and high scenarios investigated by this study. While we modeled community solar development as a function of overall solar development dynamics in each of our projections, it bears mention that community solar might have instead been conceptualized exogenously. By "exogenously," it is intended to imply that Solar for All is affected largely by administrative forces and regulations, rather than by incentives or other market-based forces.

wider community, nor did the study examine the equity or distributional impacts of solar in detail.[3]

e) The study examined the bill effect of solar on the distribution grid to an average ratepayer or customer. The study did not assess how incremental solar on the grid will impact low-income customers.[4]

Finally, OPC believes that this study is a living document that may be updated as inputs and assumptions change, and urges readers of this study to use it cautiously and within the boundaries set by the objectives and scopes or limitations indicated above.[5]

The District of Columbia passed the Clean Energy DC Omnibus Amendment Act of 2018 in December 2018, making the District's Renewable Portfolio Standard (RPS) significantly more ambitious. The new policy requires 100 percent of the District's electric supply to be sourced from renewable generators by 2032. The policy also requires 5.5 percent of that 2032 electric supply to be sourced from in-District solar (the solar "carve-out" requirement), steadily ramping up to 10 percent by 2041. Of the 56 states and territories in the United States, the District was third in instituting a 100 percent renewable requirement, following Hawai'i and California.

The overall requirement to source 100 percent of electricity from renewables by 2032 is expected to be met at a relatively low cost through the purchase of renewable energy certificates (RECs) from the regional wholesale market.[6] The District accounts for a small fraction of this large region's electrical demand, and the PJM region and adjacent states have plentiful wind and solar resources relative to the DC's RPS requirements. The District's RPS eligible renewable resources include wind, solar, biomass, landfill gas, and some hydroelectric generators located in the PJM Regional Transmission Organization (RTO), which spans the Mid-Atlantic and extends inland to Chicago, and states adjacent to the PJM footprint.[7,8] Therefore, we conclude that the

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3 OPC's solar study on the value of solar in 2017 includes direct and indirect costs and benefits to individuals and society at large. The present study did not undertake such a detailed and exhaustive analysis of values that can be attributed to solar or renewable because it was outside the scope of the study. Instead, it refers to the 2017 study.

4 An average customer in this study is assumed to be a residential customer with an average monthly electricity consumption of about 700 kWh.

5 The study was completed in the fall of 2019 (before Covid-19), but the release was delayed to incorporate comments.

6 Low cost relative to the ceiling price set by the high alternative compliance payment by DC Council., Recent ruling by the Federal Energy Regulatory Commission on minimum price offer rule (MOPR) if left unchanged, could result in either significantly higher prices or a slower development of renewable resources

7 States within PJM Interconnection (Delaware, the District of Columbia, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia), and states adjacent to the PJM Interconnection region (Alabama, Georgia, Iowa, Missouri, New York, South Carolina, and Wisconsin) are eligible to offer RPS certified electricity generated from renewable resources.

8 Throughput this report, wherever PJM footprint states or jurisdictions are mentioned for the purpose of meeting DC's RPS requirement, it will also include states adjacent to the PJM footprint.

District will comply with its RPS requirement each year up to and including 2032, with REC prices trending toward $13 per megawatt hour (MWh) (2018 dollars) throughout that period.[9]

However, the District's solar carve-out will likely prove much more challenging to meet.[10] To date, the District has not met its solar carve-out obligation due to several critical barriers: distribution system hosting capacity constraints, limited space for solar development, high upfront solar costs, customer financing barriers, the significant share represented by soft costs in the overall cost of solar deployment, and the uncertainty of the Solar Renewable Energy Certificate (SREC) program.[11,12] Meeting the solar carve-out requirement going forward is also expected to have challenges if those barriers are not addressed in the near-term. In this report, Synapse calculates that the quantity of the solar obligation constitutes a large fraction of the District's current economic solar PV potential. Moreover, though ground-mounted solar is typically less costly than rooftop solar on a per-megawatt (per-MW) basis, the availability of space for ground-mounted solar is limited given the District's dense urban environment, indicating that the solar carve-out will likely be primarily met through more expensive rooftop and parking lot canopy installations. Despite these factors, achieving the solar carve-out objectives is technically feasible through the development of rooftop and parking lot solar systems, but will require substantial ongoing investment and engagement by the District and developers alike.[13]

Synapse developed three projections (Low, Middle, and High) to characterize different future trajectories of solar installation between 2019 and 2041. The solar PV installation projections rely on historical datasets provided by the Public Service Commission and the Department of Energy and Environment. The projections envision future installations primarily on rooftops and parking lot canopies, with minimal ground-mounted installations.

These three solar projections are applied to each ward, varying with the differing rooftop and parking infrastructure that currently exists across the District. Ward 1 has the smallest share of the District's technical potential at 6.4 percent, while Ward 5 has the largest share of solar technical potential at 18.7 percent. Comparing the ward-level technical potentials to the historical

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9 In 2018, District suppliers paid an average of $2.85 for Tier 1 RECs and about $1.13 for Tier 2 RECs. Tier 2 RECs may be used for just a small fraction of the overall RPS requirement and will be completely phased out after 2019. Source: Synapse calculations based on data from DC PSC, "Report on the Renewable Energy Portfolio Standard for Compliance Year 2018."

10 It should be noted that DC's solar carve-out is a small subset of the RPS, and that DC's RPS also include solar from the PJM footprint or adjacent states.

11 Informal interviews with installers indicated that soft costs (i.e., customer acquisition, permitting, inspection, interconnection, installation, taxation, and system financing) account for about 75% of solar installation costs.

12 Whited, M., A. Horowitz, T. Vitolo, W. Ong, T. Woolf. "Distributed Solar in the District of Columbia." April 12, 2017, page 2. http://www.synapse-energy.com/sites/default/files/Distributed-Solar-in-DC-16-041.pdf.

13 It should also be noted that there is potential that some share of current parking lot space may be given over to new building construction, which could require changes to this study's assumptions with respect to the percentage of parking lot space available for solar deployment and the corresponding solar potential.

installation of solar in each ward sheds light on which wards are lagging their technical potential. To date, Wards 2 and 3 are lagging in installations relative to their technical potential.[14] In practice, the District can influence the actual quantity of solar installed in each ward through policy adjustments, marketing and other customer outreach, or by focusing the Solar for All program on specific locations.

Community solar in the District is nascent, with limited installed capacity at the time of this report's publication. Nationally, community solar projects tend to be installed in relatively large, ground-mounted installations to reduce costs. However, these installations require conditions that are rare in the District, suggesting higher installed costs for community solar in-District. Because of the District's net metering policies and the expectation that most solar PV installed in the District will be sized consistent with on-site load, Synapse does not forecast community solar built on any privately-owned rooftops or parking lots. Instead, Synapse models that all future community solar systems will be built on local government-owned rooftops and parking lots. Using the ratio of private to District-owned land, this assumption results in 13 percent of in-District solar capacity being community solar, over half of which can be built on parking lot canopies. Based on the distribution of available District-owned land, the least community solar is projected for Ward 3 and the most for Wards 7 and 8. Community solar represents a potentially effective tool to spur solar PV adoption in some regions of the city. Furthermore, community solar (especially through the Solar for All program) may be enhanced with improvements in distribution grid upgrades.

To evaluate the impact of each of the three projections on ratepayers, Synapse developed a simple rate and bill model to estimate average electricity costs for residential customers for each future year of the RPS in each projection. The RPS is modeled as impacting rates in two ways: by introducing new supplier costs associated with acquiring RECs and/or making Alternative Compliance Payments (ACP), and by reducing the total volume of electricity sales. Overall, the Middle projection appears to be just slightly more expensive on a dollars-per-unit-of-electricity basis than the Low projection. Due to the impact of lessened grid energy consumption, however, the Middle projection is associated with slightly lower total residential electricity bills through 2041. Meanwhile, the High projection is associated with both lower rates and lower bills.

These rate results do not provide a complete picture of scenario economics.[15] There are important distributional consequences. For households with PV, increases in electricity rates are compensated for by their declining grid energy consumption, and probably more than offset by

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14 This study did not evaluate the factors that have contributed to differentiated adoption of solar by ward. Undertaking such an analysis may help to identify factors that could be targeted to enhance solar adoption.

15 The study did not perform analysis of the value of solar by including environmental, human health, economic development, and other benefits. The study only assesses the market costs of solar renewable energy credits for electricity generated from solar, and the ramification of declining utility sales on rates

SREC revenues once PV system investments have been repaid. In other words, on net, households with PV are likely to face better economics under certain scenarios than they would have had there been no RPS standard at all; meanwhile, those households without PV may do worse. Synapse considered these distributional impacts through a cost-shift analysis that estimated the effect of distributed solar on the bills of average customers (i.e., the bills of customers without solar) in the Middle and High scenarios relative to the Low scenario.

Several key inputs are uncertain, including the overall viability of parking lots and municipal property for PV development, the potential for changes in zoning and development regulations in the future, and the extent to which parking lots will be given over to building construction. Also unknown is the extent to which average solar panel efficiency in the District will improve over the study period, and how energy efficiency, electrification of end-uses, and population growth will affect overall load growth. We tested the impact of changes to many of the key underlying assumptions in a sensitivity analysis at the close of this study.

Though the District has not met its ambitious solar carve-out to date, the non-compliance gap has been shrinking, suggesting that progress may be taking hold. To ensure this upward trajectory continues, Synapse makes several policy recommendations to be implemented in the near-, mid-, and long-term. We recommend that the District closely monitor solar installations, the interconnection queue through Pepco, building permit applications, and SREC prices, in order to react quickly should installations slow. Similarly, the District could require that Pepco study the distribution system's ability to host the level of PV necessary to comply with the carve-out using existing infrastructure. To the extent that the system cannot support adequate PV development, Pepco should be required to determine the investments necessary to accommodate the needed incremental solar. Pepco could be required to upgrade the distribution system—potentially with the support of ACP funds. Changing land use policies or building codes to require solar PV for new construction or substantial renovation is another way to drive solar adoption. To the extent that installations are not distributed equitably across the city based on technical potential, the District can respond with marketing outreach, Solar For All community solar installations on DC-owned rooftops and parking lots, or other targeted approaches.

2. INTRODUCTION

In 2017, Synapse Energy Economics, Inc. (Synapse) produced a report for the Office of the People's Counsel for the District of Columbia (OPC) that explored key issues related to the distributed solar target enacted in the Renewable Portfolio Standard Expansion Amendment Act of 2016. The Act set the new RPS target at 50 percent renewables by 2032 with a solar carve-out of 5 percent.[16] The report assessed barriers and policy options, the technical and economic potential of solar, the value of solar, and cost-shifting among customers at a District-wide resolution. The key barriers identified in that report included access to suitable space, a slow interconnection process through Pepco (the District's electric utility), uncertainty about the future price level of Solar Renewable Energy Certificates (SRECs), and solar upfront costs and financing.[17] While solar photovoltaic (PV) costs have continued to decline—benefiting from efficiencies in hardware production, installation, and marketing—the development of this technology in the District has remained relatively sluggish.

In December 2018, the District passed the Clean Energy DC Omnibus Amendment Act of 2018 which extended the District's Renewable Portfolio Standard (RPS) to 100 percent renewable electricity by 2032 and set a new trajectory for the solar carve-out, with targets of 5.5 percent by 2032 and 10 percent by 2041.[18] In light of this updated RPS, OPC hired Synapse Energy Economics to conduct a study evaluating the feasibility and impacts of meeting these new targets, as well as the likely mix of private and community solar across the District. The resulting report builds on Synapse's previous work for OPC, with updates to reflect the new legislation and to address the economics, geography, and other critical dimensions of the required solar buildout.

This report is comprised of four primary sections, each of which answers a key question:

Section 3: Feasibility of Attaining RPS Goals. *How feasible are the new RPS targets for the District?*

Section 4: Solar Projections. *What might the growth trajectory for solar in the District look like through 2041 by ward, and what role will community solar play in the District's future?*

Section 5: Rate Impacts. *How will the solar carve-out requirement impact electricity rates in the District?*

Section 7: Policy Recommendations. *Which policies might contribute to increases in the likelihood of the District meeting the solar carve-out?*

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16 Council of the District of Columbia, B21-0650: http://lims.dccouncil.us/Download/35409/B21-0650-SignedAct.pdf.

17 Whited, M., A. Horowitz, T. Vitolo, W. Ong, T. Woolf. "Distributed Solar in the District of Columbia." April 12, 2017, page 2. http://www.synapse-energy.com/sites/default/files/Distributed-Solar-in-DC-16-041.pdf.

18 Council of the District of Columbia, B22-0904: http://lims.dccouncil.us/Download/40667/B22-0904-SignedAct.pdf.

3. FEASIBILITY OF MEETING THE NEW RPS

Evaluating the feasibility of meeting the District's updated RPS requires an understanding of the RPS mechanism. Electric suppliers, including both Pepco and competitive electricity suppliers, are required to comply with the RPS each year. Each supplier's obligation is set at a percentage of its sales, on a megawatt-hour (MWh) basis. Under the Clean Energy DC Omnibus Amendment Act, the 100 percent renewable energy target and the solar carve-out are separate but interacting components. The legislation requires District suppliers to fulfill *both* the overall RPS Tier 1 requirement and the in-District solar carve-out requirement.[19,20] For every MWh of obligation, the supplier must retire the appropriate number of Tier 1 renewable energy credits (RECs), which are generated by qualifying renewable sources across PJM and adjacent states, as well as the appropriate number of SRECs, which can only be produced by solar in the District. In 2019, for example, for each 1,000 MWh of energy sold, a supplier's obligation was 175 MWh of qualifying Tier 1 renewable resources (17.5 percent of 1,000) and 18.5 MWh of qualifying solar-powered energy (1.85 percent of 1,000; see Table 2). Because SRECs count toward the Tier 1 requirement, attainment of the SREC target contributes to attainment of the Tier 1 target. Because net-metered solar generation in the District reduces electricity sales, District solar makes a second-order contribution to the overall RPS Tier 1 target by reducing the total number of Tier 1 RECs that must be procured.[21]

If a supplier does not procure enough SRECs, it must pay the alternative compliance payment (ACP) associated with that compliance year. The ACP value serves as a price ceiling for SRECs because a supplier would simply make an ACP rather than purchase SREC at a price that exceeds the ACP value. Because suppliers are required to either purchase SRECs or pay the legislated ACP price, cost-minimizing suppliers are expected to opt for SRECs at just under the ACP value while the market for SRECs is constrained.[22]

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19 The in-District solar carve-out includes both solar PV and solar thermal as qualifying resources.

20 The Clean Energy DC Omnibus Amendment Act also requires District electricity suppliers to retire a modest share of total sales in Tier 2 RECs each year through 2019.

21 District solar production reduces the number of SRECs that must be procured: the less solar capacity that is online in a given year within the District, the higher the SREC target, in real terms, will be.

22 Following the 2017 Synapse study, we assumed that the SREC market price would be 96.7% of the ACP value while total installed solar capacity is below the required carve-out level. With limited historical price data, determining the exact difference between the ACP and SREC price levels for a given future year is less an empirical question than one of analytical judgement. Nonetheless, over the period 2011–2016, with the ACP at $500/MWh, the average SREC price has increased from $300.16/MWh in 2011 to $477.18/MWh in 2016. This suggests that the ACP has been effective in pulling up the SREC price. See Public Service Commission of the District of Columbia. "Report on the Renewable Energy Portfolio Standard Compliance for Year 2017," and similar reports for prior years as well.

The ACP is currently set at $500 per MWh and is scheduled to ramp down in price starting in 2024.[23] In addition to the obligation to make ACP payments, a supplier that fails to meet the solar carve-out in a given year is also required to fill the "gap" with Tier I RECs from the PJM and adjacent states..

3.1. Tier 1 RPS Requirement

First, we assessed the feasibility of the District meeting its target of 100 percent Tier 1 renewable energy by 2032. As mentioned above, the compliance reports indicate that the District has fulfilled its general Tier 1 requirement in every year since 2007. By 2032, when the District is expected to supply 100 percent of its electric sales with renewable energy, total annual sales are expected to be greater than 11 million MWh.[24] In terms of technical feasibility alone, it is expected that the District will face less difficulty in continuing to meet its Tier 1 renewable energy target because of the large quantity of RECs available in the PJM and adjacent states' footprint.

We arrived at this conclusion based on a similar analysis that Synapse conducted for the state of Maryland, which quantified the feasibility of meeting an expanded RPS of 25 percent by 2020.[25] The results of that study showed that Maryland would very easily be able to meet the requirements of an expanded RPS with available PJM resources, given the small size of Maryland's load relative to the availability of RECs in the PJM region and adjacent states. In that study, we used the results from a previous analysis conducted by the National Renewable Energy Laboratory to develop a low and high estimate of available renewable resources in PJM eligible for Maryland's Tier 1 RPS (hydro, biomass, and onshore wind).[26] The low estimate was calculated to be 290 million MWh per year and the high estimate was assessed at 1,300 million MWh per year. These estimates do not include solar PV, which is not eligible for Maryland's Tier 1 RPS. However, solar PV is eligible in the District's Tier 1 RPS, which increases the low estimate to 382 million MWh and the high estimate to 11,340 million MWh per year.[27] We note

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23 Similarly, suppliers that do not meet overall Tier 1 targets are subject to the Tier 1 ACP, which is currently set at $50/MWh through 2041. While individual suppliers have missed respective Tier 1 targets, in the aggregate, the District has met its overall Tier 1 goal for each year since 2007. See summary of the Department of Energy's Berkeley Lab, titled "RPS Compliance Summary Data," available online at: https://emp.lbl.gov/sites/default/files/rps_compliance_data_nov_2018.xlsx.

24 This is based on total District electricity sales for the year 2017, as reported in the Energy Information Administration's (EIA) form 861 (10.9 million MWh), escalated annually at a rate of 0.2% and assumes full SREC compliance. EIA-861 is available at: https://www.eia.gov/electricity/data/eia861/.

25 Vitolo, T., Horowitz, A., Luckow, P., and N Santen. 2015. Meeting Maryland's RPS: A Study of Renewable Portfolio Standard Resources. Synapse Energy Economics, http://www.synapse-energy.com/sites/default/files/Meeting-Marylands-RPS-15-111.pdf.

26 Brown, A., Beiter, P., Heimiller, D., Davidson, C., Denholm, P., Melius, J., Lopez, A., Hettinger, D., Mulcahy, D., and G. Porro. 2015. "Estimating Renewable Energy Economic Potential in the United States: Methodology and Initial Results." National Renewable Energy Laboratory. Available at: www.nrel.gov/docs/fy15osti/64503.pdf.

27 Brown, et. al, 2015. p83 and 117.

that Maryland's annual electric load is more than five times the size of the District's; thus, even 25 percent of Maryland's load is still larger than the District's entire load.[28]

In 2032, the District's annual load is expected to be about 3 percent of the low estimate of PJM's available renewable resources. By measure of the high estimate from the Maryland study, the District's 2032 load is 0.1 percent of PJM's available renewable resources. Given that the District's total load in 2032 is expected to be between 0.1 and 3 percent of PJM's available renewable resources, it is expected that there will be more than enough renewable energy resources to meet the District's 100 percent target in 2032.[29] If the District meets its annual solar carve-out each year, meeting the renewable target becomes even more feasible. However, there is a chance that meeting the RPS could be more challenging if other states in PJM increase their RPS standards, creating higher demand for RECs in the region.

3.2. Solar Carve-Out

To assess the feasibility of the District meeting its solar carve-out of 10 percent by 2041, we evaluated both the technical feasibility and the economic feasibility of meeting the carve-out, as defined below:

- *Technical feasibility*: Is there sufficient space in the District (on rooftops, parking lots, and open land) to host the required amount of solar necessary to meet the carve-out?
- *Economic feasibility*: Will the economics of solar (e.g., SREC prices, installation costs) support solar development sufficiently to meet the carve-out?

Technical Feasibility

To meet the carve-out, the District needs to install a total of 665 MW of solar by 2041 (Table 2).[30,31] As will be discussed in detail in Section 4.5, our geospatial analysis shows that the District has enough space to host over 2700 MW of solar PV. After considering shading and other installation barriers, we find that the District has nearly 1300 MW of solar installation

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28 US Energy Information Administration State Electricity Profiles, https://www.eia.gov/electricity/state/.

29 It is worth noting that there is, of course, some uncertainty associated with how these assumptions about the PJM REC market will hold up going out to 2032; however, if past trends in the PJM market hold steady, the District is very likely to meet its goal of 100 percent renewable energy by 2032.

30 Following PJM, we assume 0.2% growth in load per year. PJM Load Forecast Report, January 2019, page 80. See: https://www.pjm.com/-/media/library/reports-notices/load-forecast/2019-load-report.ashx?la=en.

31 In 2019, the capacity factor of a standard solar system in the District is about 15.7 percent (NREL PVWatts). We assumed that by 2041, the average capacity factor PV in the District will be at least 22 percent – the capacity factor of the highest efficiency panels on the market. We assumed 18 percent capacity factor as the typical value given that systems installed towards the end of the study period are likely to be in less optimal locations than those installed at the start. For consistency, reported historical carve-out targets are calculated based upon an 18 percent capacity factor, which undervalue the total installed capacity that would have been required to meet historical targets.

potential. This quantity is nearly double the required installed capacity the District needs to meet its solar carve-out target in 2041; therefore, we conclude that attaining the solar carve-out is technically feasible.

Economic Feasibility

Though the solar carve-out target is technically feasible for the District, meeting the carve-out will only be *economically feasible* with the SREC price above a certain minimum level. We note that historical experience has supported the efficacy of the ACP in pulling up the SREC market price (a relationship we refer to as the ACP-SREC market mechanism), as the data in Table 1 shows.

Table 1. Annual weighted-average SREC price ($/MWh)

Year	2011	2012	2013	2014	2015	2016	2017	2018
SREC Price	$300.16	$327.57	$364.75	$416.50	$435.12	$477.18	$390.05	$396.63
ACP Price	$500.00	$500.00	$500.00	$500.00	$500.00	$500.00	$500.00/ $350.00	$500.00/ $300.00

Source: DC PSC, "Report on the Renewable Energy Portfolio Standard for Compliance Year 2018" (https://dcpsc.org/PSCDC/media/Images/Report-on-REPS-for-2019-043019-final.pdf). The ACP price schedule was set by the Distributed Generation Amendment Act of 2011 and revised in the 2016 law. Years 2017 and 2018 have split pricing to reflect grandfathering under the 2011 act and the revised (higher) ACP for new supply contracts.

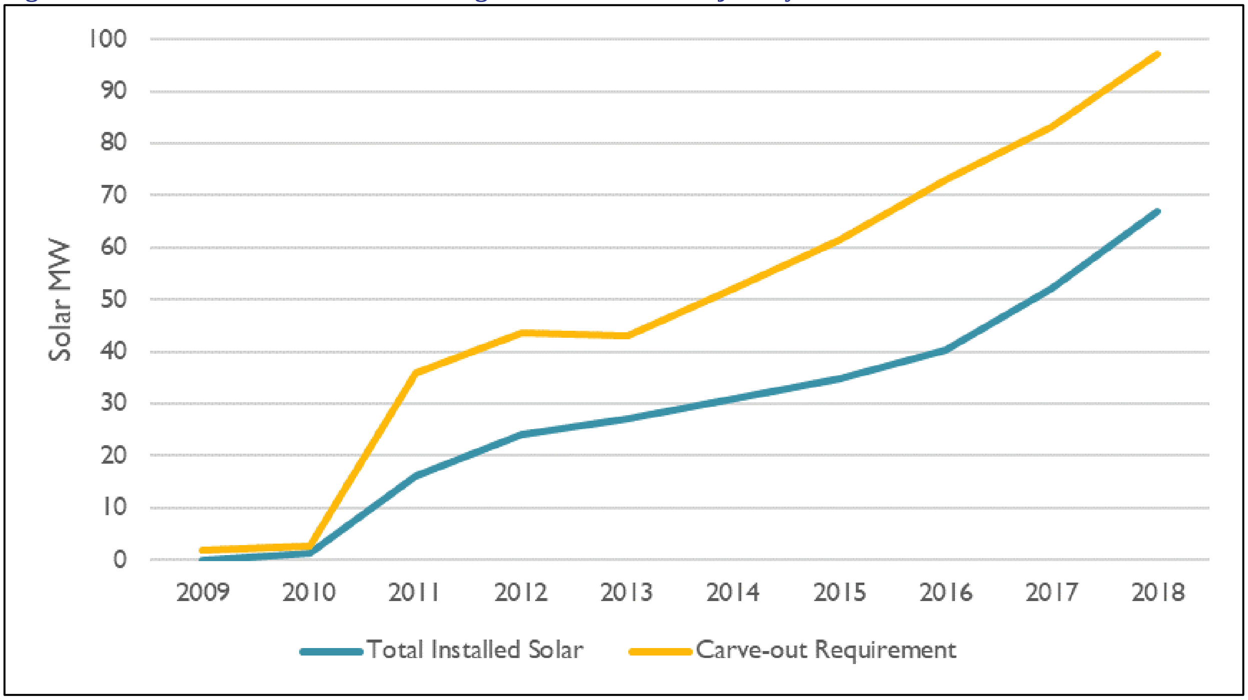
The District's ACP price, the highest in the nation, should theoretically provide sufficient stimulus through the ACP-SREC market mechanism. Yet the required solar build-out has not yet materialized.[32] The gap between the target and actual solar installations in the District has largely persisted through 2019. As of the start of 2019, the District had just 64 percent of the capacity required by the carve-out. The ACP is presently set at $500 and will fall to $400 in 2024 and to $300 in 2029.[33] Since the current ACP has not spurred the required PV buildout thus far, it raises the question of whether the District will meet its solar targets in later years under a diminished ACP.

Figure 1 presents cumulative installed solar capacity in the District, and carve-out requirements, since 2009. Table 2 on the following page provides more detailed data on RPS requirements and District compliance.

32 While the District's failure to meet the solar carve-out requirement could be taken as *prima facie* evidence that the SREC market price is insufficiently high to spur the necessary build-out, we rather follow the approach taken in the 2017 Synapse report in assuming a specific SREC price level that is a necessary but not sufficient condition for carve-out compliance. While SREC prices above the sufficient level might engender greater investment in solar, we interpret the failure to achieve the carve-out target, given an SREC price above the sufficient level, as a primarily non-economic story.

33 Clean Energy DC Omnibus Amendment Act of 2018. These values are in nominal dollars.

Figure 1. Cumulative District solar and legislated carve-out trajectory



Source: *RPS requirement is from Code of the District of Columbia §34-1432 (*https://code.dccouncil.us/dc/council/code/sections/34-1432.html) *and Synapse calculations. Historical installations are from DC PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx). Future projection is based on* Synapse calculations.

Table 2. District of Columbia RPS requirements and achievement

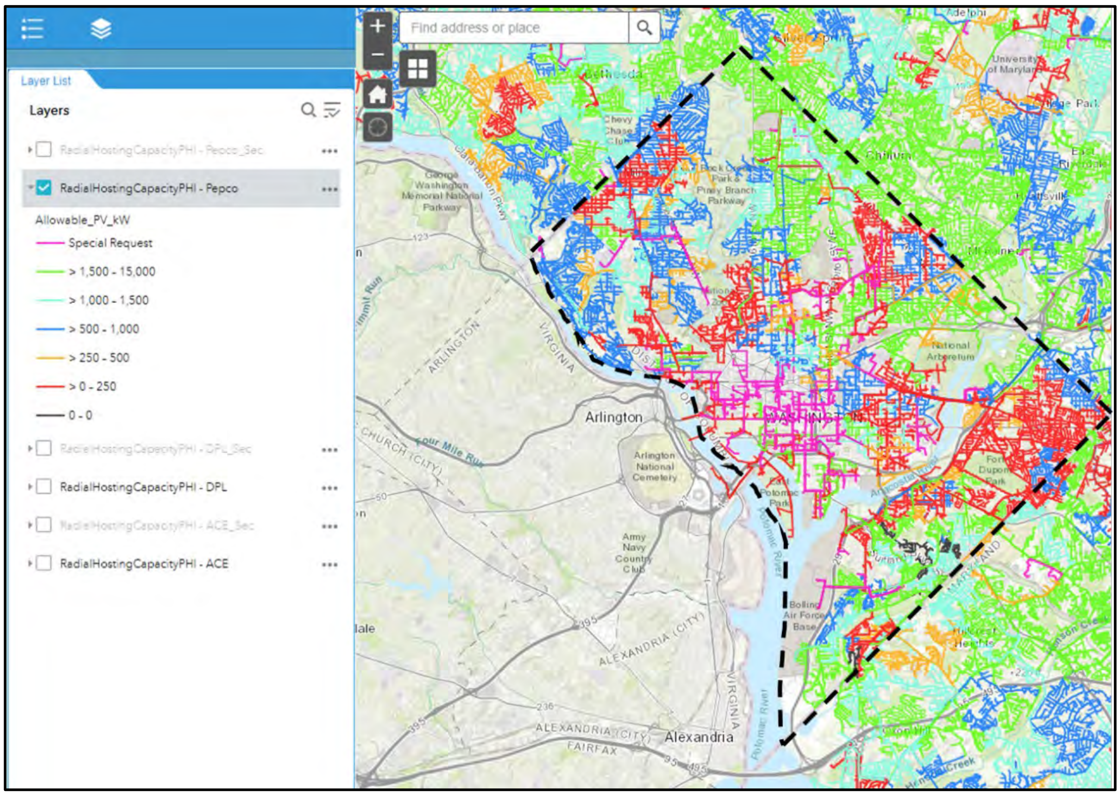
Year	Tier 1 Requirement (% Sales)	Tier 2 Requirement (% Sales)	Solar Carve-out Requirement (% Sales)	Solar Carve-out Requirement (MW)	Solar Carve-out Achievement (MW)
2009	3.00%	2.50%	0.02%	1.8	0.0
2010	3.50%	2.50%	0.03%	2.8	1.3
2011	4.00%	2.50%	0.40%	35.9	16.0
2012	5.00%	2.50%	0.50%	43.7	24.2
2013	6.50%	2.50%	0.50%	43.0	27.2
2014	8.00%	2.50%	0.60%	52.1	30.8
2015	9.50%	2.50%	0.70%	61.4	34.8
2016	11.50%	2.00%	0.83%	73.0	40.3
2017	13.50%	1.50%	0.98%	83.1	52.0
2018	15.50%	1.00%	1.15%	97.3	67.1
2019	17.50%	0.50%	1.85%	127.2	81.1
2020	20.00%	0.00%	2.18%	149.3	-
2021	26.25%	0.00%	2.50%	171.4	-
2022	32.50%	0.00%	2.60%	178.5	-
2023	38.75%	0.00%	2.85%	195.6	-
2024	45.00%	0.00%	3.15%	216.0	-
2025	52.00%	0.00%	3.45%	236.3	-
2026	59.00%	0.00%	3.75%	256.6	-
2027	66.00%	0.00%	4.10%	280.2	-
2028	73.00%	0.00%	4.50%	307.0	-
2029	80.00%	0.00%	4.75%	323.9	-
2030	87.00%	0.00%	5.00%	340.8	-
2031	94.00%	0.00%	5.25%	357.7	-
2032	100.00%	0.00%	5.50%	374.6	-
2033	100.00%	0.00%	6.00%	407.5	-
2034	100.00%	0.00%	6.50%	440.3	-
2035	100.00%	0.00%	7.00%	472.9	-
2036	100.00%	0.00%	7.50%	505.3	-
2037	100.00%	0.00%	8.00%	537.6	-
2038	100.00%	0.00%	8.50%	569.7	-
2039	100.00%	0.00%	9.00%	601.7	-
2040	100.00%	0.00%	9.50%	633.4	-
2041	100.00%	0.00%	10.00%	665.1	-

Source: RPS requirement is from Code of the District of Columbia §34-1432 (https://code.dccouncil.us/dc/council/code/sections/34-1432.html) and Synapse calculations. Historical installations are from DC PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx).

While the ACP and resultant SREC price are critical elements in spurring solar adoption in the District, the level of solar installation will be influenced by other factors too. The factors that may affect residential and commercial investment in PV include retail electricity rates, the hard and soft costs of installing solar, the ability of customers to access financing for solar, the availability of rebates and other incentives (such as tax credits), the level of investment through District-funded programs, the ease of interconnection, and hosting capacity constraints.[34] Figure 2 on the following page illustrates that many regions in the District are already experiencing hosting capacity constraints or require a "special request" to interconnect solar. Distribution system hosting capacity constraints present another significant challenge as the District aims to increase the rate of solar PV installation to meet the solar carve-out.

Given these challenges, it is uncertain whether the District will meet its solar carve-out target. To guide policy recommendations for meeting the target, Synapse developed three solar installation projections through 2041, developed with both technical and economic feasibility in mind. These projections are described in the following section.

Figure 2. Hosting capacity constraints in the District, as of July 2019.



Source: Pepco, Hosting Capacity Map (https://www.pepco.com/SmartEnergy/MyGreenPowerConnection/Pages/HostingCapacityMap.aspx). The District of Columbia is located only within the dashed black line.

34 Total costs for installing a solar PV system are typically divided into *hard* and *soft* cost categories. Hard costs are those for the physical infrastructure, while soft costs are all other associated costs, including costs for permitting, financing, marketing and customer acquisition, and interconnection, with labor as a significant element. While soft costs have dropped in the District in the recent past, there is reason to be optimistic that they may continue to fall with increasing penetration of PV. Scale economics and a maturing sector should help to optimize financial mechanisms, while the impetus for widespread adoption from the RPS should reduce marketing and customer acquisition costs for developers. Notably, the District has been awarded the SolSmart 'Gold' designation in recognition of performance in inspection and community engagement.

4. Solar Projections

Synapse developed three projections—Low, Middle, and High—for the total solar PV installed in the District from 2019 to 2041. These projections were based on historical installations in the District and are informed by the RPS and the calculated technical potential of solar in the District. As mentioned in the previous section, each projection is based in a different economic context for solar in the District, with the market price for SRECs varying with the installed capacity and annual generation of small PV. Synapse also projected the contribution of community versus private solar and the contribution of solar PV by installation type (rooftop, parking lot canopy, and ground-mount). The following sections describe our sources of data, approach, and results.

4.1. Data Sources

Synapse relied on solar installation data sets provided by the District's Public Service Commission (PSC) and the District Department of Energy and Environment (DOEE).[35,36] These comprehensive data sets include every solar PV and solar thermal installation within the District of Columbia installed from May 19, 2009 through the end of June 2019.[37] The data includes details such as capacity (in MW), address, Certification Number, and, in some cases, the GATS Unit ID. The PSC dataset also includes 20.4 MW of solar PV installations located outside the District that qualify for the RPS as grandfathered generation capacity.

This analysis also relied on the use of Geographic Information Systems (GIS) software. All datasets for the GIS analysis were derived from Open Data DC.[38]

4.2. Solar Projections for the District

Synapse produced three projections of solar development in the District. The Low projection represents a highly conservative estimate of future solar adoption in which the annual solar installation rate remains at the level experienced in 2018. The Middle projection depicts a trajectory that meets the solar carve-out for most of the period through 2041. The high projection

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35 DC PSC, Renewable Energy Portfolio Standard Program, "List of Eligible Renewable Generators.xlsx," accessed on July 29, 2019 at: https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx.

36 This dataset was acquired directly from the District DOEE through a non-disclosure agreement.

37 Because the 2009 data does not begin on January 1, it was necessary to include intra-year projections for 2009 for a fair year-over-year comparison. To calculate installations deployed in Q1 2009, we assumed that the ratio of Q1 2009 to rest-of-year 2009 was equal to the corresponding ratio in 2010.

38 Open Data DC. http://opendata.dc.gov/.

envisions solar installations exceeding carve-out requirements – an outcome only expected with a technological breakthrough or significant change in solar regulation or policy.

For all projections, we assumed that the RPS and net-metering policies will not be modified through 2041 and that building codes, historic district standards, and other restrictions will not be made more restrictive.

Low Projection for Solar PV Installations in the District of Columbia, 2019–2041

The RPS experience in the District so far has been mixed. While the District has successfully met its Tier 1 requirements since the passage of the Distributed Generation Amendment Act of 2011, suppliers have not consistently procured enough SRECs and have instead paid the ACP in each year.[39] According to Synapse's calculations, there is not presently enough solar capacity to generate the needed credits.[40]

One explanation for this shortfall is that the economics of the ACP-SREC market mechanism is not the limiting factor for District solar investment. In the Low projection, we assume that other factors—such as distribution system constraints or administrative hurdles—continue to hinder investment. Since it is unclear how much incremental solar capacity would be added each year given these limitations, we assume that the rate of installation in 2018 remains constant for the full model period. This equates to 14 MW of new solar capacity annually in each year through 2041.

As shown in Figure 3 on the following page, under the Low Projection, cumulative solar capacity is forecast to reach about 390 MW by 2041, about 59 percent of the required capacity to meet the carve-out.[41] The data associated with Figure 3 are in the Appendix.

Synapse considers this projection to be conservative, primarily because the market ability to install 14 MW of solar PV in the future already exists, without need for additional labor, improved solar economics, or new policies. However, the sunsetting of the solar federal Investment Tax Credit beginning in December 2019 and probable reduction in the SREC market price due to the legislated stepdown in the ACP value could slow the pace of solar installations, raising the prospect that solar development in the District might never reach the required level.

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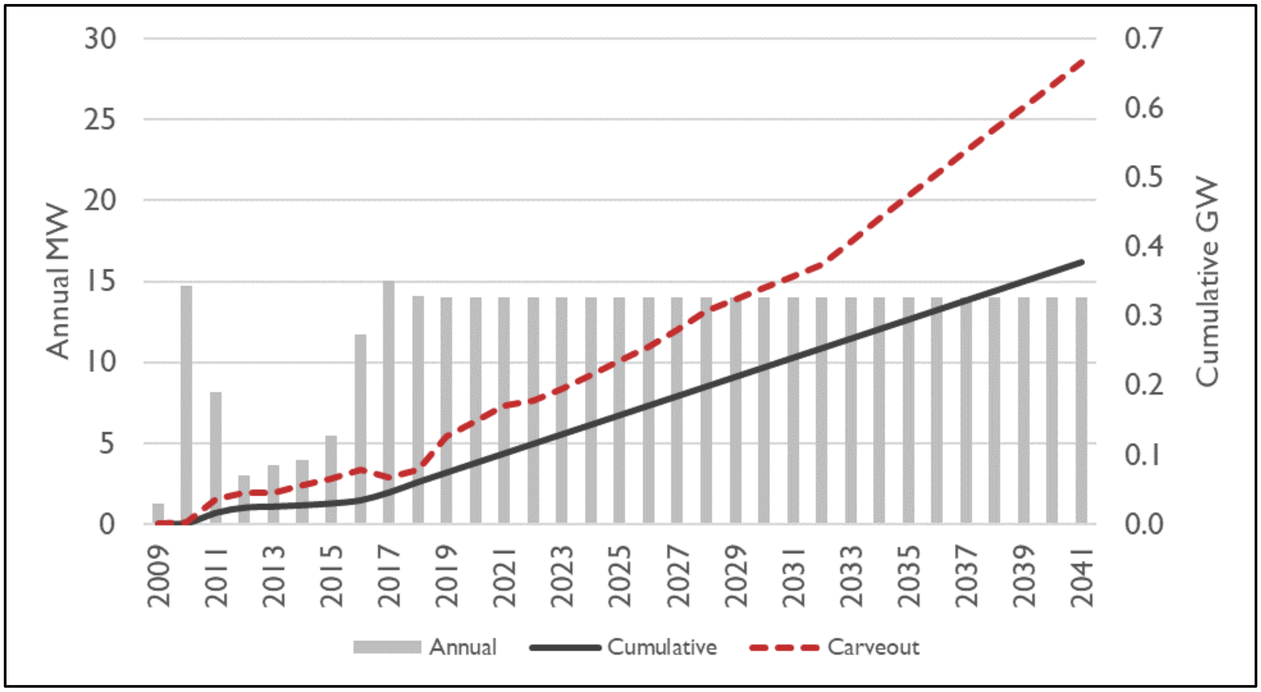
39 While District suppliers have satisfied their Tier 1 and Tier 2 requirements in the aggregate, individual suppliers have failed to achieve Tier 1 targets. Interestingly, District suppliers have overpurchased Tier 1 RECs and used the excess to satisfy Tier 2 requirements.

40 District suppliers retired less than half the required SRECs in 2017. It is worth noting that this does not reflect just a production shortfall; SRECs remain valid for three years after minting. It appears that District suppliers took advantage of the grandfathering provision in the 2016 legislation that made most supply contracts subject to an ACP that was in fact lower than the market SREC price in the District.

41 This figure includes the 20.4 MW of qualifying solar resources located outside of the District that have been grandfathered into the program.

Figure 3. Low projection of annual and cumulative solar PV in the District of Columbia



Source: RPS requirement is from Code of the District of Columbia §34-1432 (https://code.dccouncil.us/dc/council/code/sections/34-1432.html) and Synapse calculations. Historical installations are from DC PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx). Future projection is based on Synapse calculations.

Middle Projection for Solar PV Installations in the District of Columbia, 2019–2041

The Middle projection assumes that ACP-SREC market mechanism will work to bring the District into carve-out compliance in the coming years.

As mentioned in Section 3, SREC revenue is a critical driver of solar investment since it enables customers to pay off PV system investments. Thus, the SREC price directly influences the rate of solar adoption through its influence on the payback period of the solar system.[42] Payback periods and adoption rates are inversely related, with adoption rates falling as the payback periods increase. The Middle projection assumes that the District will attain its annual carve-out goals so long as the prevailing SREC price produces a sufficiently short payback period.

We adapted the methodology of the 2017 Synapse study to estimate the relationship between the SREC price and solar adoption on the District's residential, commercial, and industrial rooftops (termed "economic potential"). In that study, Synapse translated the National Renewable Energy

42 See, for example, Ben Sigrin and Easan Drury, "Diffusion into New Markets: Economic Returns Required by Households to Adopt Rooftop Photovoltaics," in *AAAI Energy Market Prediction Symposium* (AAAI Energy Market Prediction Symposium, Washington, DC, 2014). Note that the payback period is determined primarily by SREC revenues, but also influenced by the value of energy generated by solar PV installations.

Laboratory's (NREL) market diffusion results into the District context with the assumption that a peak ACP value of $500 suggests a four-year payback period for an average solar PV investment. The 2017 study formulated a reference (Middle) projection for eventual total installed capacity of 64 percent of total technical potential for residential rooftops, and 26 percent of total technical potential for commercial and industrial roofs, which was based on an assumed payback period of five years. [43]

We used a different approach to estimate the economic adoption limit for parking lots in the District. As we explain at length in Section 0, there has been little PV development up to date on DC parking lots. Although nearly complete coverage is possible in ideal conditions, a variety of site-specific and policy details reduce potential. Irregular site geometry, on-site trees to be preserved, sloping terrain, and shading due to trees or nearby structures can all reduce technical potential, as can policy constraints including total PV capacity permitted (in absolute terms or relative to on-site consumption), use permittance, setback requirements, height constraints, and historic preservation specifications, as well as uncertainty due to the lack of a clear description of the process and constraints writ large.

To account for the impact of these many potential constraints, we excluded small lots entirely from our technical potential, and chose a moderate economic adoption factor of 60%. The 2017 Synapse study had not including parking lots in its modeling, nor were NREL's market diffusion results obviously applicable to the case of lots.[44] To the extent that the District can reduce or eliminate legal and policy restrictions as well as streamline and clarify the process, a more certain estimate of technical and economic potential will be possible.

Table 3. Solar potential by sector, assuming five-year payback period

Sector	Economic Adoption Limit *a*	Technical Potential (MW) *b*	Overall Potential (MW) *a*b*
Residential	64%	400	256
C&I	26%	1,280	333
Parking Lots	60%	1,100	660
Total	-	-	1,249

Source: NREL (Whited et al. pages 99 and 104) and Synapse calculations.

43 Whited et al., 2017, pages 99 and 104. These values take roof age, orientation, angle, and shading into account. Note that even if panels were to be made free (a zero-year payback period), the Synapse analysis concluded that total installed capacity would still fall below the technical maximum capacity implied by eligible District rooftop area.

44 Note that in the case of parking lots, the various limits on development, including both District regulations and natural barriers are all expressed through the economic adoption factor, though some of these limits are of a technical or political rather than economic nature. We chose to reflect these constraints through just the economic adoption limit factor, rather than by also reducing the technical potential, to avoid providing false precision given the degree of uncertainty in the form of the constraints that may impeded solar PV development on DC parking lots.

While each year's average SREC price within the Middle projection is associated with a different payback period, and hence with a different economic potential for the District, modeling this dynamic would be difficult. We therefore used a simplifying approach and assumed just two payback periods for solar investment in the District: [45]

- Five years between 2019 and 2028 (first period), when the ACP is between $500 and $400, and
- Ten years between 2029 and 2041 (second period), when the ACP has fallen to $300.

An SREC price level that supports a five-year payback period is expected to spur enough investment in solar to eventually reach carve-out requirements. However, a 10-year payback period will not draw enough investment to stay on the carve-out trajectory.[46]

Through mid-2019, solar deployment in the District has lagged the carve-out trajectory, and we expect that it will take some time for the level of adoption and the carve-out trajectories to converge. While the total capacity of installed solar in the District is less than the carve-out requirement, we assume that solar installation will follow a logistic growth curve—also called an "S-curve" for its shape. This is a common growth dynamic for adoption of new technology. In this analysis, we used the Bass-Diffusion specification for the logistic curve, which is explained in more detail in the next section for the High Projection.

We estimate an S-curve for the first model period with an SREC price level that supports a five-year payback period on solar PV investments. As illustrated in Table 3, this SREC price level implies a maximum solar PV potential of 1,249 MW for the District. However, the District is not expected to stay on this growth curve indefinitely. Instead, once the carve-out requirement is achieved, SREC prices should decline, which will constrain growth in the market to the level of adoption necessary to meet the carve-out. If solar development were to exceed the quantity required by the solar carve-out, there would be a surplus of available SRECs and the price of SRECs would be expected to fall—presumably to the prevailing Tier 1 REC market price. Thus,

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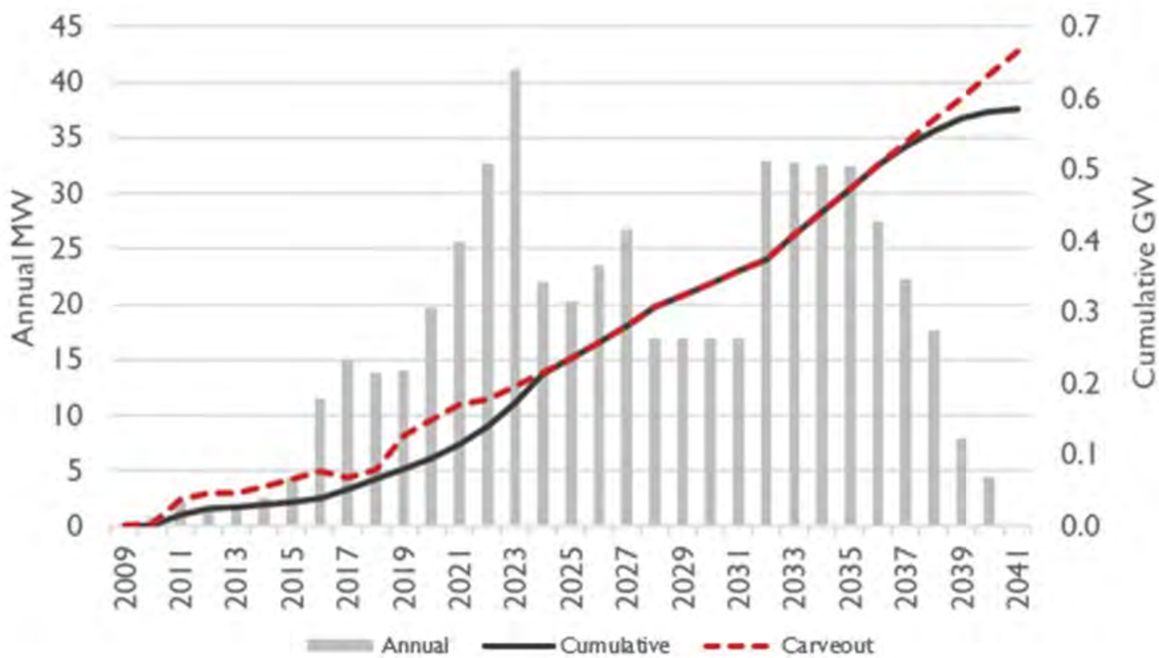
45 We note that the 5-year payback period is a rough average: an ACP of $500 in 2019 is associated with a slightly shorter payback period, while a $400 ACP in 2028 is associated with a slightly longer payback period. Similarly, the payback period for predicted SREC prices in the years between 2029 and 2041 will drift upward from 10 years, but we consider 10 years to be a suitable approximation, in light of the many other unmodeled variables that may affect the economics over the intervening period.

46 As in the Low projection, in this projection, we assumed that the RPS and net-metering policies will not be modified through 2041, and that building codes, historic district standards, and other restrictions will not be made more restrictive. We assumed that Pepco will maintain a local distribution network capable of allowing the interconnections necessary for compliance and that any additional costs, if imposed on the participants, will not substantially change the economics of solar PV installations.

we assume that the SREC market reaches an equilibrium price at the level required to spur sufficient solar development to meet the solar carve-out during the first period.[47]

The second model period begins in 2029 when the ACP drops to $300 and the assumed payback period grows to 10 years. Using the same approach for the first period, we estimate that the payback period associated with the lower SREC prices from 2029 onward implies a maximum potential for the District of just 574 MW.[48] Due to the higher growth dynamics of the first period, we project that 585 MW of solar will be installed in the Middle projection by 2041, leaving the District short of compliance by about 12 percent. Figure 4 below presents the Middle projection.

Figure 4. Middle projection of annual and cumulative solar PV in the District of Columbia



Source: RPS requirement is from Code of the District of Columbia §34-1432 (https://code.dccouncil.us/dc/council/code/sections/34-1432.html) and Synapse calculations. Historical installations are from DC

47 In the 2017 study, Synapse determined the economic incentive necessary for deployment to be about $280/MWh (2015 dollars). See Whited et al., 2017, page 134. We assume that at market equilibrium, reached in the Middle projection, the SREC value falls to this level, adjusted for inflation into given year nominal dollars.

48 This value is calculated based on the total economic potential (adoption rate factors) associated with a ten-year payback period, as determined by Sigrin and Drury; the technical potential is not presumed to change with the SREC price. The economic potential for parking lots is estimated at 60 percent in the first period and 40 percent in the second period. We assume that it declines less than the economic potential for the other categories of solar development since rooftop canopies are expected to disproportionately host community solar installations, which are expected to be less sensitive to changes in the market SREC price (given the District government's role in their development).

PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx). Future projection is based on Synapse calculations.

High Projection for Solar PV Installations in the District of Columbia, 2019–2041

The High projection envisions solar development in the District following a trajectory that is often observed in the diffusion of new technologies. We use a logistic curve, also known as an S-curve, to model how adoption might rapidly increase over the coming years. The logistic model exhibits exponential-like growth for a limited period, then levels off as it approaches a predefined limit.

Critically, this growth is only likely to take hold with some other policy intervention or dramatic technological breakthrough that changes the economics of solar, enabling a far larger share of District residents and businesses to invest in solar, in spite of a falling SREC price that would result from a glut of available SRECs. Possible factors at play in this projection include technological breakthroughs that make solar cheaper to build, novel forms of subsidization (such as federal funding), and other policy and/or legislative changes.

As discussed in the previous section, we used a variant of logistic function known as the Bass Diffusion model to develop the High projection curve.[49] There is extensive recent literature that applies the Bass Diffusion model in some form to estimate technology diffusion.[50] This model is controlled by two primary factors: historical adoption and maximum potential. The general form of the model is provided below:

$$\frac{f(t)}{1 - F(t)} = p + q[A(t)]$$

where t is the number of years that have elapsed since the start of adoption, $f(t)$ is the portion of the total potential market that adopts in a particular year, $F(t)$ indicates the fraction of the total potential market that has previously adopted the technology, p is the "coefficient of innovation," q is the "coefficient of imitation," and $A(t)$ is the total number of people who have already adopted the technology. To calculate p and q, Synapse used a least-squares approach, with historical solar PV growth in the District for the period 2009–2018. Solving for $F(t)$ in each year and multiplying by the maximum potential of a technology yields the adoption of the technology in each year.

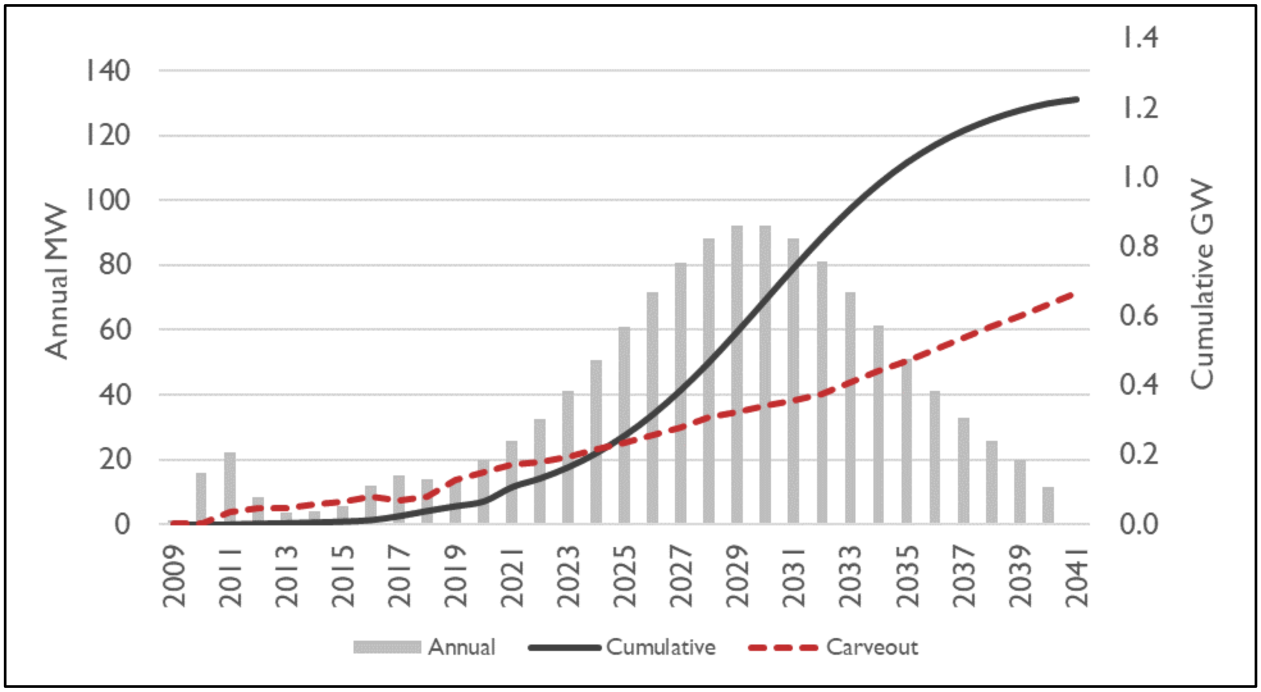
49 Bass, Frank M. "A new product growth for model consumer durables." Management science 15.5 (1969): 215-227.

50 For a recent example of using the Bass Diffusion curve to model growth dynamics in the U.S., see Dong, Changgui, Benjamin Sigrin, and Gregory Brinkman. "Forecasting residential solar photovoltaic deployment in California." Technological Forecasting and Social Change 117 (2017): 251-265. For an exploration of the underlying social forces that drive residential PV adoption, see: Curtius, Hans Christoph, et al. "Shotgun or snowball approach? Accelerating the diffusion of rooftop solar photovoltaics through peer effects and social norms." Energy Policy 118 (2018): 596-602.

We adopted the total economic potential (Section 4.2) implied by a five-year system payback period that was used for the first phase of the Middle projection model. While an argument could be made for assuming an even shorter payback period, and higher total solar potential for the District, to reflect the novel dynamics that must prevail in the District for solar adoption to exhibit logistic growth in spite of the current constraints, we maintain this total ceiling as a conservative approach to modeling hard-and-fast limitations that would be expected to eventually confront solar expansion in the District.

As shown in Figure 5, the High projection results in 1,236 MW of solar by 2041. This value includes the 20.4 MW of grandfathered solar. Annual installations peak in 2029 at about 92 MW per year. This projection results in nearly double the solar carve-out requirement being installed by 2041.[51]

Figure 5. High projection Bass Diffusion best-fit curve of Solar PV installations in DC, 2009–2041



Source: RPS requirement is from Code of the District of Columbia §34-1432 (https://code.dccouncil.us/dc/council/code/sections/34-1432.html) and Synapse calculations. Historical installations are from DC PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx). Future projection is based on Synapse calculations.

51 As in the Middle projection, this projection assumes no barriers to implementation, such as distribution constraints, delays in the interconnection process, or installation labor availability.

4.3. Solar Projections by Ward

Meeting the District's aggressive solar carve-out target will require an appropriate geographic distribution of solar installations across the District, in alignment with the distribution of solar technical potential. Moreover, the District Government also has a desire to ensure that access to solar PV is not limited to the most affluent areas of the District. Early identification of which wards are lagging their technical solar potential may help the District do targeted solar education, outreach, or community solar planning. As such, Synapse conducted a ward-level solar analysis for each of the District's eight wards comprised of the following:

- Identification of the number of existing solar installations and the total existing solar capacity in each ward;
- Calculation of each ward's share of the District's solar technical potential using GIS;
- Comparison of the technical potential and existing solar shares in each ward; and
- Application of the ward-level technical potential shares to the Low, Middle, and High District solar projections.

Historical Installations by Ward

Existing solar installations in the District were matched to a ward assignment by geocoding each installation address (i.e., converting street addresses into a latitude and longitude location), importing those locations into GIS, and joining the dataset with a shapefile of the District's ward boundaries.

Figure 6 on the following page shows the distribution of existing solar installations and capacity by ward. Interestingly, the wards with the highest number of solar installations (about 700 installations each in Wards 4 and 6) do not have the greatest total solar capacity (less than 7.5 MW each). This implies that these wards have a larger number of low-capacity PV installations (e.g., small residential or small commercial solar). Ward 4 is in the northernmost portion of the city and is primarily a residential ward.[52] Ward 6 is in the heart of the city and has very diverse neighborhood characteristics, including parts of Downtown, the residential high-rises of the Waterfront, and the historic Capitol Hill residential neighborhood.[53] Conversely, Ward 8 has relatively few solar installations (about 350) but a relatively large share of the total solar capacity in the District (about 8.7 MW), likely due to the presence of several large-capacity installations.

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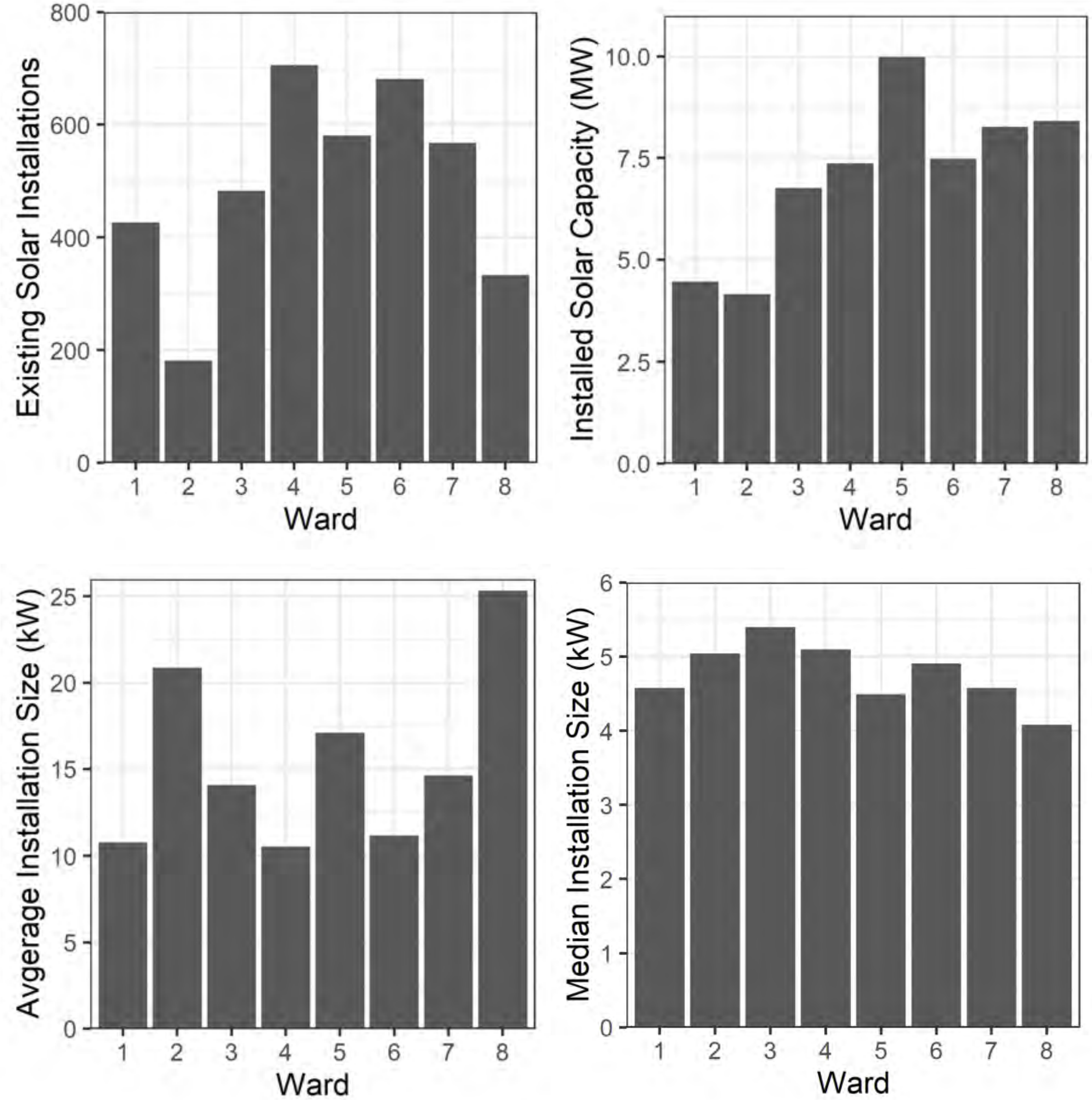
[52] About Ward 4, DC.gov Office of Planning, https://planning.dc.gov/page/about-ward-4.

[53] About Ward 6, DC.gov Office of Planning, https://planning.dc.gov/page/about-ward-6.

Ward 8 is a residential and commercial area with many large green spaces and the Bolling Air Force Base.[54]

Figure 6. Existing number of solar installations (top left), installed capacity (top right), average solar installation size (bottom left), and median installation size (bottom right) by ward through end of 2018



Source: Adapted from DC PSC, "List of Eligible Renewable Generators.xlsx," (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx) and GIS data from Open Data DC (http://opendata.dc.gov/).

54 About Ward 8, DC.gov Office of Planning, https://planning.dc.gov/page/about-ward-8.

Ward Technical Potentials

Comparing the relative technical potential of each ward to the historical share of solar installed in each ward (as a fraction of the entire District) can help us understand how the distribution of existing solar installations across each ward aligns with that ward's technical potential. If a ward's projected share of PV installations based on technical potential is substantially different from its historical PV adoption levels, it would imply that future development may differ from the technical potential due to other factors, such as home-ownership rates or income levels. This information can help fine-tune policies to improve outreach and reduce barriers to uptake that relate to the characteristics of each ward.

Synapse calculated the technical potential of each ward using GIS analysis of rooftops and parking lots.[55] For rooftop solar, we used the Reference Case economic potential results from Table 3, equivalent to 1,250 MW, and scaled it to each ward using the share of available rooftop space in each ward.[56] For parking lot solar, we used the total economic potential calculated in Section 4.2, equivalent to about 660 MW, and scaled it to each ward using the share of available parking lot space in each ward.[57]

Table 4 on the following page summarizes the comparison of historical solar installation shares and the technical potential share for each ward. As shown in the table, historical installations in Wards 2 and 3 are substantially below those wards' shares of technical potential. Ward 3 is in the upper northwest quadrant of the District, extending from the Hawthorne and Chevy Chase neighborhoods down to the border of Georgetown. It is bordered on the west by Maryland and the Potomac. Because this ward contains many affluent neighborhoods with large homes, customer economics are not a likely deterrent to solar development. Instead, a lack of awareness or interest in solar PV may be more likely factors. Ward 2 extends from Georgetown in the west to Chinatown in the east and includes the central business district and the Federal Triangle. Challenges to installing solar in Ward 2 may be related to permitting difficulties in the downtown region of DC or to the high prevalence of historic districts in the ward. Until recently, solar PV panels could not be installed on front-facing roofs of homes in DC's historic districts.

In contrast, installations to date in Ward 7 seem to be higher than expected based on its relative technical potential. Ward 7 is the easternmost ward and contains many single-family homes.[58]

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55 We excluded ground-mounted solar from this analysis based on the results in Section 4.5, which shows that ground-mount solar is not likely to represent a substantial share of the District's future solar projects.

56 Synapse did this analysis in GIS using the Building Footprints Spatial Dataset from Open Data DC, http://opendata.dc.gov/datasets/a657b34942564aa8b06f293cb0934cbd_1.

57 Synapse did this analysis in GIS using the Alleys and Parking Spatial Dataset from Open Data DC, http://opendata.dc.gov/datasets/dc3dc5310f1f4be7a1fa6cde59b564df_62.

58 District of Columbia Office of Planning, https://planning.dc.gov/.

Table 4. Comparison of historical and technical potential solar shares in each ward

Ward	Historical Solar (MW) *a*	Historical Shares (%) *b*	Technical Potential (MW) *c*	Technical Potential Shares (%) *d*	Difference *b-d*
Ward 1	4.4	6.6%	153	6.4%	0.2%
Ward 2	4.0	5.8%	291	12.2%	-6.4%
Ward 3	6.4	9.5%	298	12.5%	-3.0%
Ward 4	8.4	12.6%	267	11.2%	1.4%
Ward 5	12.1	18.1%	447	18.7%	-0.6%
Ward 6	9.8	14.6%	331	13.9%	0.7%
Ward 7	11.4	17.0%	265	11.1%	5.9%
Ward 8	10.5	15.7%	334	14.0%	1.7%
Total	**67**	**100%**	**2,385**	**100.0%**	**-**

Source: Synapse calculations based on DC PSC, "List of Eligible Renewable Generators.xlsx," (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx), GIS data from Open Data DC (http://opendata.dc.gov/), and Synapse calculations.

Because past installations are not necessarily a predictor of future solar adoption, Synapse applied the ward-based technical potentials in Table 4 to each of the solar projections developed for the District. We took this approach because the projections are intended to indicate potential, to guide the District towards what an even distribution of solar installations might look like for the District's future. For all three projections, we assumed that the annual build-out of solar in each ward is based on the appropriate District-wide projection (i.e., Low, Middle, or High), scaled by the relative technical potential of solar PV in each ward (which does not differ by projection). The following equation illustrates this approach:

$$PV_i = PV_{district} * p_i$$

In the equation above, PV_i is the annual amount of solar (MW) added in Ward i for a given projection, $PV_{district}$ is the annual amount of solar (MW) added across the District for a given projection, and p_i is the relative technical potential for solar in Ward i, calculated as a percentage as follows:

$$p_i = \frac{TP_i}{TP_{district}}$$

In the equation above, TP_i is the technical potential in MW of Ward i and $TP_{district}$ is the technical potential in MW of the entire District. This approach assumes that, regardless of the projection (e.g., Low, Middle, or High), the relative share of solar expected to be built in each ward does not change. For example, in each projection, Ward 1 is expected to host 6.4 percent of the solar capacity built in the District for each year. Figure 7, Figure 8, and Figure 9 illustrate the cumulative solar capacity built in each ward for the Low, Middle, and High projections.

Figure 7. Ward-based Low projection of solar PV adoption (MW) in the District of Columbia

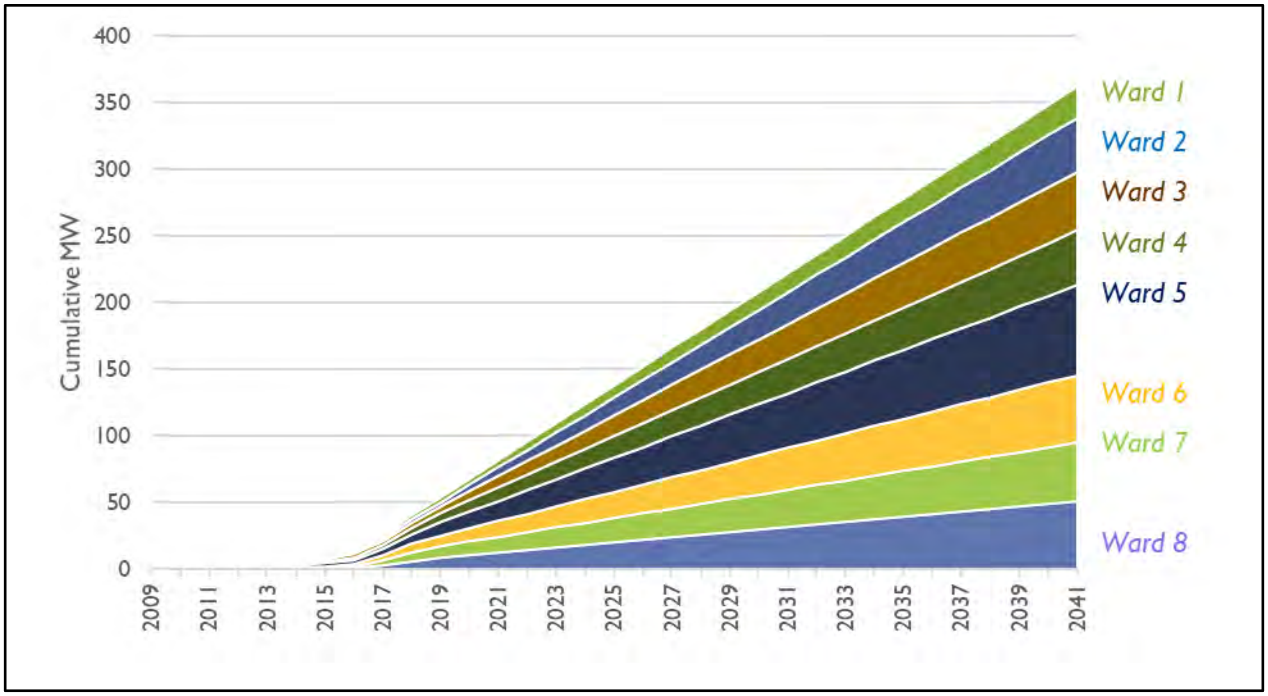


Figure 8. Ward-based Middle projection of solar PV adoption (MW) in the District of Columbia

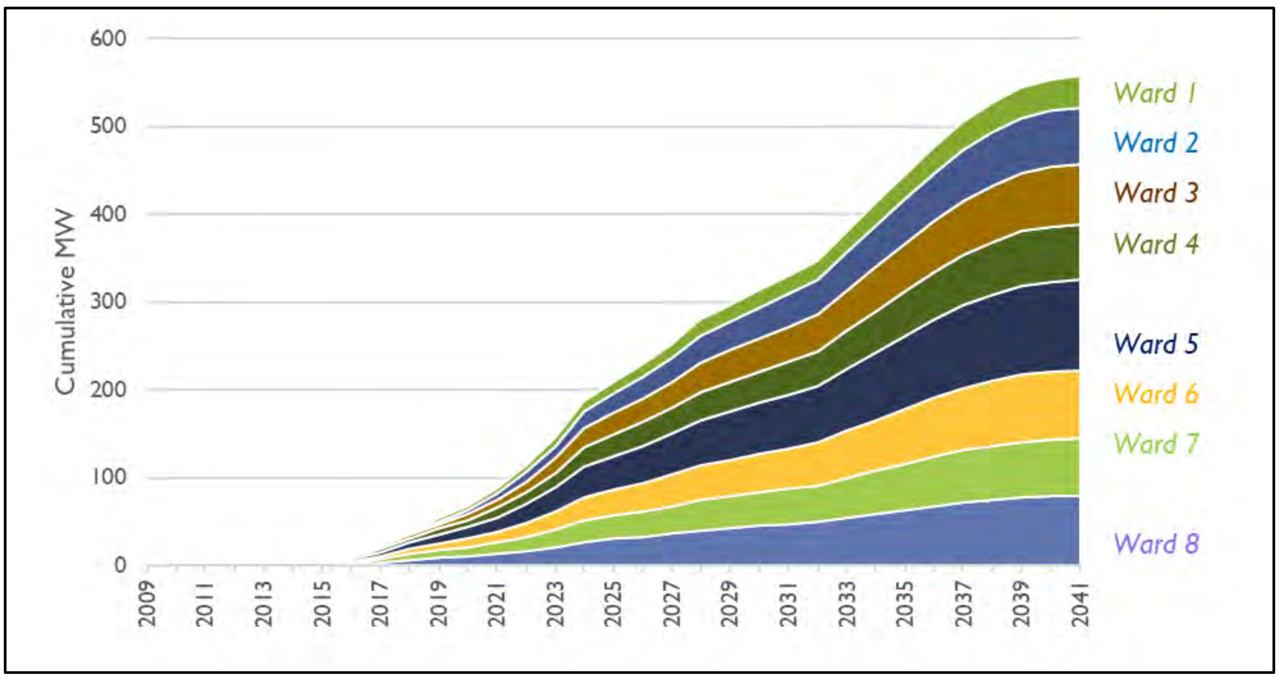
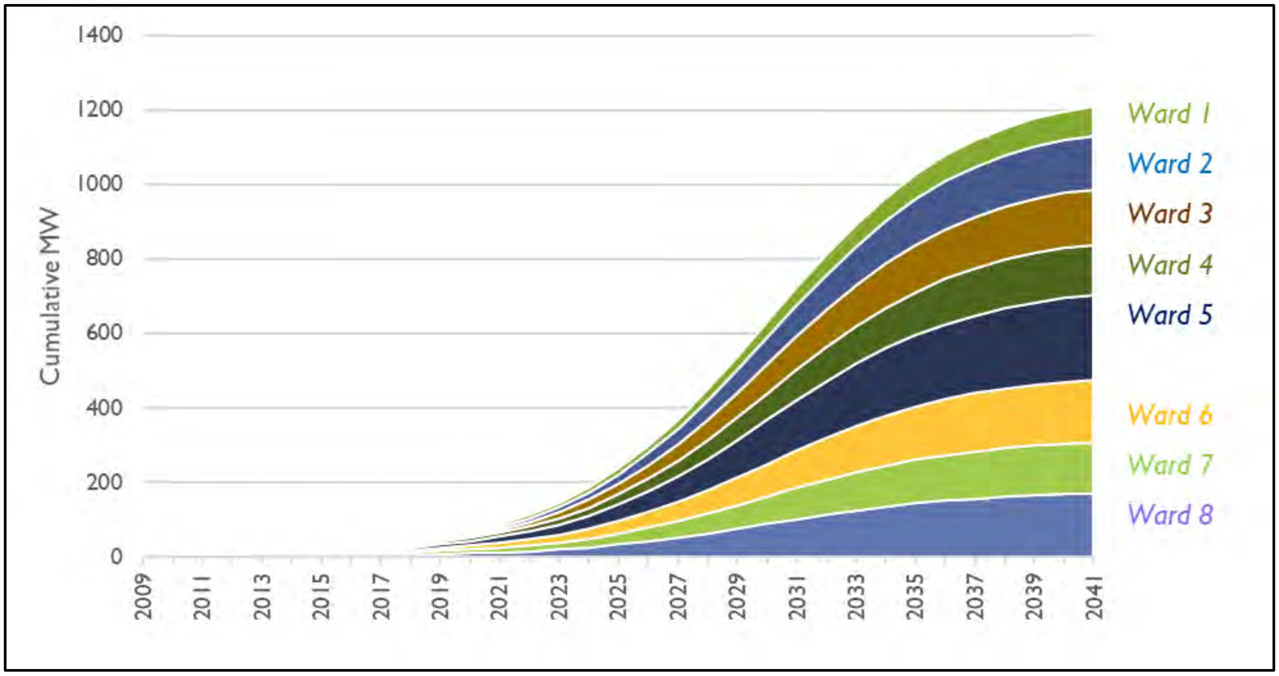


Figure 9. Ward-based how projection of solar PV adoption (MW) in the District of Columbia



Source: For Figure 7, Figure 8, and Figure 9, Synapse calculations with GIS data from Open Data DC (http://opendata.dc.gov/).

4.4. Community and Privately-Owned Solar

Community solar, referred to as a community renewable energy facility (CREF) in the District, is a project in which multiple residents or businesses can purchase or lease a "share" of solar from a large array located elsewhere in the service territory. That is, the facility does not need to be directly connected to the customer's meter. Instead, it can be located anywhere in the District. With community solar, renters and low-to-moderate income families can benefit from the value provided by solar electricity, even if they do not have a suitable rooftop or the ability to finance their own solar array. There are many different types of ownership and financing models for community solar allowed in the District, including those hosted and developed by businesses, organizations, condo associations, groups of neighbors, the municipal government, or other entities.[59] In 2013, the District passed the Community Renewables Energy Act, which supports the development of community solar in the District through policies such as community net-metering, which gives customers full retail rate credit on their electricity bill for the solar generated by the CREF.[60]

59 Community Solar in DC, Solar United Neighbors, https://www.solarunitedneighbors.org/dc/learn-the-issues-in-d-c/community-solar-in-d-c/.

60 Council of the District of Columbia, http://dcclims1.dccouncil.us/images/00001/20131003111525.pdf.

In concept, community solar is particularly attractive in the District due to the large share of renters and multi-unit dwellings in the city.[61] In reality, community solar still has challenges that are slowing its development in the District, despite the accommodating policies. These challenges include a more complex permitting process, management of multiple contracts for multiple subscribers, the need to obtain sufficient commitment from subscribers to ensure the project will be financially viable, identification of business owners and/or roof space suitable for community-scale PV systems, and the governance structure of an investor-owned utility in a restructured state where Pepco cannot own generation.[62] And for the owners of private buildings in particular (including large multifamily apartment buildings), there are insufficient financial incentives. Specifically, incentives are needed to encourage hosting community solar for the benefit of tenants over direct net-metering to offset common space energy usage, which benefits the landlord.

Since 2016 when Pepco started accepting CREF applications, there has been limited community solar development in the District. As of the end of 2019, there was only about 2.7 MW of installed community solar capacity.[63] To expedite the growth of community solar in the District, the District of Columbia DOEE implemented its Solar for All program. The program funds the development of community and single-family solar installations throughout the District by providing monetary grants to organizations to install solar for the benefit of low-income residents, seniors, non-profits, and small businesses.[64] These solar projects will be installed on both public and private property and are expected to generate enough electricity to power up to 6,800 households by 2032, with the goal of eventually providing power to 100,000 low-to-moderate income households.[65,66] About 50 percent of installations are expected to be on public District-owned land and 50 percent are expected to be on privately-owned land (e.g., commercial, large multifamily, non-profit, affordable housing, industrial).[67] Of the community

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61 Nearly 60 percent of housing in the District is rented. 2013-2017 American Community Survey 5-Year Estimates, Form B25003. See: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_B25003&prodType=table.

62 Whited, et al., 2017.

63 See District of Columbia Public Service Commission Docket RM9.

64 Department of Energy and Environment, Renewable Portfolio Standard Expansion Amendment Act of 2016 and Solar for All Annual Report, October 8, 2016- September 30, 2017, available at https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/2017%20Solar%20for%20All%20Annual%20Report.pdf.

65 https://www.positivechangepc.com/uncategorized/dcseu-seeking-solar-contractors-and-developers-for-solar-for-all/ .

66 DC DOEE, Solar for All, https://doee.dc.gov/solarforall.

67 Roughly calculated based on information available at: https://doee.dc.gov/node/1049202

solar projects that had been proposed at the time of this report, only one of them was planned as a ground-mounted installation.[68] The rest were to be on rooftops and parking lot canopies.

Community Solar In the District

The District-wide solar projections described in the sections above do not differentiate between private and community solar installations. Because the District has a strong interest in the success of community solar in its jurisdiction, Synapse developed a projection of community solar within the larger solar PV projection. However, forecasting community solar in the District is challenging for several reasons, including:

- There is has been limited community solar installation in the District, which makes it infeasible to develop projections based on historical community solar installation rates.
- Although Solar for All has been a successful government-funded program, its success has been primarily due to government subsidies, coordination of sponsors through a centralized program, and use of municipal rooftop space. The rate of future development of community solar through the Solar for All program therefore largely depends on policy decisions, rather than market trends.
- It is difficult to develop a projection based on community solar project economics due to the wide variety of potential ownership and financing models and the predominance of government-subsidized projects thus far.
- It is difficult to extrapolate the growth rate of community solar from other jurisdictions (e.g., Minnesota, Massachusetts, and California) to the District of Columbia because those states have much more open land available for large community solar. The District is limited primarily to rooftops and parking lot canopies (see Installation Type section), which severely constrains the potential size of a typical community solar project and reduces the benefits of economies of scale.

For the reasons listed above, Synapse made several simplifying assumptions in order to develop community solar projections for the District. These assumptions were guided by the concept that the government-funded Solar for All program will likely only continue until it meets its goal of providing bill savings for 100,000 low-to-moderate income households. Therefore, community solar ownership and financing models must eventually begin to rely on private entities. We applied the following conservative assumptions based on that concept:

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68 Oxon Run is a ground-mounted 3 MW installation sponsored by the Department of General Services in the District. This installation is also a pilot project to test energy storage solutions coupled with solar. For more information, see: https://www.ncpc.gov/docs/actions/2019February/8035_Ground_Solar_Array_Facility_at_Oxon_Run__Delegated_Action_Feb2019.pdf.

1. District-owned property is more likely to host community solar than private property and U.S. government property;[69,70]
2. District-owned land will only host community solar installations, and all future community solar installations will be located on District-owned land;
3. The fraction of rooftop capacity that is District-owned is equal to the fraction of eligible land that is owned by the District; and
4. The pace of solar PV development on District-owned land will equal the pace of PV development on other land.

Under these assumptions, calculating a forecast for community solar requires calculating the fraction of appropriate District-owned land relative to all land appropriate for solar PV. Synapse performed land area calculations in QGIS using map data ("Building Footprint," "District Government Land," and "Alleys and Parking Lots") sourced from OpenData.dc.gov. We calculated municipal building footprint and municipal parking lot footprint areas by intersecting the two shapefiles to create a new set of data that only includes the building footprint of municipal land.

To calculate community solar potential, we first summed the municipal building and municipal parking lot footprints, which total about 5.8 million square meters. We then summed the total building (excluding federal government buildings) and parking lot footprints, which total about 44.5 million square meters. Then, we divided the municipal footprint total by the eligible footprint total (see Table 5).[71] The result of this calculation is that 13 percent of the District's rooftop and parking lot area is located on municipal buildings, and thus a good candidate for community solar.

69 Though this assumption does not align with the existing Nixon-Peabody community solar installation in the District (which was installed on the roof of a private building), experience in other jurisdictions suggests that municipal property is most likely to be eligible for community solar installations due to the simpler permitting and approval processes.

70 It is highly unlikely that federal government property would be used for a solar installation that benefits only local District residents. Given that the District's only community solar installation is on a privately-owned building, there is the potential for future community solar installations on privately-owned land or roofs. However, for the purposes of simplicity, we assumed conservatively that only municipal land and buildings will host future community solar installations.

71 Eligible land does not include parcels classified as parkways, parks, vacant land, medians, playgrounds, piers, boathouses, pumping stations, or special use.

Table 5. Building footprint of municipal and all-District buildings

Shapefile	Area (square meters)
Municipal Building Footprint	3,683,076
All Eligible Building Footprint	33,748,151
Fraction of Municipal Buildings	*6%*
Municipal Parking Lot Footprint	2,251,432
All Eligible Parking Lot Footprint	10,844,278
Fraction of Municipal Parking Lots	*21%*
Fraction of Municipal Buildings and Parking Lots in the District	***13%***

Source: Synapse calculations with GIS data from Open Data DC (http://opendata.dc.gov/).

We applied the 13 percent value to the solar projections for each year to estimate community solar capacity. Because of the challenges in developing community solar in the District, the fraction of community solar installed out to 2041 is very likely to be less than 13 percent of the total solar installed each year. However, this value provides an upper bound on the expected build-out for community solar in the District. To estimate the likely installation rate of community solar in the District based on project economics would require a clear understanding of the most financially viable community solar model for the District. To our knowledge, such a model does not yet exist. The fraction of privately hosted community solar installations per year is much more difficult to predict for the reasons described in detail above, unless projected in the context of a program like Solar for All in which private landowners participate as program rooftop sponsors. Therefore, the fraction of privately hosted community solar is likely to be less than that of municipally hosted community solar.

Multiplying the aggregate PV forecast by 87 percent provides the forecasted minimal non-community solar capacity. Low, Middle, and High community and private solar projections are shown in Figure 10, Figure 11, and Figure 12. Cumulative community solar deployment in the Low projection is 50 MW, in the Middle projection is 89 MW, and in the High projection is 150 MW.

Figure 10. Community and private solar growth in the District under Low projection

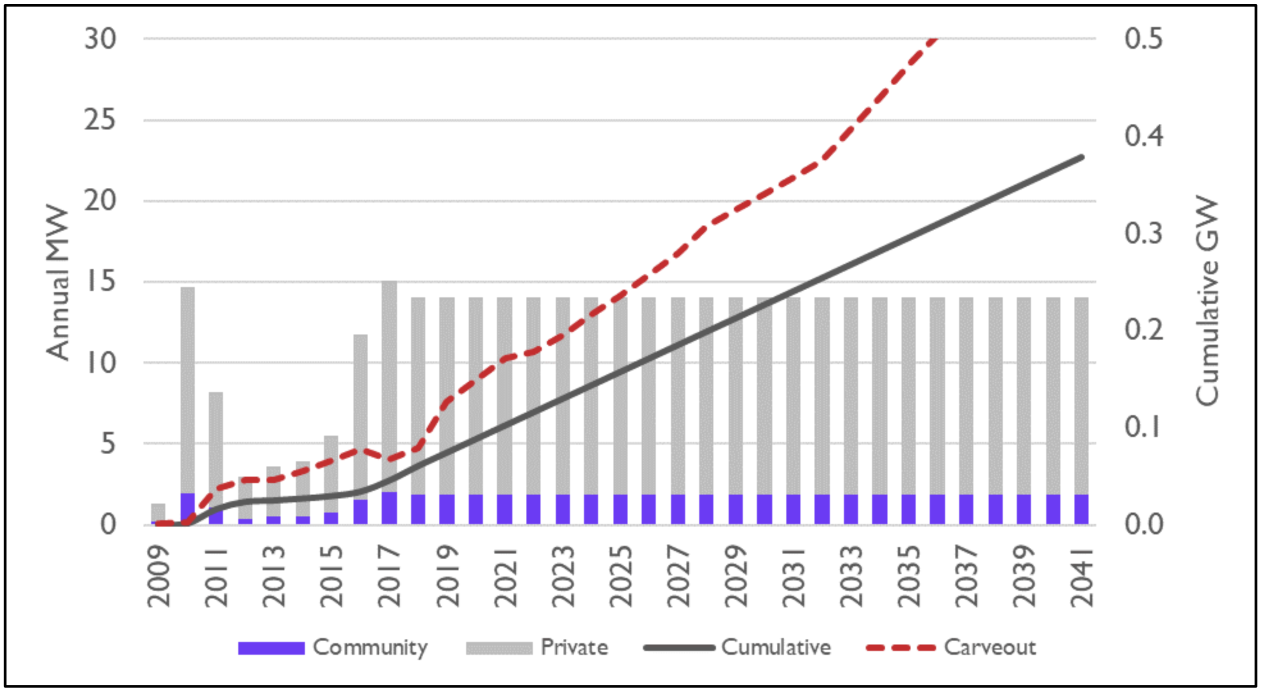


Figure 11. Community and private solar growth in the District under Middle projection

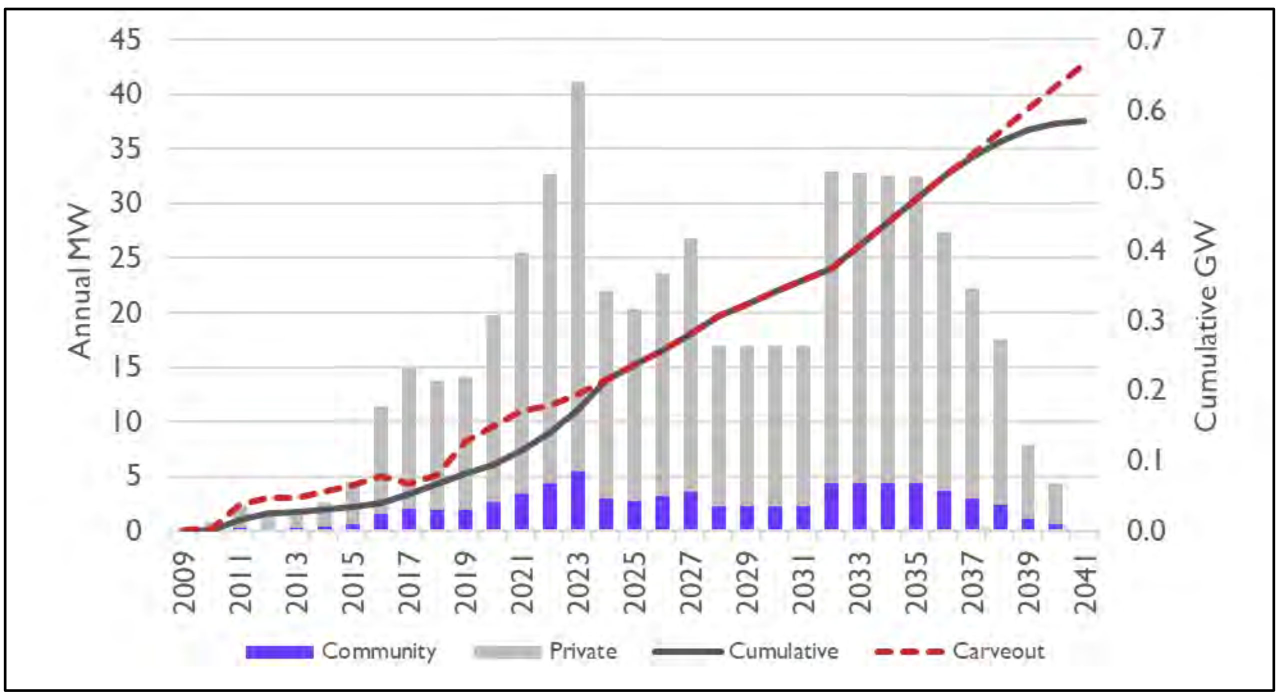
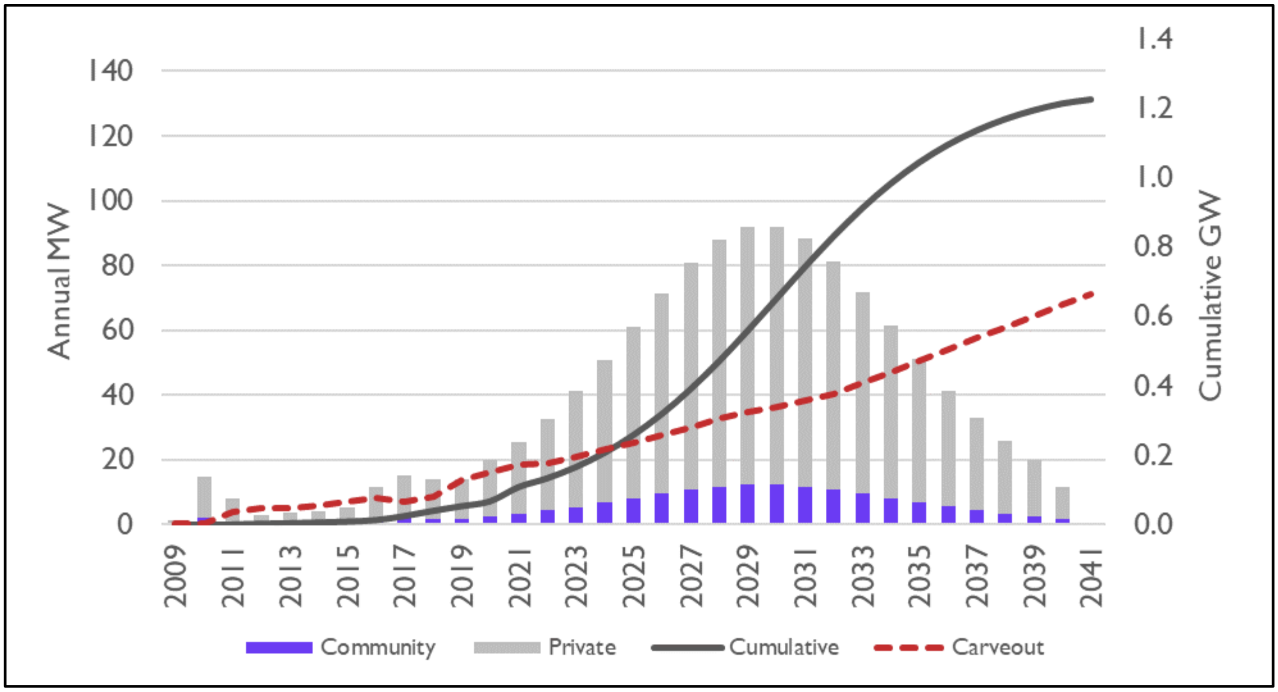


Figure 12. Community and private solar growth in the District under High projection



Source: For Figure 10, Figure 11, and Figure 12, RPS requirement is from Code of the District of Columbia §34-1432 (https://code.dccouncil.us/dc/council/code/sections/34-1432.html) and Synapse calculations. Historical installations are from DC PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx). Future projection is based on Synapse calculations.

Community Solar by Ward

To calculate the potential for community solar on District property by ward, we divided the total area in the Building Footprint dataset by the municipal building footprint area in the District Government dataset that was deemed eligible for community solar.[72] Table 6 shows the resulting fraction of community solar potential for each ward. The fraction of community solar potential was applied to all three projections for each ward and is held constant across the study period. For reference, the total community rooftop solar potential across the District, as calculated in the prior section, is about 6 percent of total solar PV potential, while parking lot community solar is approximately 21 percent (Table 5). Combined, the total community solar potential in the District (rooftop and parking lot) is about 13 percent. The community solar potential in each ward ranges from 4 to 24 percent. The highest potential for community solar is in Wards 7 and 8, which are both adjacent to the Anacostia River and are host to a large

72 Eligible land does not include parcels classified as parkways, parks, vacant land, medians, playgrounds, piers, boathouses, pumping stations, or special use.

proportion of District-owned land. Table 7 summarizes the total solar potential for each ward in 2041, separated by type of solar installation and projection type.

Table 6. Fraction of community solar potential relative to the total solar potential in each ward

Ward	Community Solar Technical Potential (%)
Ward 1	12%
Ward 2	8%
Ward 3	4%
Ward 4	9%
Ward 5	14%
Ward 6	14%
Ward 7	24%
Ward 8	24%

Source: Synapse calculations based on "District Government Land" GIS shapefile, Open Data DC (http://opendata.dc.gov/).

Table 7. Private and community solar potentials for each ward in each projection

Ward	Existing Solar Installs (MW) 2009-2018	Solar PV Potential %	2041 Low Projection (MW)		2041 Middle Projection (MW)		2041 High Projection (MW)	
			Private	Community	Private	Community	Private	Community
1	2.7	6%	21.4	3.0	37.5	5.2	64.9	9.0
2	2.4	12%	42.6	3.5	74.9	6.2	129.6	10.7
3	3.8	12%	45.4	1.9	79.7	3.3	138.0	5.8
4	5.1	11%	38.6	3.7	67.8	6.5	117.3	11.3
5	7.3	19%	61.1	9.7	107.4	17.1	185.8	29.6
6	5.9	14%	45.0	7.5	79.2	13.2	136.9	22.8
7	6.8	11%	32.0	10.0	56.2	17.6	97.3	30.4
8	6.3	14%	40.0	12.9	70.3	22.7	121.6	39.3
Total	**40.3**	**100%**	**326**	**52.3**	**573.1**	**91.9**	**991.5**	**159.1**

Source: Synapse calculations based on GIS data from Open Data DC (http://opendata.dc.gov/). Historical installations from DC PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx).

4.5. Parking Lot, Rooftop, and Ground-mount Solar

Synapse collected and examined all datasets containing information about the installation type of existing solar in the District (i.e., rooftop, ground-mount, parking lot canopy).[73] None of the primary datasets from DOEE or PSC contain any data about this characteristic of solar installations. Upon further research, Synapse learned that there are three existing solar parking lot canopy installations and few (if any) commercial scale ground-mount solar installations in the District.[74] Therefore, Synapse calculated a rough estimate of the technical potential for parking lot canopy installations and conducted a manual examination of installation type for recent large-scale solar installations in the District.

Using GIS data for "Alleys and Parking," Synapse filtered for parking lots that are most likely to be candidates for solar canopies. We selected a threshold of 185 square meters (2,000 square feet),[75] assuming a parking lot canopy is not likely to be built if it cannot host at least 20 kilowatts (kW) of solar panels.[76] After filtering the dataset, there are 10.8 million square meters of eligible parking lot space in the District. This represents a solar potential of about 1.1 gigawatt (GW); however, this value does not take shading or other installation challenges into account. If we assume that 60 percent of the available parking lot surface area can be used to host solar canopies, that leaves about 660 MW of potential capacity from parking lot canopies in the District.[77] This represents about 48 percent of the District's total solar economic potential (see Table 8).[78] Further, about 20 percent of parking lots larger than 185 square meters are owned by the District of Columbia.[79] Given the large potential for parking lot canopy solar in the District, the predominance of municipal ownership of parking lots, and the priority to expand community

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73 Though there are other installations types, such as floating solar and rights-of-way solar, those are outside the scope of this project.

74 To our knowledge, the only parking lot canopy solar installations in the District are located at Catholic University and the KIPP charter schools at 1405 Brentwood Parkway NE and 2600 Douglass Road SE. See https://www.greenstatepower.com/project/kipp-dc/ for more information.

75 One kW of solar panels typically requires 10 square meters of space, or 100 square feet.

76 We assumed that solar installations under 20 kW would typically be able to fit onto a roof. Additionally, parking lot solar is more expensive to build than rooftop solar, so an installation would likely need to take advantage of economies of scale.

77 It is incredibly difficult to estimate technical potential of parking canopies in urban areas because so few have been constructed in these conditions. Although nearly complete coverage is possible in ideal conditions, a variety of site-specific and policy details reduce potential. Irregular site geometry, on-site trees to be preserved, sloping terrain, and shading due to trees or nearby structures can all reduce technical potential, as can policy constraints including total PV capacity permitted (in absolute terms or relative to on-site consumption), use permittance, setback requirements, height constraints, and historic preservation specifications, as well as uncertainty due to the lack of a clear description of the process and constraints writ large. To the extent that the District can reduce or eliminate legal and policy restrictions as well as streamline and clarify the process, a more certain estimate of technical potential will be possible.

78 Rooftop capacity taken from the Reference case of Whited et al (2017), page 99.

79 This value was calculated in GIS. All large parking lots comprise 10.8 million square meters, while municipal parking lots comprise 7.7 million square meters.

solar for low-income residents, it follows that the District ought to consider the development of community solar projects on parking lots—especially municipally owned parking lots.

Given that the District is an urban setting, Synapse assumed that the percentage of ground-mounted solar installations is extremely low. To check this assumption, we did a manual examination of the largest capacity installations using satellite images in Google Maps. This manual check showed that each large installation is a rooftop installation or is currently unknown (if Google's satellite image has not been updated since the installation). However, there will be at least two ground-mount installations, one at Oxon Run (2.65 MW) and another at Catholic Charities (2 MW).[80] Because of the difficulty of projecting future installations based on one government-funded example, Synapse maintains its assumption that less than 1 percent of solar installations in the District will be ground-mounted.

Table 8. Estimated percentage of potential solar installations by type

Installation Type	Technical Potential (MW)	Adoption Fraction (%)	Installation Potential (MW)	Share of Potential Solar Installations
Rooftop	1680	35%	590	47%
Parking Lot	1100	60%	660	52%
Ground-mount	0-50	0-20%	0-10	0-1%
Total	**2780 - 2830**	**-**	**1250 - 1260**	**-**

Source: Synapse calculations and Whited et al. (2017).

Synapse assumed that the shares of potential solar installations shown in the fifth column of Table 8 hold true at any point in the solar growth curve, for the Low, Middle, and High projections. The results for each projection are shown in Figure 13, Figure 14, and Figure 15 below. The cumulative parking lot solar capacity by 2041 in the Low projection is 197 MW, in the Middle projection is 324 MW, and in the High projection is 566 MW.

80 DC Department of Energy and Environment: https://doee.dc.gov/service/oxonrunsolar.
National Catholic Reporter: https://www.ncronline.org/news/environment/catholic-charities-build-dcs-largest-solar-array.

Figure 13. Shares of parking lot and rooftop solar in the Low projection

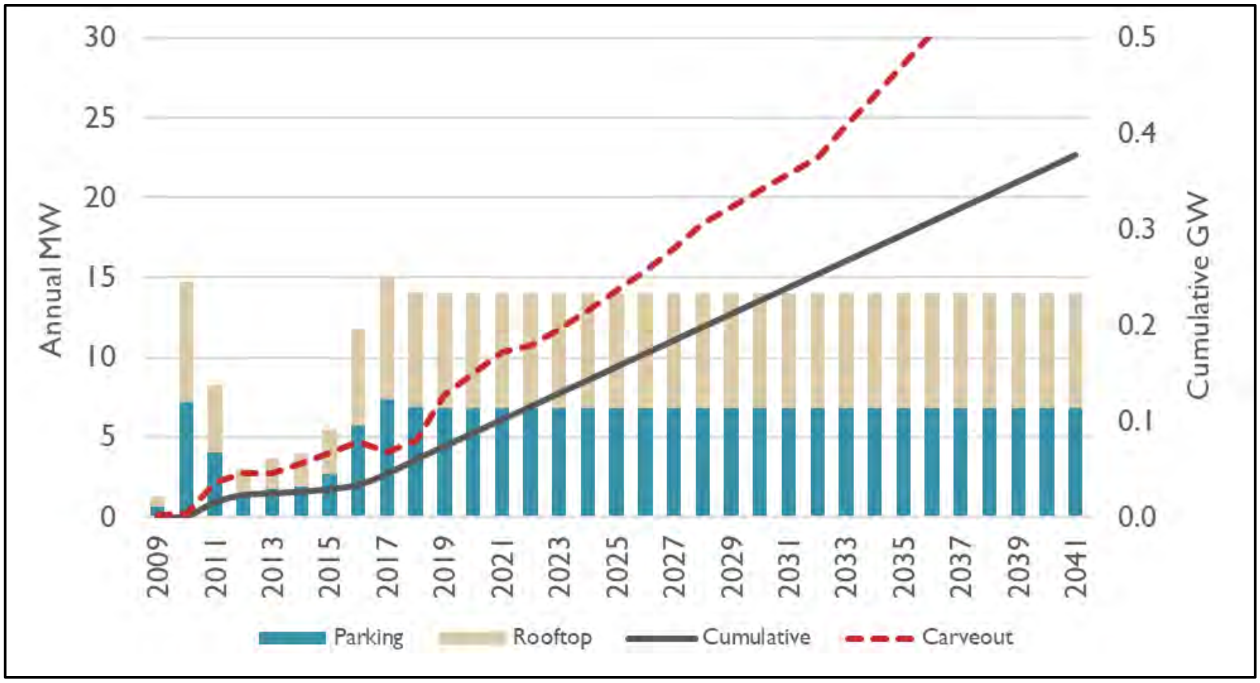


Figure 14. Shares of parking lot and rooftop solar in the Middle projection

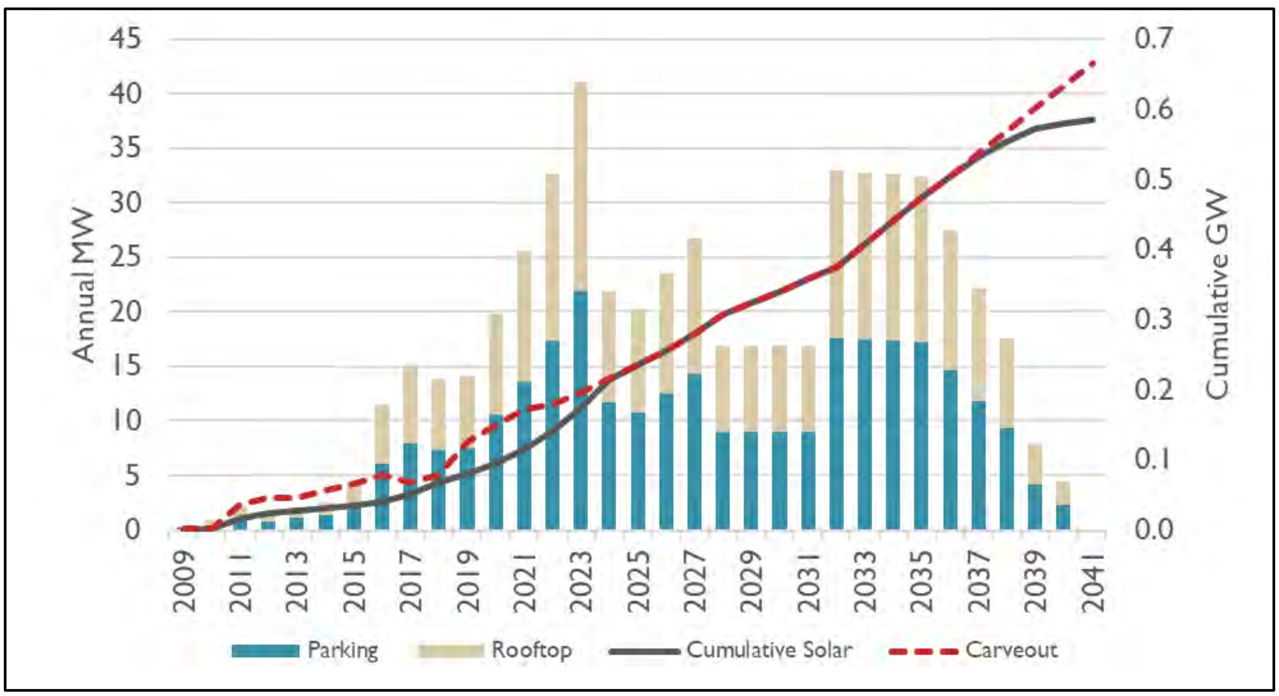
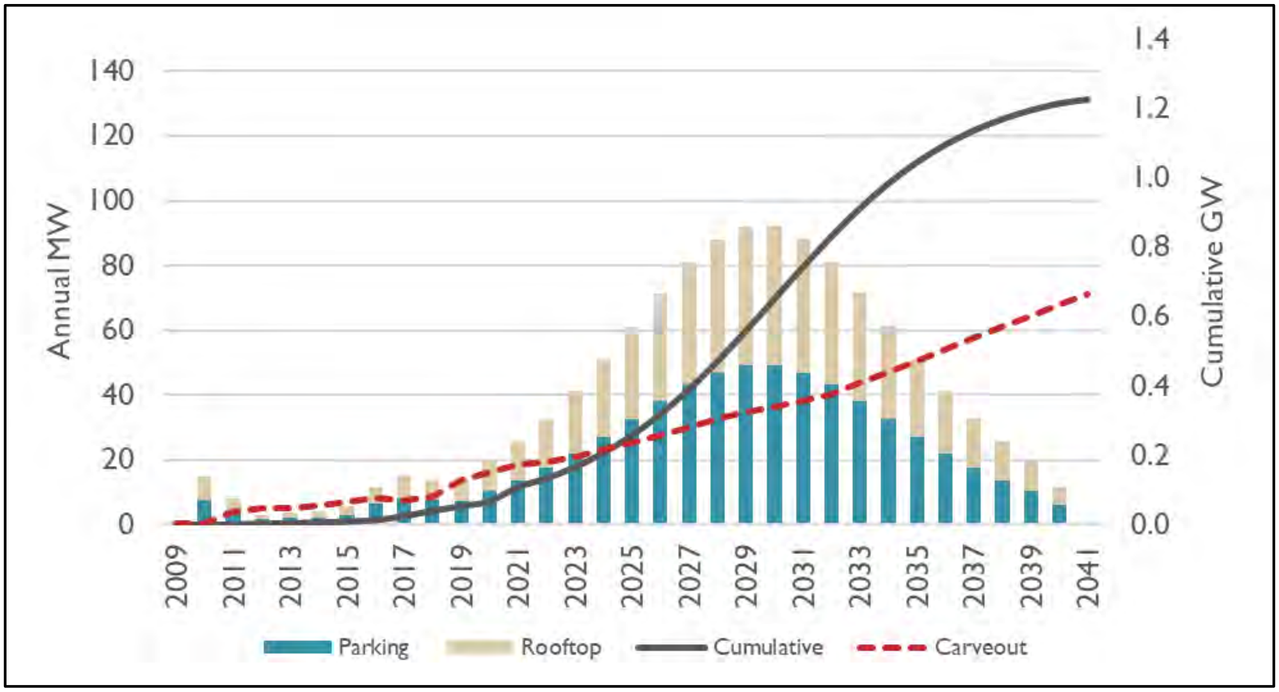


Figure 15. Shares of parking lot and rooftop solar in the High projection



Source: For Figure 13, Figure 14, and Figure 15, RPS requirement is from Code of the District of Columbia §34-1432 (https://code.dccouncil.us/dc/council/code/sections/34-1432.html) and Synapse calculations. Historical installations are from DC PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx). Future projection is based on Synapse calculations with GIS data from Open Data DC (http://opendata.dc.gov/).

Wards

As a final step, Synapse evaluated the parking lot and rooftop solar potential for each ward. Consistent with the analysis of ground-mount solar in the previous section, Synapse's assumption was that the percentage of solar installations that are ground-mounted is extremely low. To calculate the percentage of available space for parking lot solar within each ward, Synapse divided the parking lot area in each ward (calculated using GIS) by the sum of the parking lot area and the building footprint area. The resulting percentage is shown in the third column of Table 9. The total potential for parking lot solar in the District is about 24 percent, and the potential of each ward ranges from 10 percent to 40 percent. The wards with the highest potential for parking lot solar development are Wards 5, 7, and 8. Inversely, the wards with the highest potential for rooftop solar are Wards 1, 2, 3, and 4.

Synapse assumes that the percentages shown in Table 9 and Table 10 hold true at any point in the solar growth curve of each ward, for the Low, Middle, and High projections.

Table 9. Total available space for parking lot and rooftop solar in each ward

Ward	Parking Lot Solar Potential (sq. meters)	Parking Lot Solar Potential (%)	Rooftop Solar Potential (sq. meters)	Rooftop Solar Potential (%)
1	452,628	15%	2,487,183	85%
2	545,100	10%	5,131,466	90%
3	963,632	17%	4,726,838	83%
4	701,512	14%	4,441,390	86%
5	2,847,560	35%	5,252,774	65%
6	1,355,526	22%	4,882,950	78%
7	1,577,148	33%	3,258,121	67%
8	2,401,171	40%	3,567,428	60%
Total	**10,844,278**	**24%**	**33,748,151**	**76%**

Source: Synapse calculations based on GIS data from Open Data DC (http://opendata.dc.gov/). Parking lot and rooftop area potentials are not scaled for shading or roof age and so percentages do not align with the results in Table 7.

Table 10 and Figure 16 on the following page illustrate the relative breakdown of each type of solar installation in each ward based on technical potential—private rooftop, private parking lot, community rooftop, and community parking lot. Private rooftop installations make up the greatest potential at 63 percent. Unlike the analysis conducted in the 2017 Synapse report, this value does not de-rate rooftop space located in the District's historic districts. This is due to a recent decision by the Historic Preservation Review Board in the District that allows solar panels to be built on street-facing roofs.[81] While parking lots make up 24 percent of the technical potential for solar in the District, 8 percent of parking lot potential in the District is owned by the District and therefore is a good candidate for community solar.

Figure 16 further illustrates that Ward 5 (in the District's northeast quadrant) not only has the highest solar potential in the District but also leads the District in terms of solar potential in all four categories. In comparison, Ward 2 has an equivalent private rooftop solar potential to Ward 5 but has a very small potential in terms of private parking or community solar, causing it to have the fifth-highest solar potential of all eight wards. In total, Wards 5 and 8 have the highest aggregate parking lot solar potential, while Wards 2 and 5 have the highest aggregate rooftop solar potential.

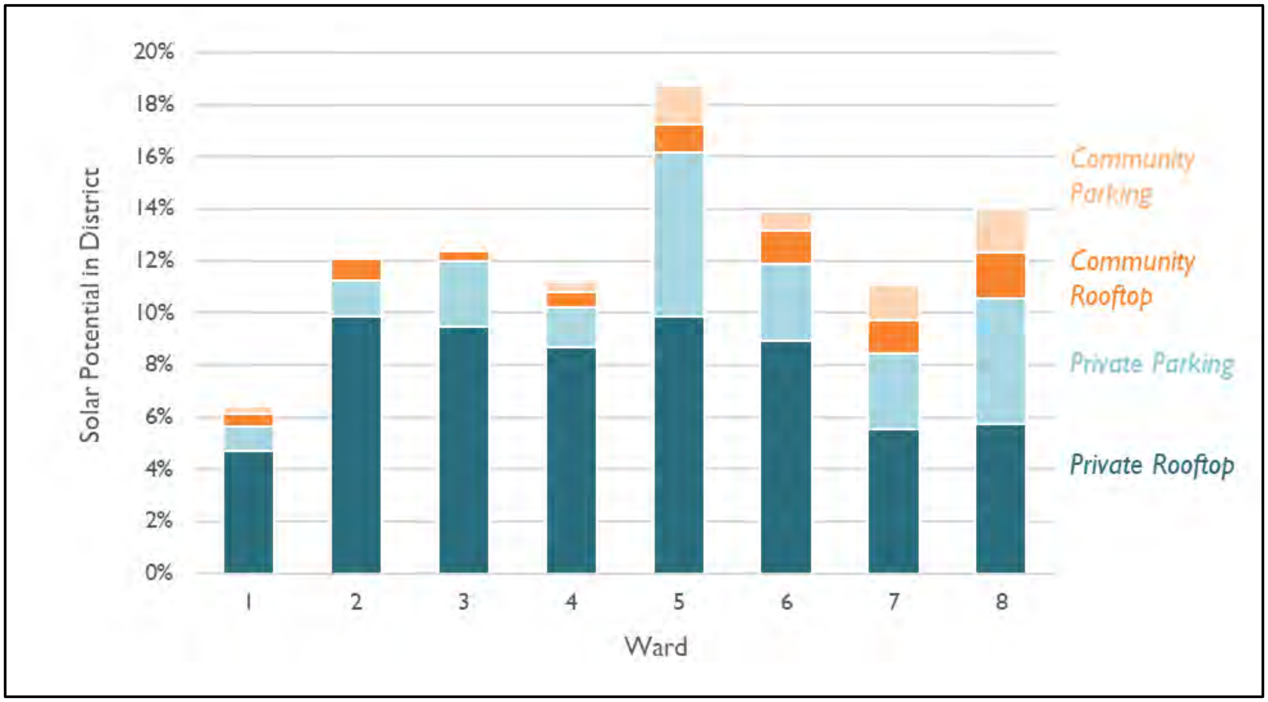
[81] https://ggwash.org/view/70784/in-a-shift-front-facing-takoma-solar-panels-win-dc-historic-preservation-hprb-approval.

Table 10. Distribution of solar technical potential by type of solar and ward

	Private Rooftop	Private Parking	Community Rooftop	Community Parking	Total Potential
Ward 1	4.7%	0.9%	0.5%	0.3%	6.4%
Ward 2	9.9%	1.4%	0.8%	0.1%	12.2%
Ward 3	9.5%	2.5%	0.4%	0.1%	12.5%
Ward 4	8.7%	1.5%	0.6%	0.4%	11.2%
Ward 5	9.9%	6.3%	1.1%	1.5%	18.7%
Ward 6	8.9%	3.0%	1.3%	0.7%	13.9%
Ward 7	5.5%	2.9%	1.3%	1.4%	11.1%
Ward 8	5.7%	4.9%	1.7%	1.7%	14.0%
Total	62.8%	23.4%	7.7%	6.1%	100.0%

Source: Synapse calculations based on GIS data from Open Data DC (http://opendata.dc.gov/).

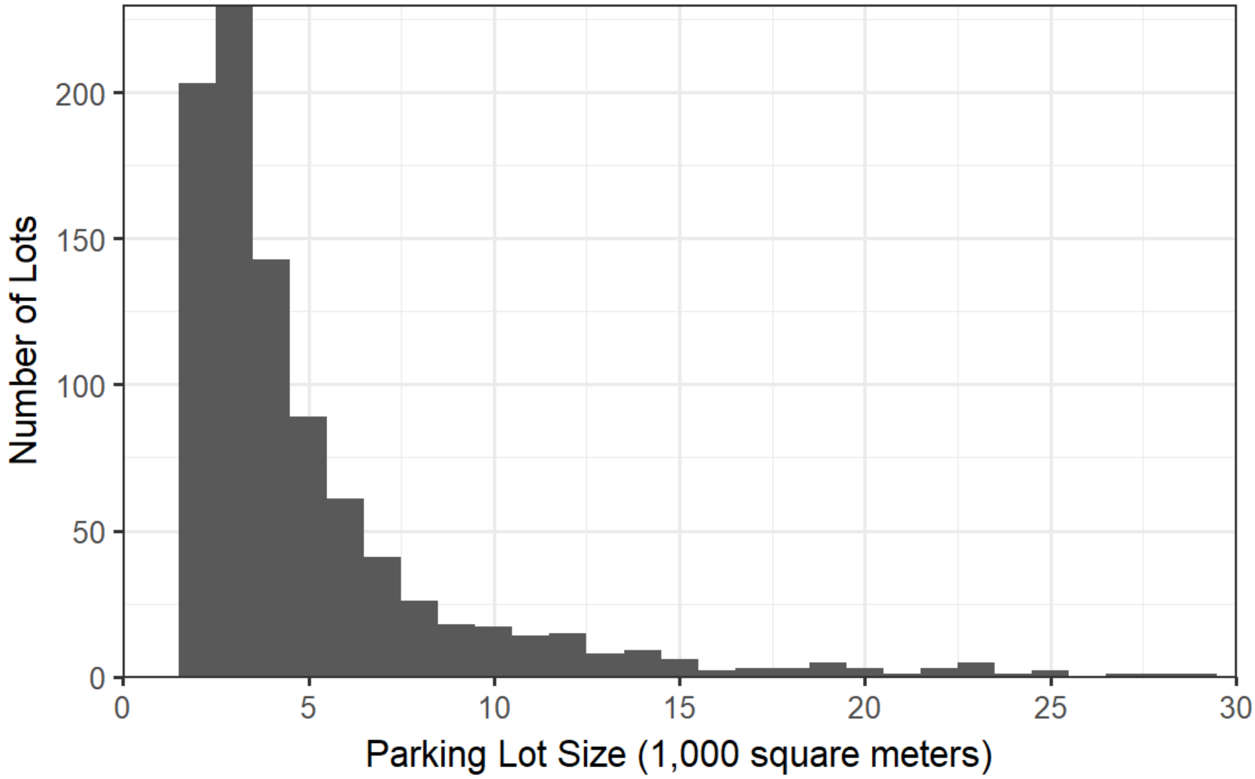
Figure 16. Technical potential fraction of each type of solar by ward



Source: Synapse calculations based on GIS data from Open Data DC (http://opendata.dc.gov/).

Though there is good potential for parking lot solar in the District, a closer examination of the distribution of parking lot size (Figure 17) shows that most parking lots in the District are smaller than 10,000 square meters. The median parking lot size in the District is 3,700 square meters and the average parking lot size is 5,900 square meters. This means that meeting the technical potential of parking lot solar will likely be more expensive than if the District had a small number of very large lots.

Figure 17. Histogram of parking lot size in the District



Source: Synapse calculations based on Open Data DC (http://opendata.dc.gov/).

5. Rate and Bill Impacts

To understand the impact of the different projections for solar in the District on rates, Synapse constructed a rate impact model.

We used historical load, customer, and revenue totals for Pepco as a proxy for the overall District. To formulate a baseline electricity consumption forecast, we took historical Pepco residential electricity consumption and escalated it at 0.2 percent per year, following PJM's forecast methodology.[82] Assuming that Pepco's revenue is equal to its revenue requirement, we projected future revenue requirements by escalating historical revenue using the same factor of 0.2 percent per year. For the residential class, we calculated average rates by dividing total projected revenue requirements by total projected sales.

The following are key modeling assumptions:

82 PJM Load Forecast Report, January 2019, page 80. See: https://www.pjm.com/-/media/library/reports-notices/load-forecast/2019-load-report.ashx?la=en.

- As discussed above, Pepco's revenue requirement is assumed to track total consumption, not total sales.[83]
- Total sales are equal to total consumption minus solar PV generation.
- We assume a 2 percent annual inflation rate.
- Tier 1 REC prices are presumed to escalate to $13 (in 2018 dollars) by 2028.[84]
- All SRECs produced in a year are modeled as being bought and retired in the same year as they are produced.
- The RPS and ACP schedules that were established in the 2018 legislation are not expected to be altered through 2041. Thus, we expect the real value of the ACP to decline with the effect of inflation over time.
- SREC and ACP costs are assumed to be recovered from ratepayers. Although energy suppliers may not currently be passing ACP costs on to ratepayers, suppliers can request recovery of these costs. We expect that they will do so if these costs become large.
- All District solar is assumed to be net metered.[85]
- Total annual solar energy production in a given year is based on the installed capacity at the start of that year.

83 In other words, we are assuming that new distributed solar resources do not reduce Pepco's revenue requirement. While these resources are likely to provide a range of benefits, through avoided energy and generation, transmission, and distribution costs, we assume that these benefits are offset by the increased costs associated with upgrading distribution hosting capacity.

84 Vitolo et al., 2015.

85 Currently in the District, all solar installations under 100kW are subject to single-channel net energy metering (NEM), receiving credit for exports to the grid at the full retail electricity rate, while larger installations are paid at the avoided generation rate. Through the end of 2018, approximately 52% of all PV capacity in DC was represented by installations under 100 kW. The reality of PV is the District is thus more complicated than what has been modeled. To fully account for the differential tariff treatment of larger solar facilities, it would be necessary to determine the fraction of energy that is consumed onsite vs. exported to the grid at these larger units, which is difficult to achieve with the available data. In the context of our model results, our assumption of total net metering is likely to bias our results somewhat unfavorably; the true impact of distributed generation on rates would likely be somewhat lower if we accounted for the impact of lesser-than-retail compensation rates for larger solar facility generation. For more detail on net metering in DC., see: https://www.energy.gov/savings/net-metering-8

5.1. Results

Low Projection

The Low projection implies that the RPS mechanism is insufficient to induce the required solar buildout, likely due to the influence of other obstacles preventing widespread solar installation in the District. These obstacles might include prospective residential and commercial solar owners not being able to finance the upfront investment costs of solar, space and rooftop integrity constraints limiting the amount or ease of solar installation, permitting challenges, and delays in the interconnection process (due to either Pepco administration bottlenecks or distribution system hosting capacity constraints) that increase the cost of solar installation.

Middle Projection

If the RPS works as expected, the ACP will support the market SREC price and induce adequate solar construction in the District through 2036. Though there might be periods when solar installations overshoot or undershoot the solar carve-out, for simplicity, we model precise compliance. It is reasonable to assume that any noise above and below the line would likely be offset through higher compliance and lower SREC burdens, and that the overall effect would be negligible for District ratepayers. From 2037 onward, with the ACP at $300, the market SREC price is not expected to be high enough to maintain compliance, and the District is projected to again fall below the carve-out trajectory.

High Projection

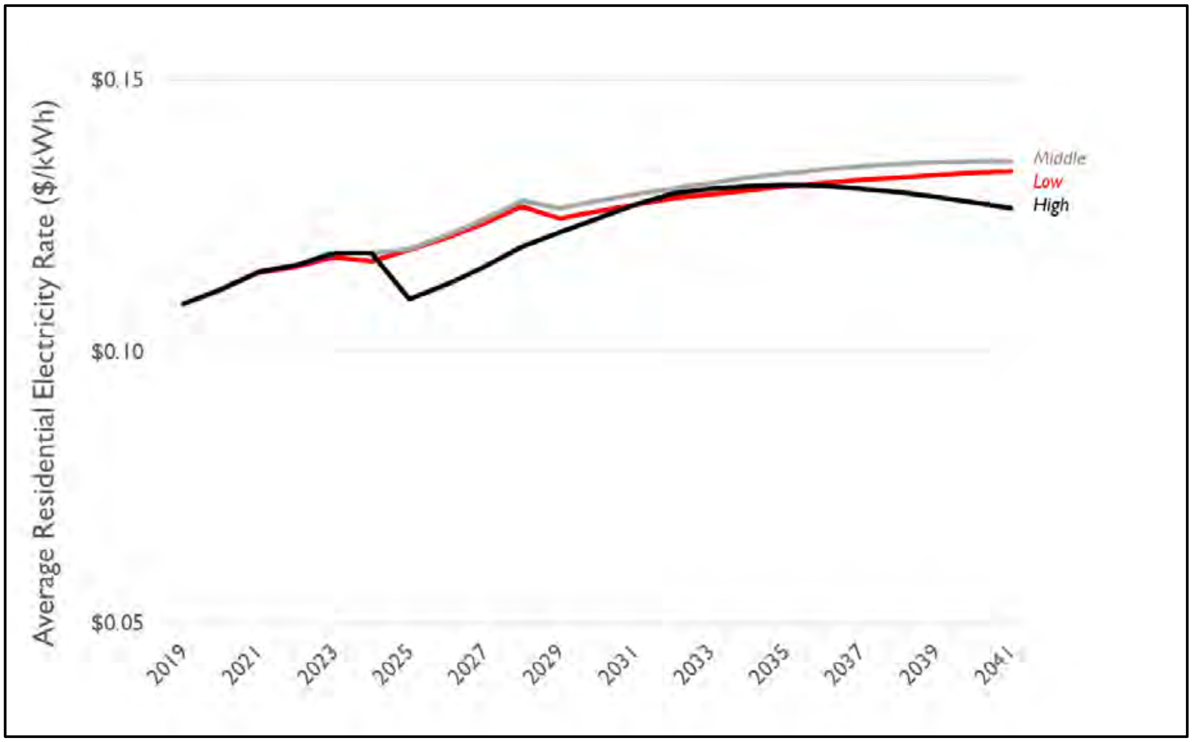
While the High projection might appear best from the standpoint of promoting District solar, it is unlikely to take hold without some other exogenous factor, such as a policy shift, a new subsidy stream, or an improvement in solar technology that radically changes its economics. In the High projection, the solar installations surpass the solar carve-out requirements, resulting in excess SRECs. The glut of SRECs would mean low RPS program costs and no compliance fees, and so the modeled average rate impacts are more favorable compared with the other projections. Under these conditions, District SREC prices fall to the price of Tier 1 RECs in the general PJM market, assumed to be $13 (2018 dollars). In the High projection, it is unclear whether residential and commercial investment in solar PV is generally reliant on the revenue stream from the sale SRECs, as we assumed was the case in the Middle projection, or if mass investment in PV is made feasible through other subsidies or compelled through other legislation.

It is critical to note that there would likely be other associated costs in this projection that would not directly face ratepayers through their electricity bills, but which residents might nonetheless be forced to cover in taxes, construction costs, or increased real estate prices. The most likely example of such a cost is a new subsidy mechanism, which would operate to induce solar construction using funds from outside the utility system.

Rate Impact Results

Figure 18 presents the expected annual average residential electricity rate for each projection in real 2018 dollars.

Figure 18. Average Residential Electricity Rates by Projection, 2019-2041



Source: Synapse calculations. Revenue and historical load data for Pepco from Form EIA-861 (https://www.eia.gov/electricity/data/eia861/). Note that the y-axis does not start at $0.

There are notable kinks in each of the curves. In the Low and Middle projection curves (red and grey), the impact of the second drop in the value of the ACP in 2029 is associated with a flattening of the curve. At this point, the drop in the ACP pulls down the market SREC price, such that suppliers are spending nearly the same amount on their combined SREC and ACP obligations in the Low and Middle scenarios. In the curve for the High projection (black), average rates drop between 2024 and 2025, when the carve-out requirement is surpassed and the market price for SRECs drops precipitously.

Discussion of Rate Impacts

The RPS legislation and net-metering tariff affect electric rates through three distinct channels:

1. Suppliers incur costs that are passed on to ratepayers when they purchase RECs and SRECs or incur compliance costs, increasing electric rates.

2. Solar that is generated in the District reduces sales, increasing rates.
3. Solar that is generated in the District reduces the energy consumed in the district, thereby reducing the quantity of RECs and SRECs that must be purchased, exerting downward pressure on rates.

Overall, rates are expected to grow in each of the projections. In the Low and Middle projections, this effect is due to the impacts of both a reduction in sales and an increase in expenditures on ACP payments and SREC purchases; in the High projection, this effect is primarily due to decreasing sales.

As Figure 18 illustrates, higher levels of solar penetration do not necessarily produce lower electricity rates, and compliance may not always produce lower rates than noncompliance. For much of the model period, the Low, Middle, and High projections produce very similar average residential electricity rates. This is particularly true between 2029 and 2037, when the High projection closely tracks both of the other projections. The fact that the three scenarios are aligned for several consecutive years is a somewhat surprising outcome given the much greater level of solar penetration and associated savings on alternative compliance payments and SREC purchases in the High projection. Yet these positive impacts appear to be offset by the effect of declining sales, which, all things equal, pushes rates up.

In addition, the Middle projection, with carve-out compliance and savings on ACP payments, never produces lower rates than the Low scenario. This is due to the fact that under an assumption of constant revenue requirements across the scenarios, the effect of declining sales on average rates is more pronounced that the impact of reduced compliance payments.

Rate Impacts

As discussed previously, there is no obvious baseline scenario against which to gauge rate impacts for each of the projections. Nevertheless, to facilitate a quantitative evaluation of rate impacts, we have chosen to designate the Low scenario as a baseline, and have derived relative impacts for the Middle and High scenarios, which are presented on the following page in Figure 19 on the following page.[86]

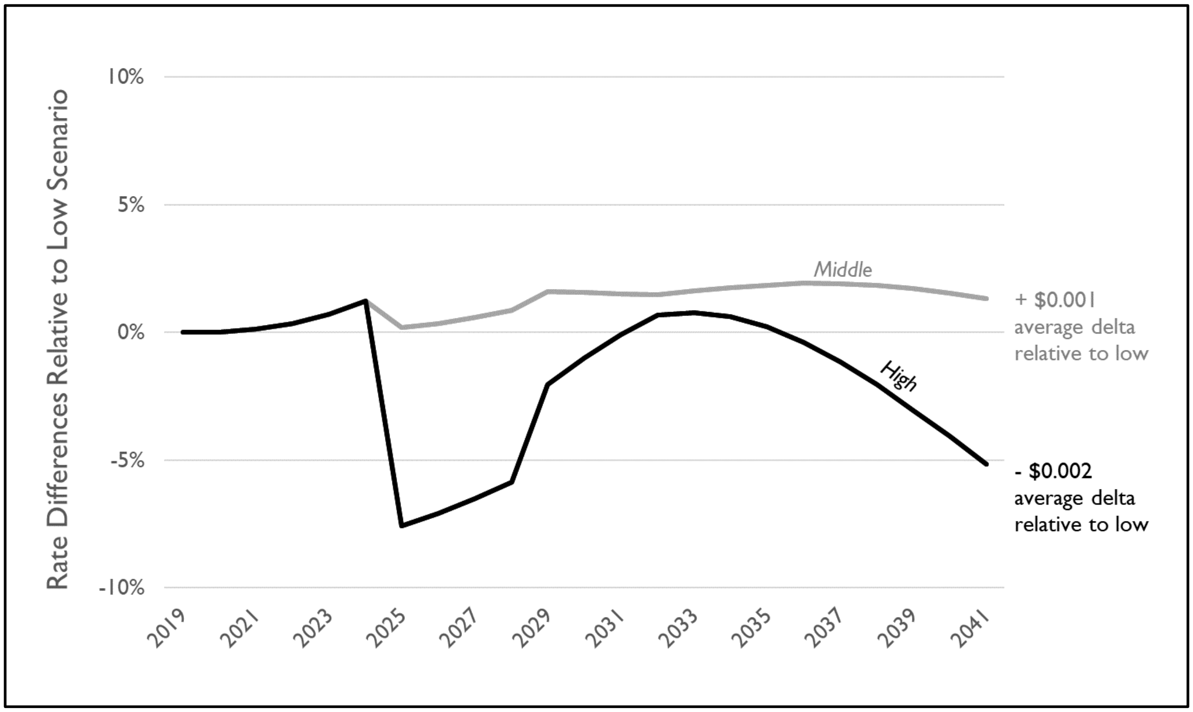
When interpreting these results, it is critical to remember that we have assumed the same core system revenue requirements for all scenarios, which are based on historical revenue requirements and escalated at 0.2 percent per year. As we explained previously, we assume that the costs to integrate such a large balance of new solar resources will offset any system savings in energy, generation capacity, and other costs over the model period. Thus, with the cost-of-

[86] The Low scenario takes a business-as-usual perspective toward the rate of solar growth, assuming that the growth rate that prevailed in 2018 will hold steady through the model period.

service unchanged between the scenarios, differential rates are the result of compliance and SREC cost differences, and the varying degrees of sales reductions.

As shown in the graph, the Middle scenario results in very minor rate impacts relative to the Low scenarios, on the order of 1-2 percent, while the High scenario generally results in rate decreases, in some years exceeding 5 percent rate reductions.

Figure 19. Difference in Average Rates Relative to Low Scenario



Source: Synapse calculations. Revenue and historical load data for Pepco from Form EIA-861 (https://www.eia.gov/electricity/data/eia861/).

Bill Impacts and Other Considerations

Average rates provide an incomplete view of ratepayer impacts. While the rates in the Middle projection are expected to be slightly higher than those in the Low projection through 2041, ratepayers are also expected to meet more of their energy needs from behind-the-meter (home) PV systems, and thus will be purchasing less energy from Pepco. Examining average bills in addition to rates thus provides a more complete picture of the economic impacts in each projection.

In the Middle projection, average residential customer bills are expected to be about $8 per year lower than in the Low projection (2018 dollars). Over the course of the full model period, this amounts to nearly $54 million of total savings (2018 dollars). Average monthly bills are lower in the Middle projection for two reasons. First, as mentioned above, while households are projected to face slightly higher electricity rates in the Middle scenario, this is offset by reduced consumption of electricity. Second, the Middle scenario is associated with compliance savings relative to the Low scenario.[87]

Meanwhile, the High projection delivers even greater bill savings than the Middle projection, with both lower average electricity rates, and lower average electricity consumption. However, without some transformative factor – and potentially other costs, which are not reflected in this analysis – the High scenario is unlikely to materialize.

Cost-Shifting

The financial impact of distributed solar installations on non-solar customers is described as cost shifting. A cost-shifting analysis focuses on *who* benefits from distributed solar, rather than on the total benefits to the system as a whole.

As described in Synapse's 2017 report,

> Cost-shifting from solar to non-solar customers occurs largely due to the reduction in electricity sales from customers generating their own electricity. The electric utility's total costs may not decline as rapidly as the reduction in sales, leaving a revenue shortfall. To make up for this, the electric utility must increase rates, resulting in higher bills for non-solar customers. However, if distributed solar provides energy and capacity during the hours when it is most costly to produce and distribute electricity, the value of distributed solar may offset the need to increase rates due to lower sales. Whether distributed solar increases or decreases rates will depend on the magnitude and direction of each of these factors. In very general terms, if the credits provided to solar customers exceed the average long-term avoided costs, then average long-term rates will increase, and vice versa.[88]

This analysis has made the simplifying assumption that new solar will not reduce Pepco's revenue requirements. Instead, for the purposes of this analysis, we assume that the avoided energy, capacity, and transmission and distribution costs associated with meeting the solar carve-out will be exactly offset by the cost of integrating the additional solar. This is unlikely to hold in reality, as the benefits associated with solar to the utility system could grow very large. However, the estimation of this effect was outside of the scope of this analysis. To properly gauge the impact on the utility's revenue requirements would require a value-of-solar study that accounts for the benefits and costs associated with a large quantity of solar through 2041.

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87 In both the Low and Middle projections, suppliers make significant alternate compliance payments. Like SREC payments, these expenditures put upward pressure on rates. However, the ACP revenue generated by the District may yield benefits, especially to less advantaged residents, through the re-distribution of those payments into the District's Renewable Energy Development Fund (which supports the Solar for All program). Ultimately, both the SREC and ACP expenditures, financed by the mass of ratepayers, should be understood as a transfer; the funds do not leak out of the system but instead accrue as benefits to specific constituencies.

88 Whited et al., 2017, p. 13

While the 2017 Synapse report did include a value of solar analysis, this analysis is not intended to be extrapolated far into the future. As noted in the report, "a value of solar study is designed to analyze the impacts of a small amount of additional solar installed in the near-term, rather than large quantities of the resource installed many years in the future. Thus the results in this study should not be assumed to still hold for significant increases in PV deployment, or for many years into the future."[89] We also note that the 2017 study did not account for the costs associated with compliance, since these were assumed to be present regardless of the course of solar development in the District.

The current study has taken a different approach. Instead of comparing a single scenario with a base case, we have assessed the impact of different degrees of solar development, focusing on the differential costs for compliance and SREC acquisition across these scenarios. Therefore, in this section, we provide the results of potential cost-shifting due to meeting the solar carve-out, assuming that the costs associated with solar exactly offset their benefits to the utility system.

Using these simplifying assumptions, we estimate the impacts of meeting the solar carve-out on an average customer's annual bill under both Middle and High scenarios, relative to the Low scenario, assuming average monthly usage of 664 kWh/month.[90] We find that the Middle scenario is $11.62 per-year costlier for the average customer than the Low scenario, while the High scenario is associated with an average annual savings of $18.07 for the same customer, relative to the Low scenario. These results should be considered in tandem with the average bill impact results presented previously. Therefore, while the Middle scenario is on average about $8 cheaper per-year than the Low scenario for *all customers*, it is nearly $12 more expensive annually for customers with average energy usage (e.g., customers without solar).

It is worth noting that in the short-run, all scenarios – Low, Middle, and High – are expected to result in higher average bills for customers without solar, and lower average bills for owners of solar, than a no-RPS alternative. Since the RPS is already in place, however, we have not conducted a cost-shifting analysis with respect to such a baseline.

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89 Whited, et al. 2017, p.13.

90 PEPCO Exhibit (F)-2, Class Cost of Service Study, Formal Case 1139, June 30, 2016, Pages 52-53.

6. SENSITIVITIES

This report has addressed big questions about solar development in the District over the coming two decades. There are many factors at play in determining what course this development will take, and we used a core set of assumptions and inputs to formulate projections through three distinct models.

In this section, we examine sensitivities in three dimensions of our analysis. We consider sensitivities in our estimate of the overall potential for solar development for the District. Alterations to the assumed technical and economic potential will change the projected development trajectories in at least the Middle and High scenarios. We also evaluate whether the study's assumptions about municipal property availability are too optimistic. Finally, we test sensitivity to changes in the load forecast which might occur with more aggressive end-use electrification.

We address each of these sensitivities qualitatively first, and then we calculate the effects of changing key parameters on scenario outcomes.

Solar PV Development Potential Sensitivities

We consider three factors that could affect overall solar development potential in the District:

(1) Changes in regulations governing solar PV installation on parking lots and construction of buildings on parking lots

(2) Limitations to solar PV development on municipal property

(3) Improvements in PV panel efficiency

Parking Lots

This study expanded on the previous Synapse report by including parking lots in the modeling of DC solar development. In our analysis, parking lots represented about 52 percent of District techno-economic potential. As explained previously, Synapse accounted for the various constraints on development potential in two steps: First, we excluded all lots under 2000 square feet. Next, we assumed that only 60 percent of remaining area could be developed. Under the High scenario, this is the portion that is projected to be developed, while less parking lot development occurs in the Low and Middle scenarios.

We used the 60 percent factor to reflect all limitations to development, including technical, political, and economic constraints. Though a more granular analysis might attempt to parse out the relative influence of each of these kinds of constraints toward a more precise accounting of the techno-economic potential for parking lot development, this was beyond the scope of the present analysis.

Assuming the 60 percent factor for potential is a valid reflection of current conditions, future conditions could still evolve in such a way over the coming two decades that the total development potential for lots might shrink. Specifically, development regulations in the District could tighten up, restricting where PV canopies can be erected or expanding the required buffer between the edge of the canopy and the property line. In addition, some parking lots may be given over to building construction. To the extent that building rooftops are less likely to host solar installations (as our modeling assumes), this would lead to a net reduction in overall potential.[91]

For this sensitivity, we assumed that an additional 25 percent of non-municipal parking lot technical potential is not usable due to various limitations. (Municipally owned parking lots are subject to a more conservative sensitivity restriction, discussed below.) While it could be assumed that a portion of this excluded share is converting into buildings, and thus results in some new rooftop technical potential, we have taken a more conservative tack and simply excluded it.

Municipal Land Development Potential

This report assumed that municipal property in the District would be developed at the same rate as private property. Since approximately 13 percent of all non-Federal land in DC is owned by District government, it was estimated that in each scenario, about 13 percent of all development would occur on District land. It was further assumed that all PV development on municipal land would take the form of community solar, and that all future community solar development in the District would occur on municipal land.

In practice, municipal land may be more limited in development potential than private property due a range of different and perhaps incremental constraints. Moreover, while residents and businesses in the District have ample incentive to install solar in order to reap generous SREC revenues, no such spur exists for the DC government. As noted in Section 4.4, future community solar development—and thus future solar development on District property—is apt to be driven by policy, not economics. It is not clear whether, independent of other constraints to development on District-owned land, there will be adequate impetus to install as much solar on District property as is projected in our modeling.

91 The short-term economics of solar PV investment are good enough under current SREC market conditions in the District that developers need not commit to decades-long life for a new canopy installation in order to turn a profit. Even given uncertainty about the future utilization of a given lot, it might still make good economic sense to erect a canopy for a term of only five to ten years.

For this sensitivity, we assume a 50 percent reduction in the total portion of municipal land (parking lots and rooftops) that is usable. Reducing the technical potential on District-owned land depresses total installations in both the Middle and High projections.[92]

Future Advances in PV Technology

In this analysis, we assumed an 18 percent capacity factor for PV in the District. However, expected advances in PV technology will likely raise average capacity factors above this value by the end of the model period. We therefore included a sensitivity for the average District capacity factor. Since we are using a single factor for the entire modeling period, however, this factor must respect lower efficiency in the historical period and near future term. Thus, for this sensitivity, we assume an overall average capacity factor of 20 percent for the whole study period.

Load Forecast Sensitivities

In the main analysis, we assumed a 0.2 percent rate of load growth, following PJM's forecast methodology. This rate of change reflects countervailing influences. On the one hand, energy conservation should depress load growth. On the other hand, electrification of end-uses will tend to increase load. For this sensitivity, we assumed a greater role for electrification relative to conservation, resulting in a greater rate of load growth. We chose to model a 0.5 percent growth rate for the full study period based on the highest year-on-year rate of growth assumed by PJM over the period 2019-2034.[93]

Quantitative Analysis of Sensitivities

Out of a total parking lot technical potential of about 1100 MW, about 21 percent is owned by the District. Following the discussion above, we reduce this potential by 50 percent. The balance of the parking lot technical potential, privately owned, is reduced by 25 percent.[94] Meanwhile, total rooftop technical potential is approximately 1680 MW. Only the District-owned share, about 6 percent, is subject to a 50 percent reduction under the sensitivity assumption. Overall, the combined reductions in technical potential from general parking lot and specific municipal

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92 It is worth considering whether a reduction in the technical potential of municipal land need imply a reduction in total solar development on municipal land under the assumption that this development will consist exclusively of community solar installations, as long as the total development on District-owned land is never forecast to exceed the total technical potential of District-owned land. To evaluate the sensitivity of community solar development to technical potential, however, would require a different model of community solar development than has been used here.

93 See https://www.pjm.com/-/media/library/reports-notices/load-forecast/2019-load-report.ashx?la=en.

94 Note that we have chosen to treat the municipal sensitivity as taking precedence over the general parking lot sensitivity, to the effect that the general parking lot reduction factor of 25 percent is applied to just privately-owned lots.

sensitivities results in about 383 MW less of technical potential—a reduction of about 14 percent for the District.

Scenario Impacts

The introduction of technical potential sensitivities does not impact the projected installations in the Low projection but affects results in both the Middle and High projections, as shown in Figure 20 and Figure 21 on the following page. Note that we have held constant the study's load growth and capacity factor assumptions for these figures. The reduction in technical potential is most critical in the Middle projection, resulting in the District falling out of carve-out compliance four years earlier and installing about 20 percent fewer MW of solar.

Figure 20. Middle projection of solar PV in DC with technical potential sensitivity

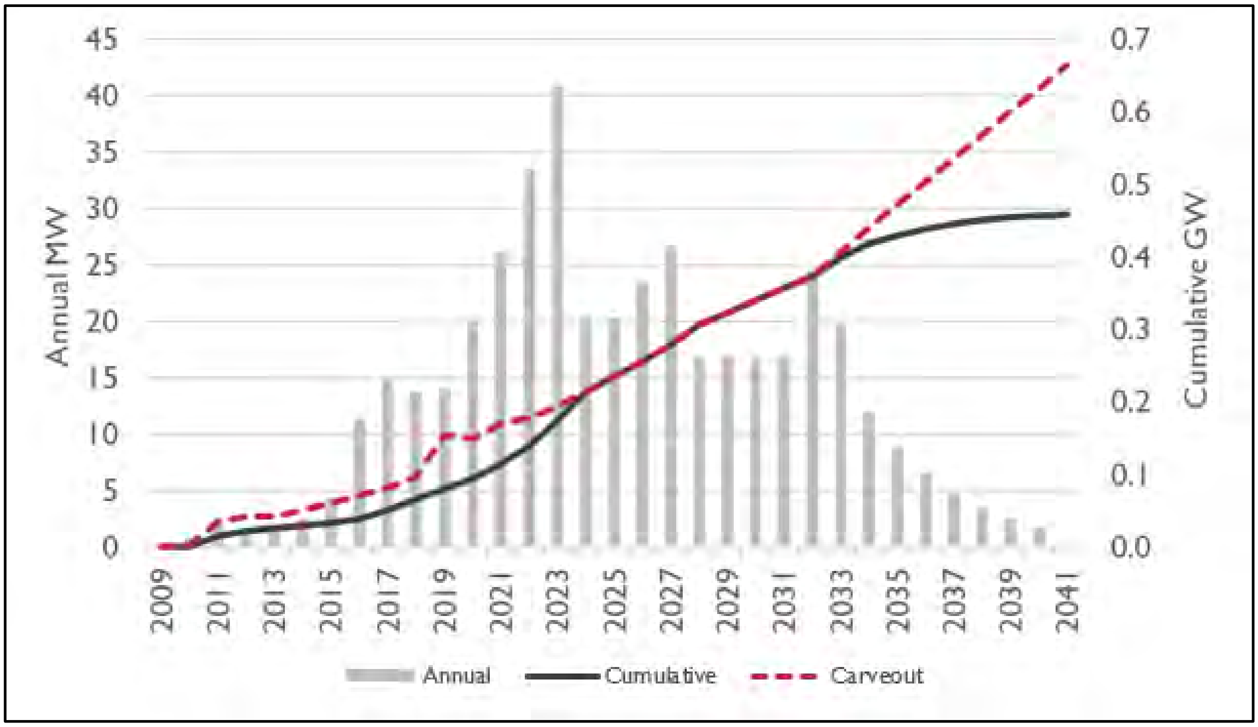
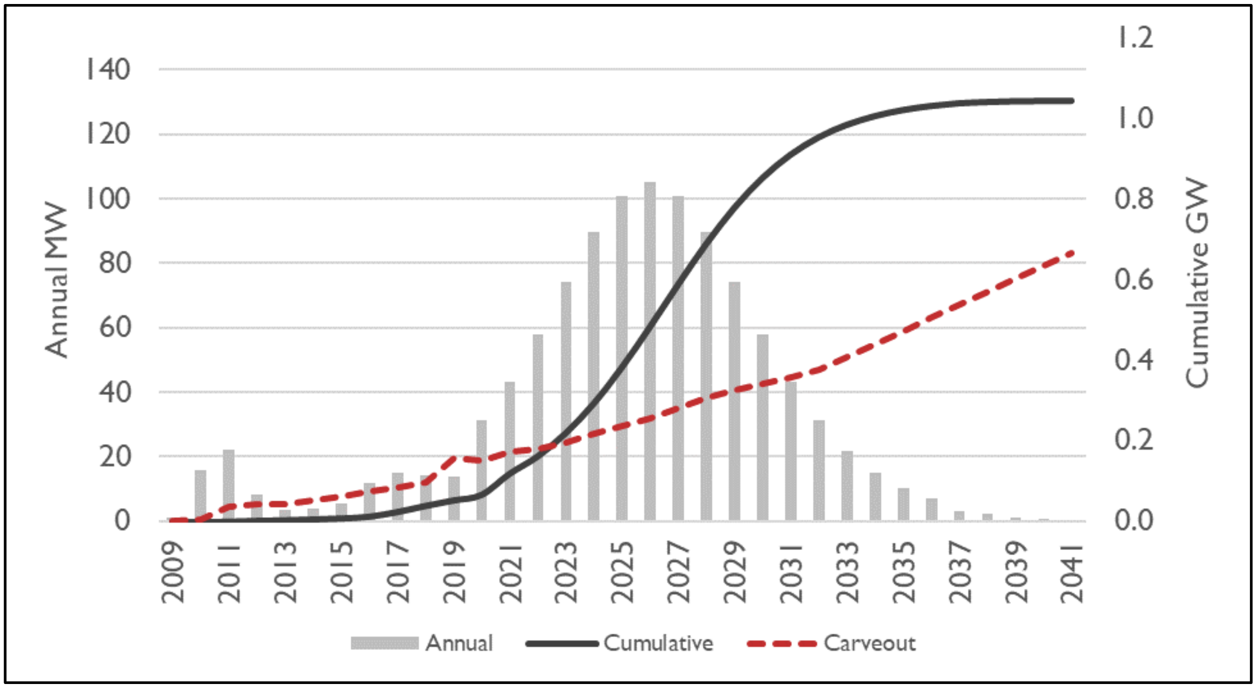


Figure 21. High projection of solar PV in DC with technical potential sensitivity



Source: For Figure 20 and Figure 21, RPS requirement is from Code of the District of Columbia §34-1432 (https://code.dccouncil.us/dc/council/code/sections/34-1432.html) and Synapse calculations. Historical installations are from DC PSC, "List of Eligible Renewable Generators.xlsx" (https://dcpsc.org/Utility-Information/Electric/Renewables/Renewable-Energy-Portfolio-Standard-Program.aspx). Future projection is based on Synapse calculations with GIS data from Open Data DC (http://opendata.dc.gov/).

Rate and Bill Impacts

Finally, we present rate and bill impacts for different combinations of sensitivity adjustments in Table 11.[95]

Table 11. Low and Middle projection average rate and bills impacts

				Average Rate	Average Bill
Low Projection	Reference Technical Potential	Reference Load Forecast	Reference PV Efficiency	$0.124	$991.81
			High PV Efficiency	$0.125	$993.75
		High EE Load Forecast	Reference PV Efficiency	$0.120	$959.50
			High PV Efficiency	$0.121	$961.22

95 In the interest of concision, results for the High projection have not been included.

	Low Technical Potential	Reference Load Forecast	Reference PV Efficiency	$0.124	$991.81
			High PV Efficiency	$0.125	$993.75
		High EE Load Forecast	Reference PV Efficiency	$0.120	$959.50
			High PV Efficiency	$0.121	$961.22
Middle Projection	Reference Technical Potential	Reference Load Forecast	Reference PV Efficiency	$0.126	$1003.43
			High PV Efficiency	$0.121	$962.66
		High EE Load Forecast	Reference PV Efficiency	$0.118	$938.96
			High PV Efficiency	$0.118	$939.36
	Low Technical Potential	Reference Load Forecast	Reference PV Efficiency	$0.126	$1000.18
			High PV Efficiency	$0.126	$1000.09
		High EE Load Forecast	Reference PV Efficiency	$0.122	$968.36
			High PV Efficiency	$0.121	$967.66

7. Policy Recommendations for the District

Based on the analyses in the sections above, Synapse developed a set of recommendations to help ensure that the District can meet its solar carve-out target of 10 percent by 2041, approximately 665 MW according to our calculations. Each concrete policy action item is listed in the sections below, with a detailed description of the analysis supporting each policy recommendation.

7.1. Monitor SREC Market and Solar Economics

It is still too early to characterize the District’s solar installation trajectory. While the historical experience since 2011 appears to suggest linear growth dynamics (Low projection), the early period of an exponential function also appear linear (Middle and High projections). What happens over the coming years will clarify this question. If growth ramps up rapidly, then the District will more likely attain compliance with the carve-out.

In the near-term, Synapse recommends that the District monitor future solar installations and the SREC market closely to see whether the ACP mechanism is sufficient to encourage the required amount of solar to reach the carve-out. Based on the results from the rate impact analysis, we encourage the District to aim towards compliance with the solar carve-out as early as possible to minimize future ratepayer impacts. Overall, District ratepayers will do best in aggregate under some degree of RPS compliance, and the Middle projection results in lower average bills for ratepayers than the Low projection – but compliance will be difficult to attain after the ACP falls to $300. At that point, we do not expect that there will be sufficient stimulus available through SREC revenues to produce the needed scale of investment in District solar PV.

7.2. Construct Other Financial Incentives

Even if the solar shortfall were to persist over the coming years, it would not necessarily be prudent to raise the ACP or otherwise try to inflate the SREC price. A shortfall in solar capacity may suggest that there are problems in the form of compensation, not the level of compensation, or that other barriers are present. For example, the fact that SREC prices are variable increases the risk that the project will not be able to obtain financing, since the price of future SRECs is unknown. Because of this, project developers may opt for more sophisticated financing solutions to mitigate price risk. One option is to sell the rights to future SRECs to a brokerage firm, such as Sol Systems, which currently offers 10-year SREC annuities at approximately $234 per SREC.[96] A customer who chooses this option is revealing that the risk associated with SREC volatility reduces the current value of the SREC by approximately 50 percent for that customer. To address the risk imposed by SREC volatility, the District could choose to offer feed-in tariffs at a price that remains fixed for 10 years but is lower than the price of SRECs.

Starting in 2020, the federal solar investment tax credit (ITC) will begin to sunset (i.e., decline from its current rate of 30 percent). By 2022 to 2023, the ITC will be completely gone. Though solar installation costs are expected to continue decreasing over the next decade, this phase-out is still a considerable loss in upfront savings to future solar installers in the District. The District may consider developing an up-front incentive (such as using Renewable Energy Development Funds) to supplement the loss of this program, given that upfront costs still represent a substantial hurdle to solar installations.

More broadly, the District should act to support other upfront financial products (e.g., solar loans or a green bank) that leverage future revenue streams to support lumpy capital outlay. Since compliance is so clearly in the ratepayer interest, there may be cause for using additional ratepayer funds to promote development of in-District solar.

96 As of April 2019, Sol Systems offers a 10-year annuity that is priced at $360/SREC for the first three years, followed by $180/SREC for the following seven years. https://www.solsystems.com/srec-customers/state-markets/washington-d-c/.

7.3. Implement Solar-Supportive Building Codes

The District could consider using the building codes to require solar PV for all new construction and even for substantial renovation. This change could be softened in any number of ways. A project cost threshold could limit this regulation to construction where total project cost, gross square footage, or total project cost per square foot exceeds a threshold. Exceptions could be made for solar availability, workforce housing, or for any other policy rationale. Similar to inclusionary zoning for affordable housing policies, a developer could even be allowed to buy out of the obligation, with the money used to fund existing (or new) solar programs in the District. The state of California has a PV installation obligation for new construction beginning in 2020.[97] The city of Watertown, Massachusetts requires solar PV on most new commercial buildings.[98] To the extent that a similar District policy would apply to enough rooftops, the PV deployment curve would most closely match the shape of the High Scenario.

7.4. Monitor Solar Adoption Across Wards and Conduct Outreach

As demonstrated in Section 4.3, historical solar development in some wards has not aligned with their technical potential. As shown in Table 4, Wards 2 and 3 are lagging their technical potential. As a percentage technical potential, Ward 2 is lagging by more than 50 percent. Similarly, Ward 3 is lagging its technical potential by nearly 25 percent.

Synapse recommends that the District closely monitor the adoption of solar in each ward over the next several years. If Wards 2 and 3 continue to lag their potential, even after the second round of Solar for All, ward-specific outreach or policies may be necessary to help encourage development of solar in these under-performing wards. Ward 2 may benefit from policies focused on facilitating faster development of solar in the downtown or historic areas of the District (e.g., permitting, interconnection, or historic board approval improvements), while Ward 3 may benefit from outreach geared towards affluent households that may be interested in the environmental benefits of adding solar to their home. If, in the future, there are under-performing wards with higher percentages of low-to-moderate income households, education could be focused on the benefits of solar and ways to access capital for low-to-moderate income households. If these types of actions are implemented before the ward installation gaps become

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97 Bill Chappell, "California Gives Final OK to Requiring Solar Panels on New Houses." National Public Radio, December 6, 2018. https://www.npr.org/2018/12/06/674075032/california-gives-final-ok-to-requiring-solar-panels-on-new-houses.

98 Craig LeMoult, "Watertown Requires Solar Panels on New Buildings, and Massachusetts Considers Following Suit Statewide." WGBH, February 1, 2019. https://www.wgbh.org/news/local-news/2019/02/01/watertown-requires-solar-panels-on-new-buildings-and-massachusetts-considers-following-suit-statewide.

any wider, they may facilitate the equitable distribution of solar across the District's wards. The District may also consider focusing future Solar for All installations in under-performing wards.

7.5. Continue Supporting Community Solar Through SFA Program

To support the District reaching its solar carve-out target, Synapse recommends a long-term continuation of the Solar for All program, specifically the focus on low-income families and community solar development. Given that 60 percent of households in the District are renter-occupied, home ownership and upfront costs are likely strong barriers to solar adoption, both of which are alleviated by strong community solar and low-income programs.

According to Synapse's calculations in this report, the District needs to meet about 665 MW of solar by 2041 to achieve the solar carve-out target. In the reference case referred to in Synapse's 2017 Value of Solar report,[99] the technical potential for small (single-family) residential solar is 360 MW and for large multi-family is 40 MW. The likely adoption potential for residential buildings is 64 percent, yielding an estimated 230 MW of small residential solar and 26 MW of large multi-family solar. For commercial and industrial buildings, the technical potential is about 813 MW[100] and the likely adoption potential is 26 percent, yielding an estimated 211 MW of commercial and industrial solar. Summing small residential, large residential, and commercial and industrial, the total likely adoption of solar is 467 MW. This leaves a gap of about 198 MW of solar to reach the 2041 target. Community solar and parking lot solar will need to fill the remaining capacity requirement to meet the carve-out. Our recommendation is that the District continue the Solar for All program towards a goal of at least 200 MW of installed community solar capacity by 2041. Furthermore, we encourage consideration of parking lot canopy solar to meet this community solar target, since the District has promising potential for parking lot solar (over 600 MW). About 70 percent of that parking lot space is District-owned and therefore could be developed by the District's Solar for All program more quickly than on privately-owned land. As such, targeting District-owned parking lots for future Solar For All community solar installations is a promising option to help the District meet its solar carve-out. Finally, to take advantage of economies of scale, we recommend that the District focus its attention on the largest District-owned parking lots, as the unit cost generally declines as the total parking lot canopy size increases.

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99 Whited et al., 2017, pages 99 and 104.

100 Whited et al. (2017) lists a reference potential of 10.5 million square meters for the GC&I sector on page 98. Subtracting our value of 3.7 million square meters of District-owned rooftops, we are left with 65% of the potential in the GC&I sector. 65 percent of 1,250 (Whited et al. page 99) yields 813 MW of potential for the commercial and industrial sector.

7.6. Reopen and Leverage Pepco Interconnection Docket

The Commission has reopened proceedings dealing with small generator interconnection and related matters in RM-40 and FC1050. On April 10, 2020, the Commission issued notice of proposed rulemaking under RM-40-2020-01, to amend Chapter 40 (District of Columbia Small Generator Interconnection Rules) of Title 15 (Public Utilities and Cable Television) of the District of Columbia Municipal Regulations (DCMR). The purpose of the amendment is to address system upgrade costs related to the interconnection of community renewable energy facilities (CREF), small generator interconnection timelines, and small generator interconnection costs. The amendment is also intended to incorporate a definition of Advanced Inverter, require Potomac Electric Power Company (Pepco) to mandate the deployment of advanced inverters in the District of Columbia effective January I, 2022 to comply with IEEE 1547-2018 standards, and to establish a timeline and goals for inverter setting profiles.

As the District moves toward meeting its solar carve-out and increased deployment of distributed generation resources, it is imperative to regularly review the interconnection rules. Revising standards related to interconnection may allow for both improved safety of human and physical resources, as well as increased interconnectivity levels without requiring physical equipment upgrade. It is also imperative to require that Pepco update and make the hosting capacity map accessible to regulators, stakeholders, and investors in distributed energy resources.

7.7. Require Pepco to Monitor, Report, and Address Distribution System Limitations

Given the existing distribution system hosting capacity constraints already facing the District (Figure 2), Synapse strongly recommends that the District require Pepco to regularly monitor and report significant distribution grid constraints that affect the adoption of distributed energy resources including solar. In 2018, Pepco filed the Capital Grid Project plan with the Commission. The plan has two phases, Phases I and II, and involves spending $850 million for an infrastructure construction project that may be completed in 2026. Phase I deals with aging infrastructure problems and Phase II is about the construction of a new substation. The Commission approved both phases in 2019. However, it is imperative to assess the impact of the implementation of Phase II of the capital grid project in meeting the District's solar obligations under the Clean Energy DC Omnibus Amendment Act of 2018.[101] The Commission could mandate the net metering working group or create another working group that would review Pepco's current physical infrastructure and future upgrade needs to meet the District's RPS solar carve-out. The working group could determine the necessary physical upgrades, the location and

[101] Commission's Order No. 20286 in FC1130 includes directives to submit revised distribution system planning and open a Microgrids docket. The Commission's order in FC1130 offers support to the findings of this study.

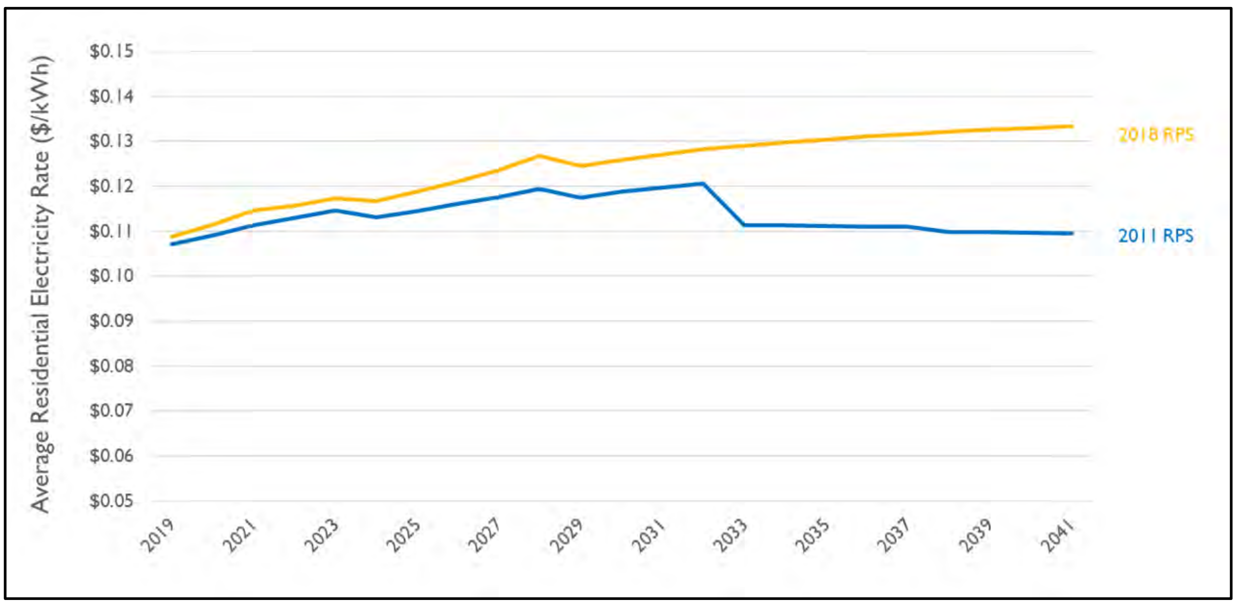
costs of those upgrades, and the schedule necessary to ensure that Pepco is not slowing solar installation in the District or causing the District to miss its solar carve-out target. The plan generated by this group should balance expected net cost with broad fairness, both across wards and across customer types and building types.

7.8. Consider Modifications to the RPS Statute

Should the District continue to fall short of the carve-out requirements, policymakers and legislators might consider modifying the RPS statute. One possibility would be to restore the previous solar carve-out targets and ACP cost trajectory to the levels set in the Distributed Generation Amendment Act of 2011. With a target for in-District solar of just 5 percent, the District would stand a greater chance of attainment, and the overall ratepayer costs of shortfall would be reduced.

To evaluate the merits of rolling back the RPS to the previous form, we compared the average residential rates from the Low projection with those that would be expected given the same growth trajectory, but assuming that the 2011 act were to be restored.

Figure 22. Low Projection Average Residential Electricity Rates under the 2011 and 2018 RPS Statutes



Source: Synapse calculations. RPS is found in Code of the District of Columbia §34-1432 (https://code.dccouncil.us/dc/council/code/sections/34-1432.html). Data on Pepco from Form EIA-861 (https://www.eia.gov/electricity/data/eia861/). Note that the y-axis does not start at $0.

As Figure 22 illustrates, reverting to the former RPS would mitigate against the upward rate pressure generated by the compliance burden. This would occur for two reasons. First, suppliers would be required to make fewer ACP payments. Second, the legislated ACP would be less costly after 2032.

While suppliers would be expected to purchase the same number of SRECs under the old RPS and a low-growth trajectory—with total SREC production still undershooting carve-out requirements—the gap to be filled by ACPs would ultimately be lower, due to the slightly lesser carve-out requirements in the final years of the old RPS. Moreover, the total ACP obligation would be less costly. Under the old RPS, the ACP is legislated to fall to $50 in 2033, rather than remaining at $300 through 2041.

We note that while this alternative may look beneficial, certain other benefits, both quantifiable and non-quantifiable, would be lost. District residents would stand to earn less through SREC revenues, and with lesser ACP funds, community solar development might be reduced.

APPENDIX

Low Projection

Table 12. Low projection of annual and cumulative solar PV in the District of Columbia

Year	Annual Installed Capacity (MW)	Cumulative Capacity (MW)	Solar Target (MW)
2009	1.3	0.0	1.8
2010	14.7	1.3	2.8
2011	8.2	16.0	36.8
2012	3.0	24.2	46.0
2013	3.6	27.2	46.0
2014	4.0	30.8	56.0
2015	5.5	34.8	66.0
2016	11.8	40.3	78.0
2017	15.1	52.0	67.8
2018	14.1	67.1	79.4
2019	14.0	81.1	127.2
2020	14.0	95.2	149.3
2021	14.0	109.2	171.4
2022	14.0	123.2	178.5
2023	14.0	137.2	195.6
2024	14.0	151.3	216.0
2025	14.0	165.3	236.3
2026	14.0	179.3	256.6
2027	14.0	193.3	280.2
2028	14.0	207.3	307.0
2029	14.0	221.4	323.9
2030	14.0	235.4	340.8
2031	14.0	249.4	357.7
2032	14.0	263.4	374.6
2033	14.0	277.5	407.5
2034	14.0	291.5	440.3
2035	14.0	305.5	472.9
2036	14.0	319.5	505.3
2037	14.0	333.6	537.6
2038	14.0	347.6	569.7
2039	14.0	361.6	601.7
2040	14.0	375.6	633.4
2041	14.0	389.6	665.1

Note: The rows highlighted in gray are historical solar installations, not projected installations, except for 2019, which is partially forecast, based on historical data through June 2019.

Table 13. Ward-based Low projection of annual adoption of solar PV (MW) in the District of Columbia

Year	Total	Ward 1	Ward 2	Ward 3	Ward 4	Ward 5	Ward 6	Ward 7	Ward 8
2009	1.3	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0
2010	14.7	0.1	0.0	0.2	0.1	0.3	0.1	0.0	0.0
2011	8.2	0.2	0.2	0.9	0.3	0.2	0.5	0.0	0.0
2012	3.0	0.1	0.1	0.2	0.1	0.4	0.2	0.1	0.2
2013	3.6	0.2	0.1	0.1	0.4	0.4	0.3	0.2	0.3
2014	4.0	0.3	0.2	0.4	0.4	0.7	0.3	0.2	0.1
2015	5.5	0.3	0.3	0.7	0.6	1.1	0.5	0.7	0.3
2016	11.8	0.9	0.5	0.5	1.3	1.7	1.5	2.5	2.6
2017	15.1	0.5	1.0	0.8	1.9	2.3	2.5	3.2	2.9
2018	14.1	0.8	0.8	1.3	1.7	2.5	2.0	2.4	2.2
2019	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2020	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2021	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2022	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2023	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2024	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2025	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2026	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2027	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2028	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2029	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2030	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2031	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2032	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2033	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2034	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2035	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2036	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2037	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2038	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2039	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2040	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0
2041	14.0	0.9	1.7	1.8	1.6	2.6	1.9	1.6	2.0

Note: The rows highlighted in gray are historical solar installations, not projected installations, except for 2019, which is partially forecast, based on historical data through June 2019.

Figure 23. Ward 1 Low projection solar potential by installation type

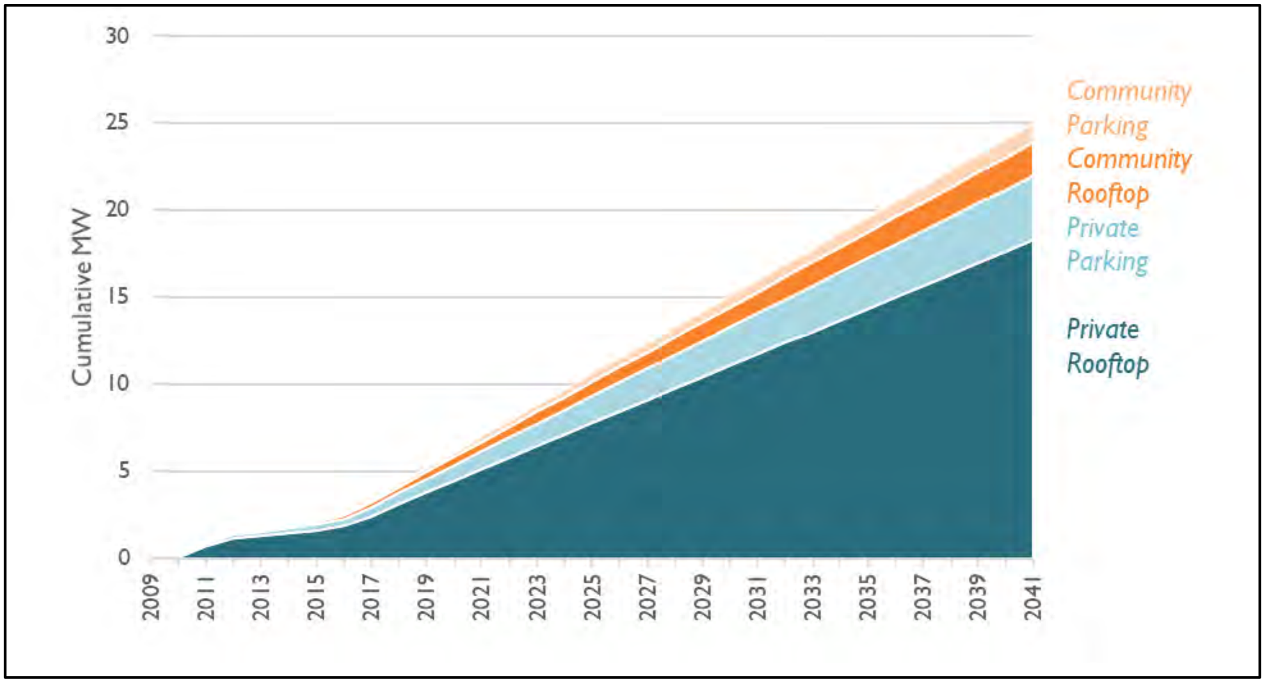


Figure 24. Ward 2 Low projection solar potential by installation type

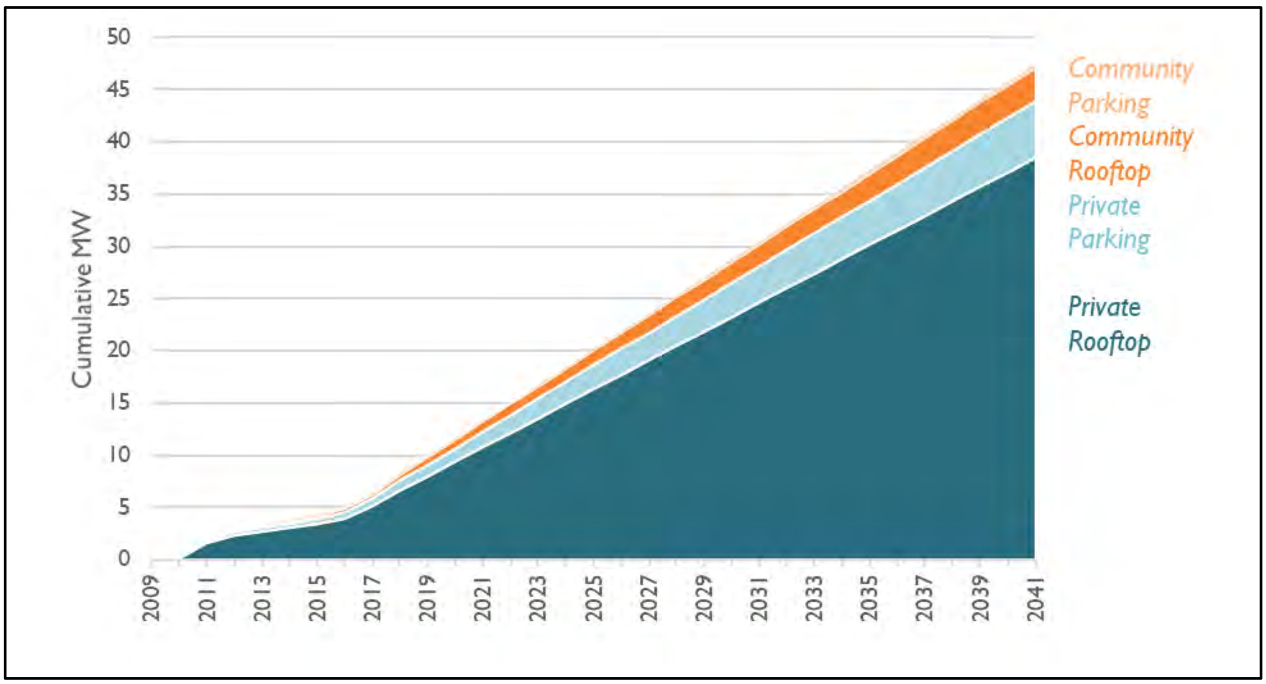


Figure 25. Ward 3 Low projection solar potential by installation type

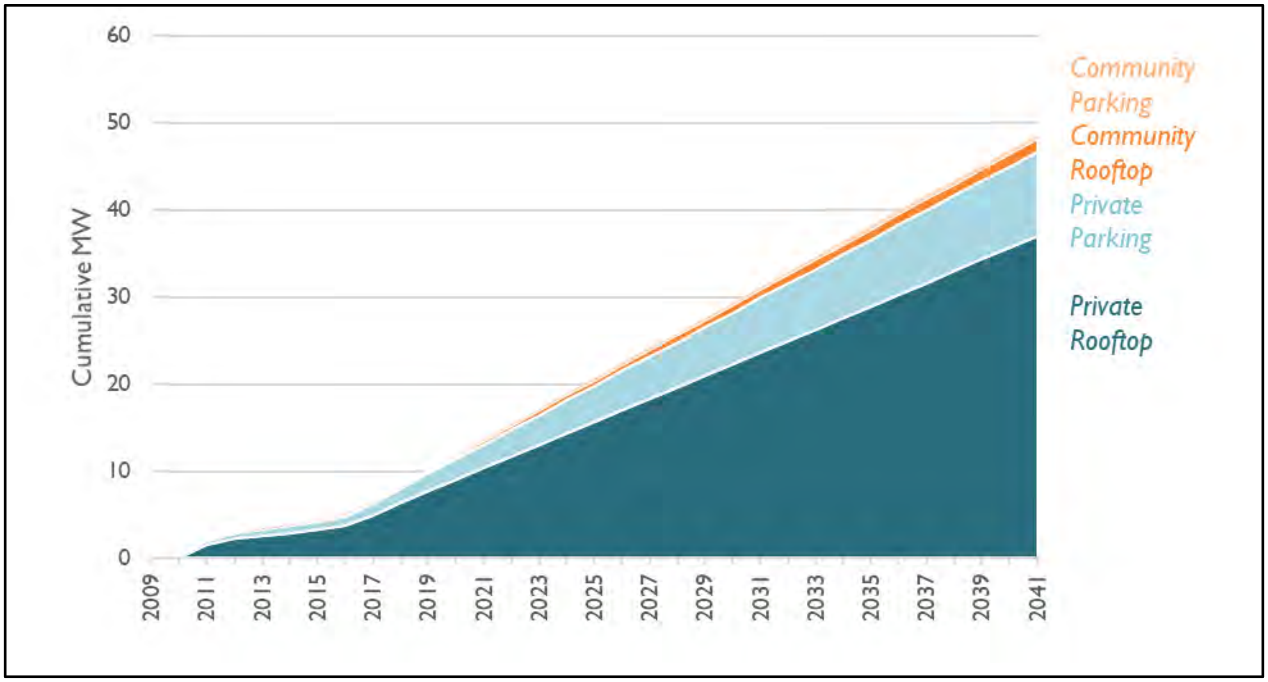


Figure 26. Ward 4 Low projection solar potential by installation type

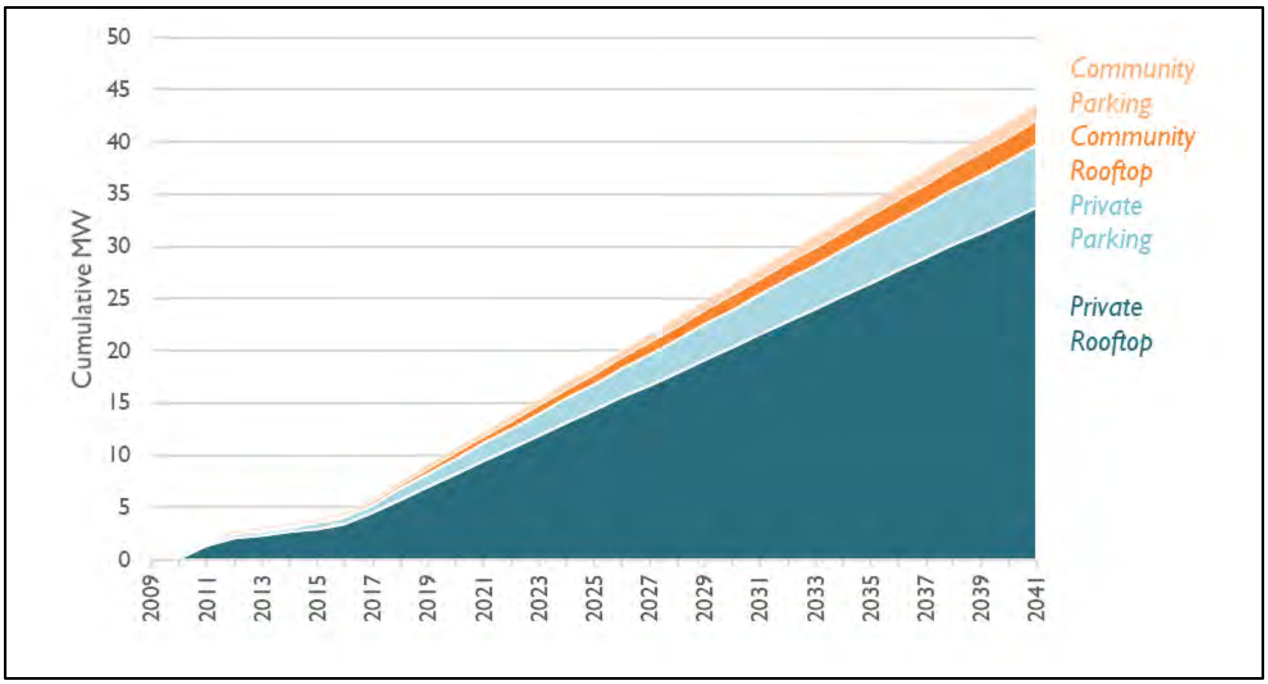


Figure 27. Ward 5 Low projection solar potential by installation type

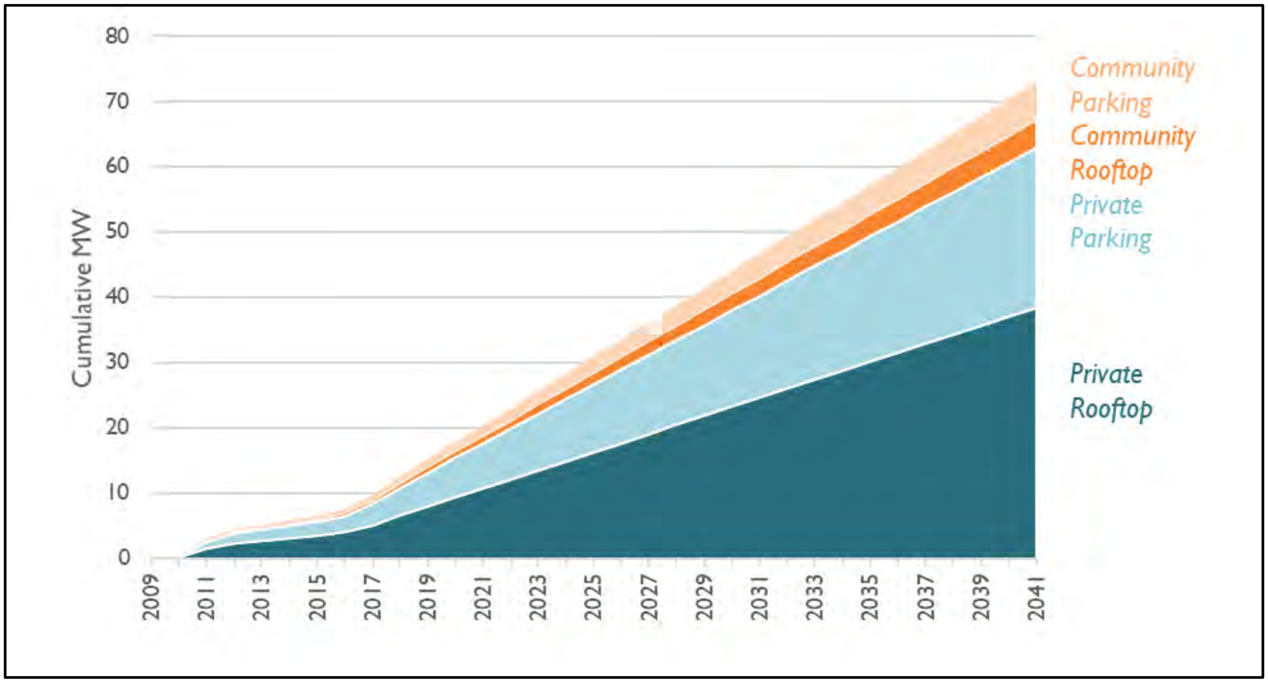


Figure 28. Ward 6 Low projection solar potential by installation type

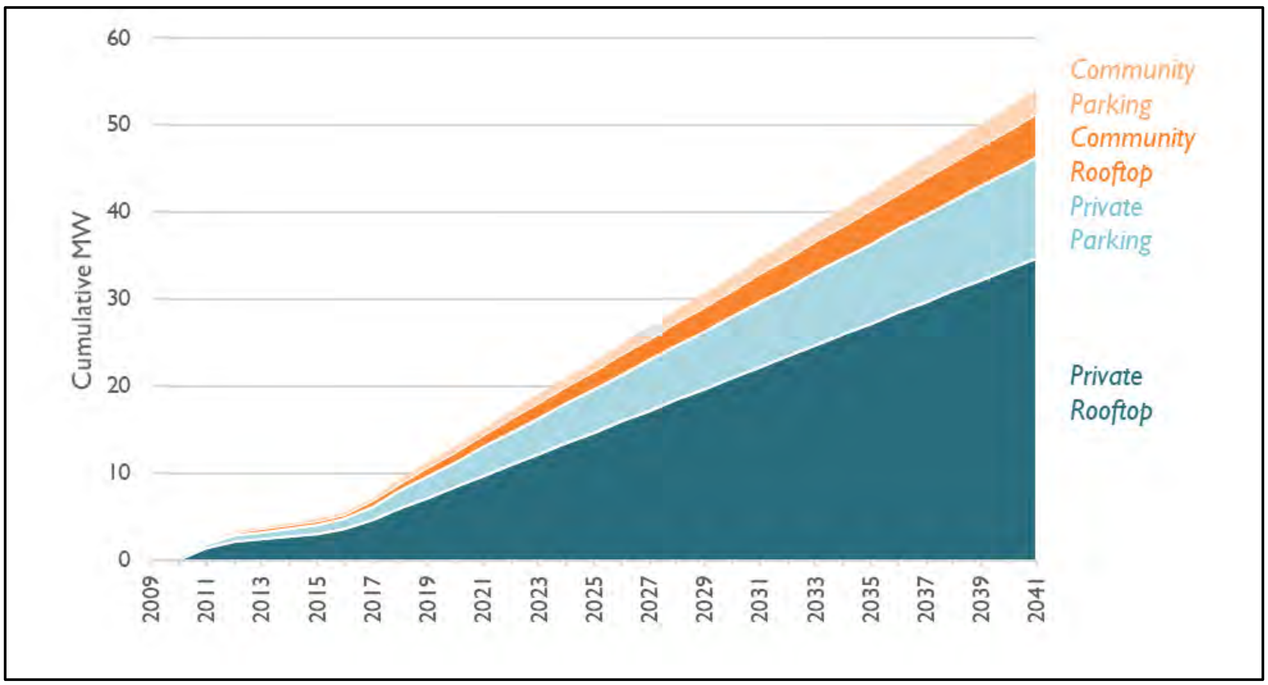


Figure 29. Ward 7 Low projection solar potential by installation type

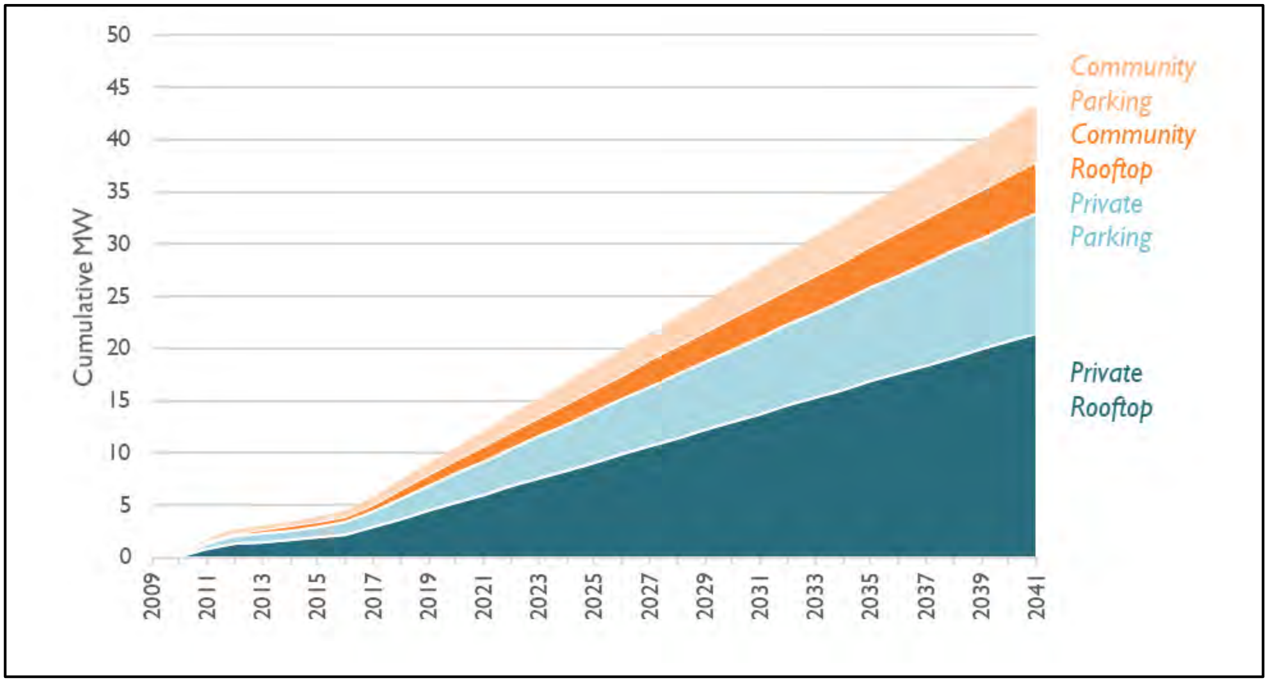
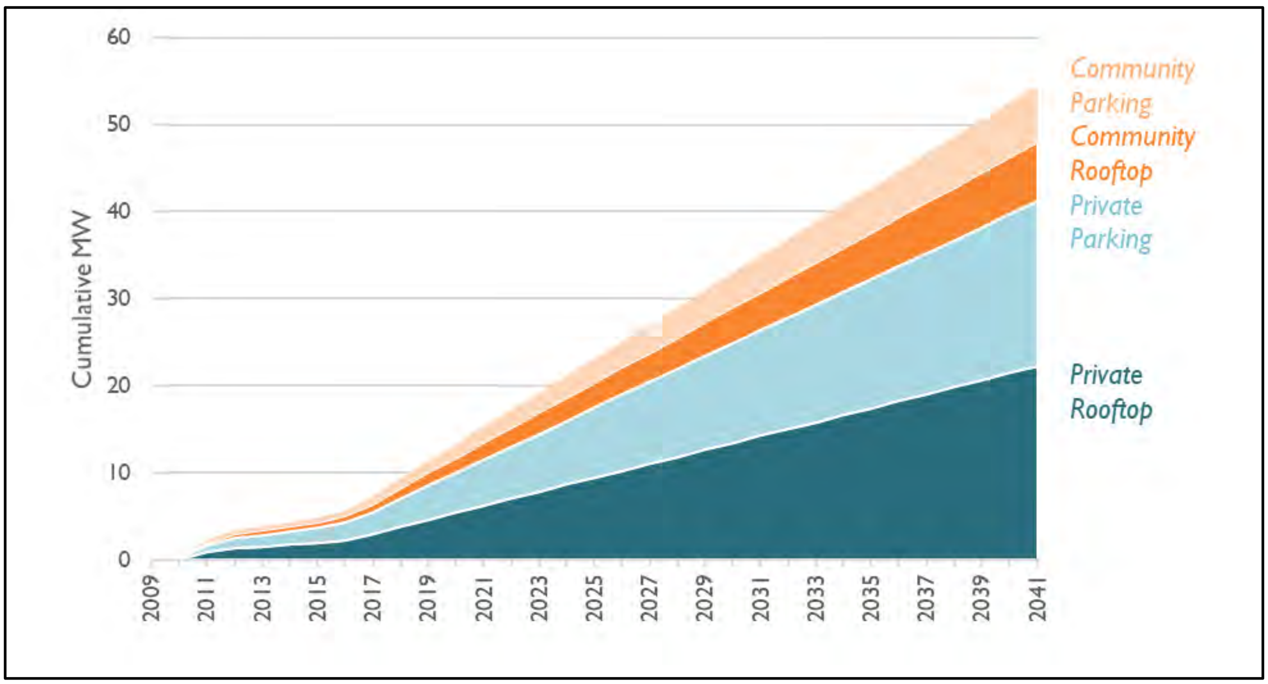


Figure 30. Ward 8 Low projection solar potential by installation type



Source: For Figure 23 - Figure 30, Synapse calculations with GIS data from Open Data DC (http://opendata.dc.gov/).

Middle Projection

Table 14. Middle projection of annual and cumulative solar PV in the District of Columbia

Year	Annual Installed Capacity (MW)	Cumulative Capacity (MW)	Solar Target (MW)
2009	1.3	0.0	1.8
2010	14.7	1.3	2.8
2011	8.2	16.0	36.8
2012	3.0	24.2	46.0
2013	3.6	27.2	46.0
2014	4.0	30.8	56.0
2015	5.5	34.8	66.0
2016	11.8	40.3	78.0
2017	15.1	52.0	67.8
2018	14.1	67.1	79.4
2019	14.1	81.1	127.2
2020	19.8	95.2	149.3
2021	25.6	115.0	171.4
2022	32.7	140.5	178.5
2023	41.1	173.2	195.6
2024	22.0	214.3	216.0
2025	20.3	236.3	236.3
2026	23.6	256.6	256.6
2027	26.8	280.2	280.2
2028	16.9	307.0	307.0
2029	16.9	323.9	323.9
2030	16.9	340.8	340.8
2031	16.9	357.7	357.7
2032	32.9	374.6	374.6
2033	32.8	407.5	407.5
2034	32.6	440.3	440.3
2035	32.4	472.9	472.9
2036	27.4	505.3	505.3
2037	22.2	532.8	537.6
2038	17.6	555.0	569.7
2039	7.9	572.5	601.7
2040	4.4	580.4	633.4
2041	0.0	584.8	665.1

Note: The rows highlighted in gray are historical solar installations, not projected installations, except for 2019, which is partially forecast, based on historical data through June 2019.

Table 15. Ward-based Middle projection of annual adoption of solar PV (MW) in the District of Columbia

Year	Total	Ward 1	Ward 2	Ward 3	Ward 4	Ward 5	Ward 6	Ward 7	Ward 8
2009	1.3	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0
2010	14.7	0.1	0.0	0.2	0.1	0.3	0.1	0.0	0.0
2011	8.2	0.2	0.2	0.9	0.3	0.2	0.5	0.0	0.0
2012	3.0	0.1	0.1	0.2	0.1	0.4	0.2	0.1	0.2
2013	3.6	0.2	0.1	0.1	0.4	0.4	0.3	0.2	0.3
2014	4.0	0.3	0.2	0.4	0.4	0.7	0.3	0.2	0.1
2015	5.5	0.3	0.3	0.7	0.6	1.1	0.5	0.7	0.3
2016	11.8	0.9	0.5	0.5	1.3	1.7	1.5	2.5	2.6
2017	15.1	0.5	1.0	0.8	1.9	2.3	2.5	3.2	2.9
2018	14.1	0.8	0.8	1.3	1.7	2.5	2.0	2.4	2.2
2019	14.1	0.9	1.7	1.8	1.6	2.6	2.0	1.6	2.0
2020	19.8	1.3	2.4	2.5	2.2	3.7	2.7	2.2	2.8
2021	25.6	1.6	3.1	3.2	2.9	4.8	3.6	2.8	3.6
2022	32.7	2.1	4.0	4.1	3.7	6.1	4.5	3.6	4.6
2023	41.1	2.6	5.0	5.1	4.6	7.7	5.7	4.6	5.8
2024	22.0	1.4	2.7	2.7	2.5	4.1	3.1	2.4	3.1
2025	20.3	1.3	2.5	2.5	2.3	3.8	2.8	2.3	2.8
2026	23.6	1.5	2.9	2.9	2.6	4.4	3.3	2.6	3.3
2027	26.8	1.7	3.3	3.3	3.0	5.0	3.7	3.0	3.7
2028	16.9	1.1	2.1	2.1	1.9	3.2	2.4	1.9	2.4
2029	16.9	1.1	2.1	2.1	1.9	3.2	2.3	1.9	2.4
2030	16.9	1.1	2.1	2.1	1.9	3.2	2.3	1.9	2.4
2031	16.9	1.1	2.1	2.1	1.9	3.2	2.3	1.9	2.4
2032	32.9	2.1	4.0	4.1	3.7	6.2	4.6	3.7	4.6
2033	32.8	2.1	4.0	4.1	3.7	6.1	4.6	3.6	4.6
2034	32.6	2.1	4.0	4.1	3.6	6.1	4.5	3.6	4.6
2035	32.4	2.1	4.0	4.1	3.6	6.1	4.5	3.6	4.5
2036	27.4	1.8	3.3	3.4	3.1	5.1	3.8	3.0	3.8
2037	22.2	1.4	2.7	2.8	2.5	4.2	3.1	2.5	3.1
2038	17.6	1.1	2.1	2.2	2.0	3.3	2.4	2.0	2.5
2039	7.9	0.5	1.0	1.0	0.9	1.5	1.1	0.9	1.1
2040	4.4	0.3	0.5	0.5	0.5	0.8	0.6	0.5	0.6
2041	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: The rows highlighted in gray are historical solar installations, not projected installations, except for 2019, which is partially forecast, based on historical data through June 2019.

Figure 31. Ward 1 Middle projection solar potential by installation type

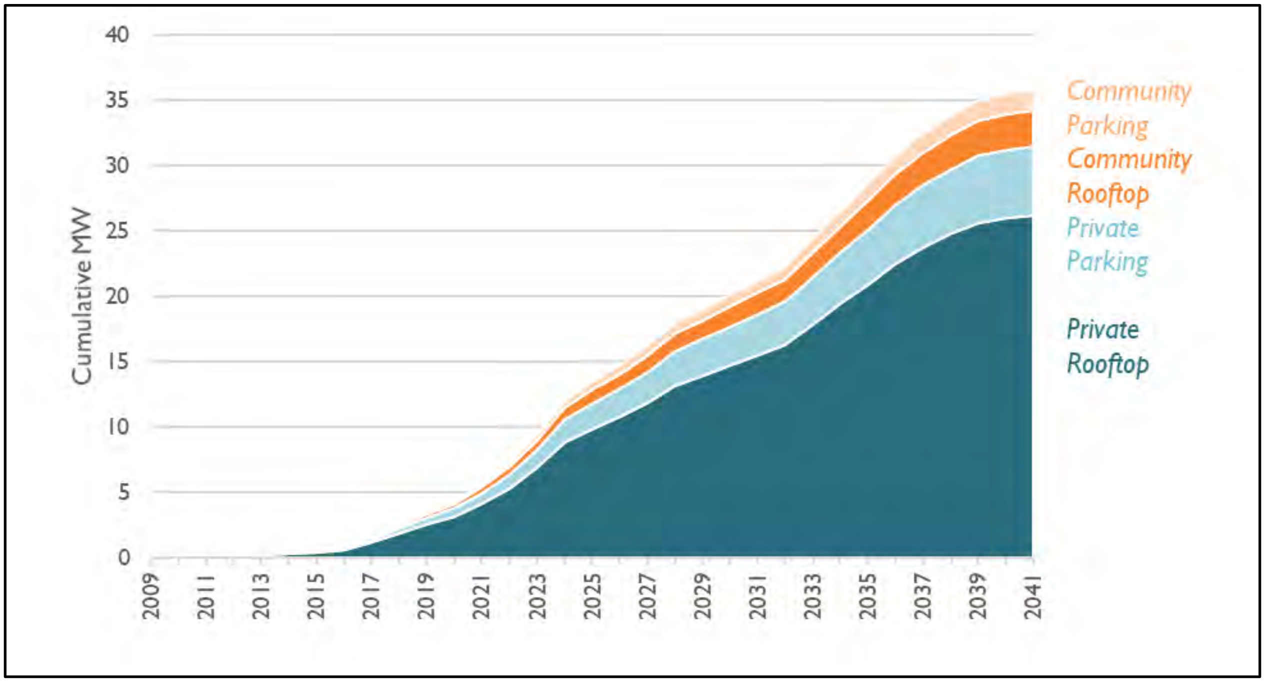


Figure 32. Ward 2 Middle projection solar potential by installation type

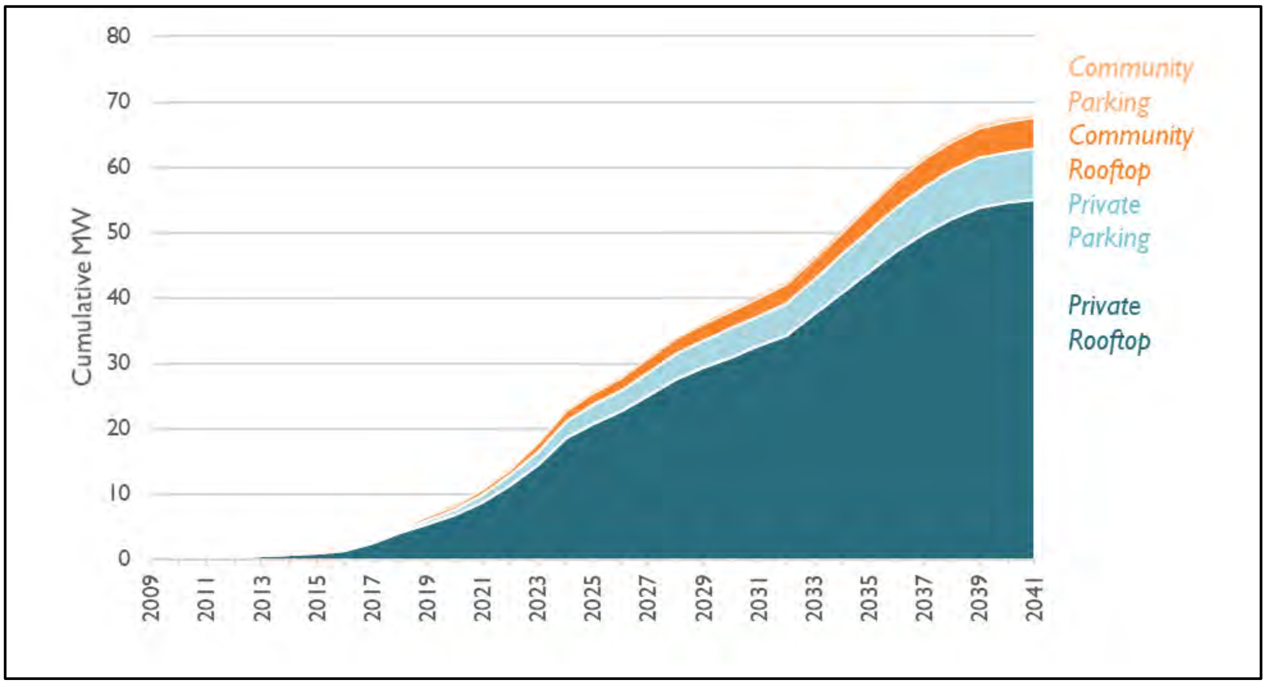


Figure 33. Ward 3 Middle projection solar potential by installation type

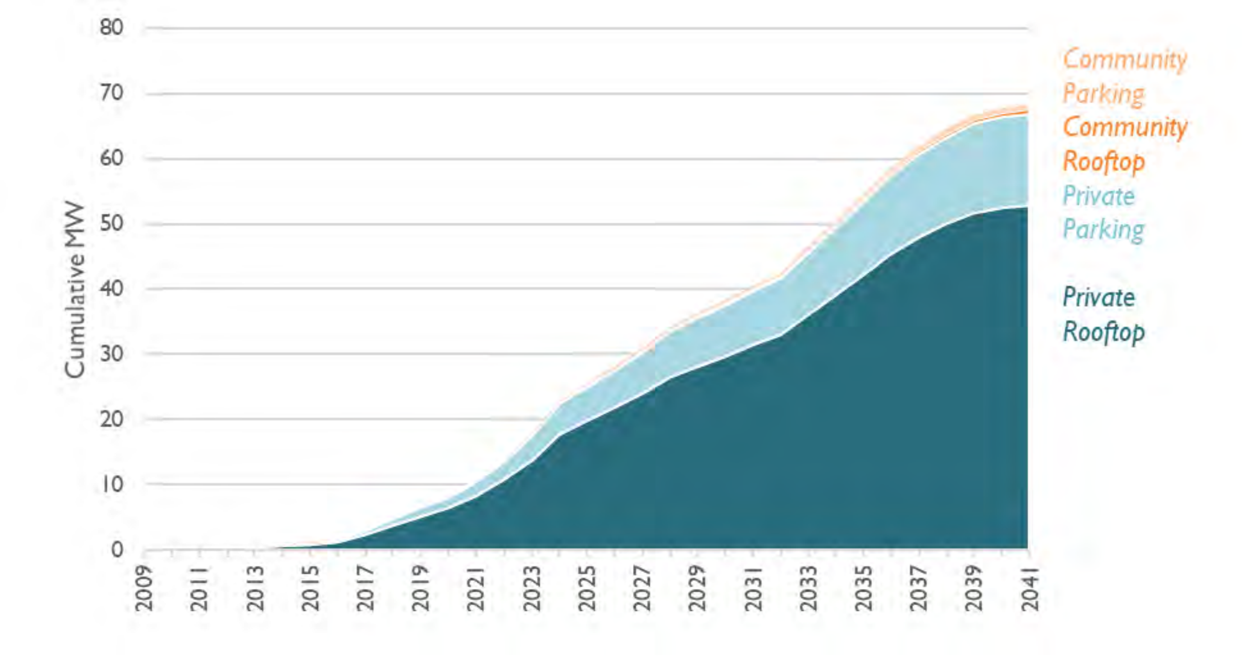


Figure 34. Ward 4 Middle projection solar potential by installation type

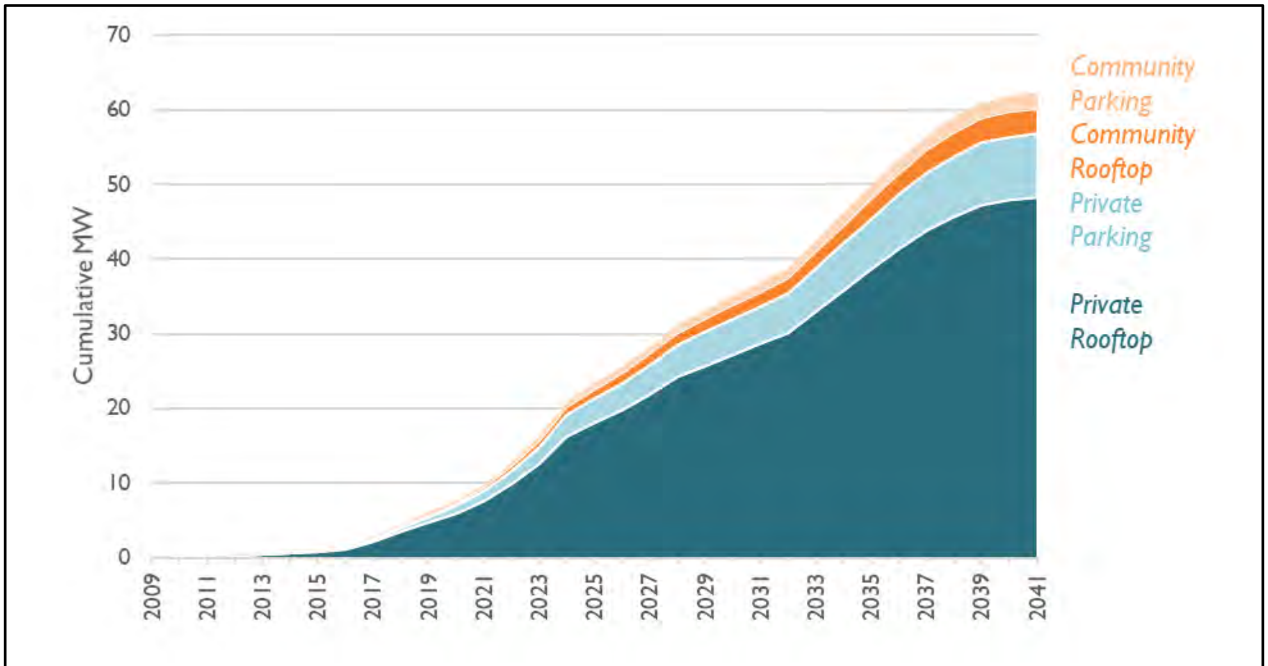


Figure 35. Ward 5 Middle projection solar potential by installation type

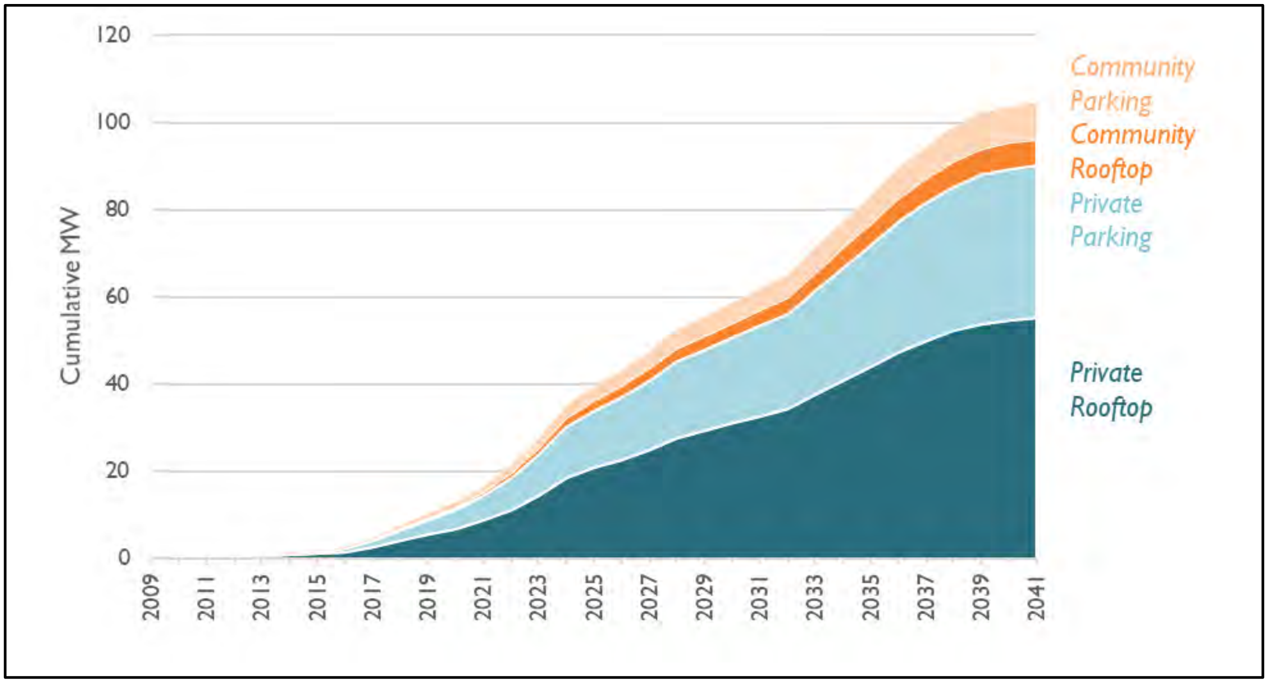


Figure 36. Ward 6 Middle projection solar potential by installation type

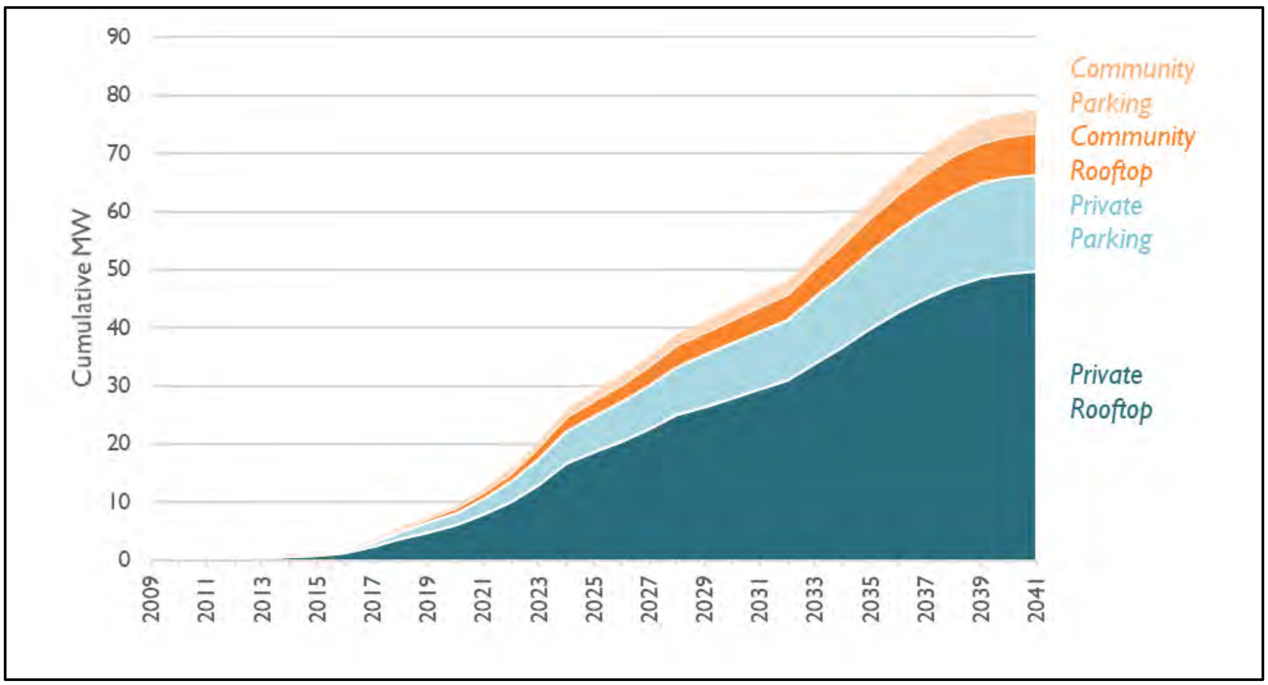


Figure 37. Ward 7 Middle projection solar potential by installation type

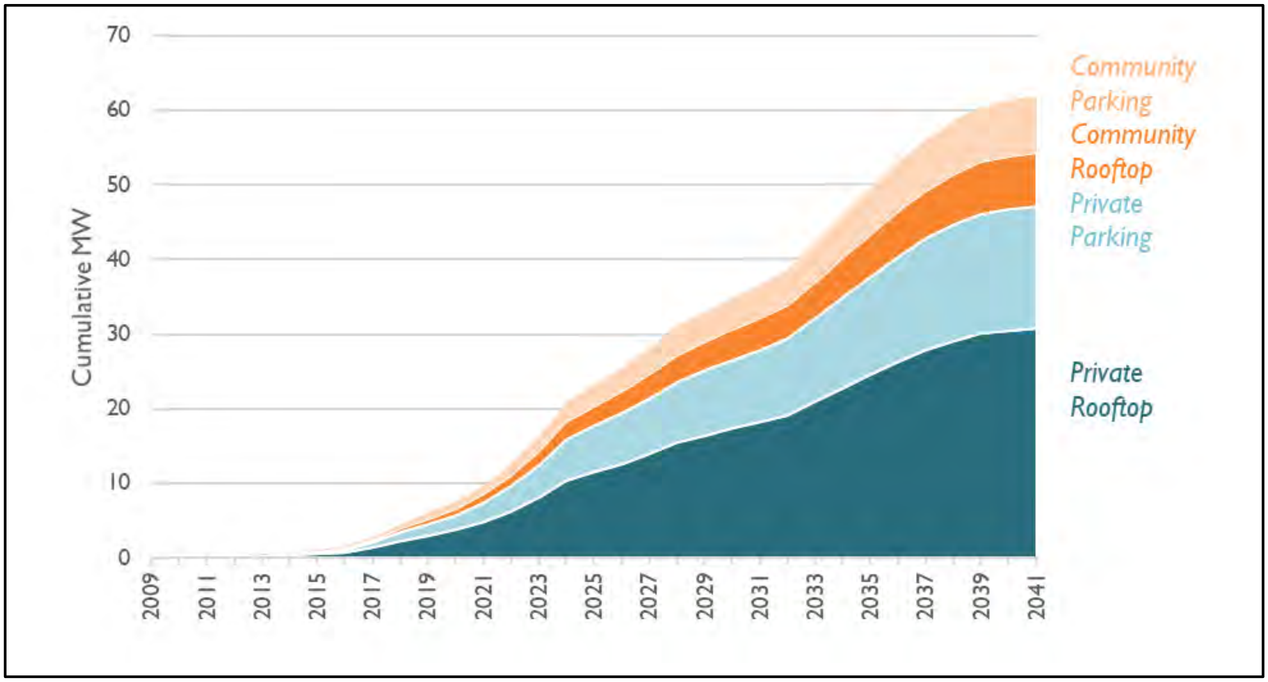
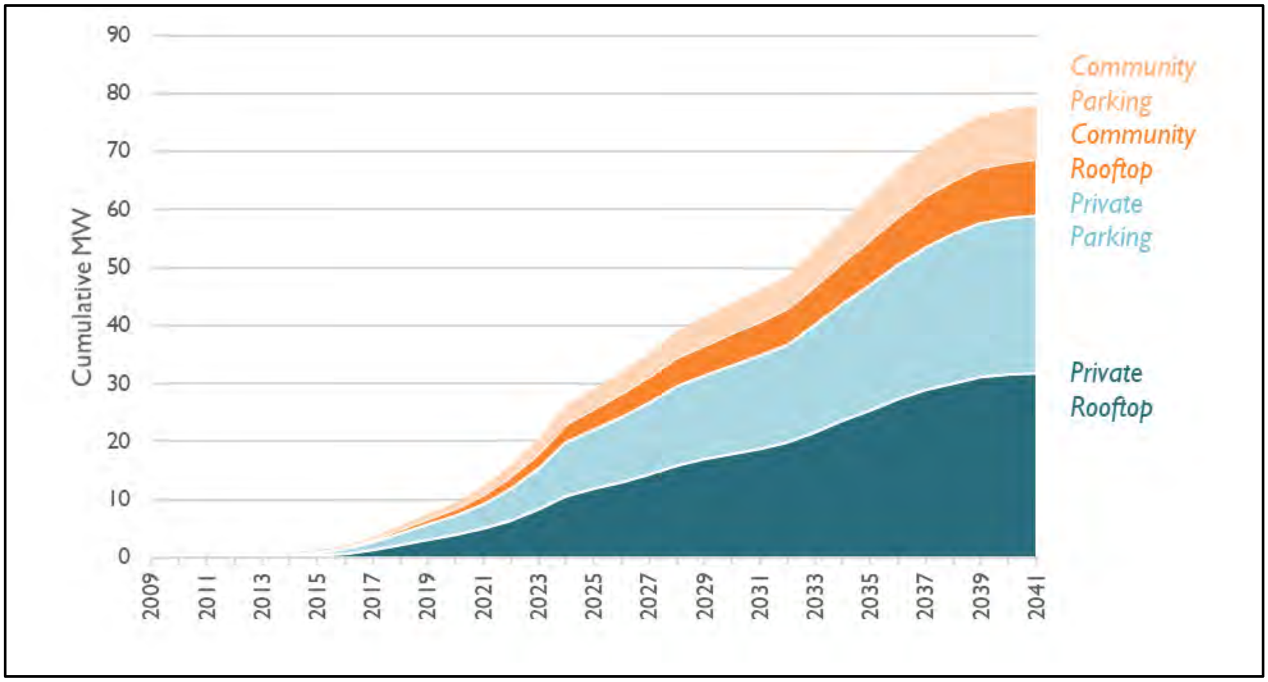


Figure 38. Ward 8 Middle projection solar potential by installation type



Source: For Figure 31 - Figure 38, Synapse calculations with GIS data from Open Data DC (http://opendata.dc.gov/).

High Projection

Table 16. High projection of annual and cumulative solar PV in the District of Columbia

Year	Annual Installed Capacity (MW)	Cumulative Capacity (MW)	Solar Target (MW)
2009	1.3	0.0	1.8
2010	14.7	1.3	2.8
2011	8.2	16.0	36.8
2012	3.0	24.2	46.0
2013	3.6	27.2	46.0
2014	4.0	30.8	56.0
2015	5.5	34.8	66.0
2016	11.8	40.3	78.0
2017	15.1	52.0	67.8
2018	14.1	67.1	79.4
2019	14.0	81.1	127.2
2020	19.8	95.1	149.3
2021	25.6	114.9	171.4
2022	32.7	140.5	178.5
2023	41.1	173.1	195.6
2024	50.7	214.2	216.0
2025	61.1	265.0	236.3
2026	71.5	326.1	256.6
2027	80.9	397.6	280.2
2028	88.1	478.5	307.0
2029	92.0	566.6	323.9
2030	92.1	658.6	340.8
2031	88.3	750.7	357.7
2032	81.1	838.9	374.6
2033	71.8	920.1	407.5
2034	61.4	991.9	440.3
2035	51.0	1053.3	472.9
2036	41.4	1104.3	505.3
2037	32.9	1145.6	537.6
2038	25.8	1178.5	569.7
2039	19.9	1204.3	601.7
2040	11.6	1224.2	633.4
2041	8.8	1235.8	665.1

Note: The rows highlighted in gray are historical solar installations, not projected installations, except for 2019, which is partially forecast, based on historical data through June 2019.

Table 17. Ward-based High projection of annual adoption of solar PV (MW) in the District of Columbia

Year	Total	Ward 1	Ward 2	Ward 3	Ward 4	Ward 5	Ward 6	Ward 7	Ward 8
2009	1.3	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0
2010	14.7	0.1	0.0	0.2	0.1	0.3	0.1	0.0	0.0
2011	8.2	0.2	0.2	0.9	0.3	0.2	0.5	0.0	0.0
2012	3.0	0.1	0.1	0.2	0.1	0.4	0.2	0.1	0.2
2013	3.6	0.2	0.1	0.1	0.4	0.4	0.3	0.2	0.3
2014	4.0	0.3	0.2	0.4	0.4	0.7	0.3	0.2	0.1
2015	5.5	0.3	0.3	0.7	0.6	1.1	0.5	0.7	0.3
2016	11.8	0.9	0.5	0.5	1.3	1.7	1.5	2.5	2.6
2017	15.1	0.5	1.0	0.8	1.9	2.3	2.5	3.2	2.9
2018	14.1	0.8	0.8	1.3	1.7	2.5	2.0	2.4	2.2
2019	14.0	0.9	1.7	1.7	1.6	2.6	1.9	1.6	2.0
2020	19.8	1.3	2.4	2.5	2.2	3.7	2.7	2.2	2.8
2021	25.6	1.6	3.1	3.2	2.9	4.8	3.6	2.8	3.6
2022	32.7	2.1	4.0	4.1	3.7	6.1	4.5	3.6	4.6
2023	41.1	2.6	5.0	5.1	4.6	7.7	5.7	4.6	5.8
2024	50.7	3.3	6.2	6.3	5.7	9.5	7.0	5.6	7.1
2025	61.1	3.9	7.5	7.6	6.8	11.4	8.5	6.8	8.5
2026	71.5	4.6	8.7	8.9	8.0	13.4	9.9	7.9	10.0
2027	80.9	5.2	9.9	10.1	9.0	15.1	11.2	9.0	11.3
2028	88.1	5.7	10.7	11.0	9.9	16.5	12.2	9.8	12.3
2029	92.0	5.9	11.2	11.5	10.3	17.2	12.8	10.2	12.9
2030	92.1	5.9	11.2	11.5	10.3	17.2	12.8	10.2	12.9
2031	88.3	5.7	10.8	11.0	9.9	16.5	12.3	9.8	12.3
2032	81.1	5.2	9.9	10.1	9.1	15.2	11.3	9.0	11.4
2033	71.8	4.6	8.8	9.0	8.0	13.4	10.0	8.0	10.0
2034	61.4	3.9	7.5	7.7	6.9	11.5	8.5	6.8	8.6
2035	51.0	3.3	6.2	6.4	5.7	9.6	7.1	5.7	7.1
2036	41.4	2.7	5.0	5.2	4.6	7.7	5.7	4.6	5.8
2037	32.9	2.1	4.0	4.1	3.7	6.2	4.6	3.7	4.6
2038	25.8	1.7	3.1	3.2	2.9	4.8	3.6	2.9	3.6
2039	19.9	1.3	2.4	2.5	2.2	3.7	2.8	2.2	2.8
2040	11.6	0.7	1.4	1.4	1.3	2.2	1.6	1.3	1.6
2041	8.8	0.6	1.1	1.1	1.0	1.6	1.2	1.0	1.2

Note: The rows highlighted in gray are historical solar installations, not projected installations.

Figure 39. Ward 1 High projection solar potential by installation type

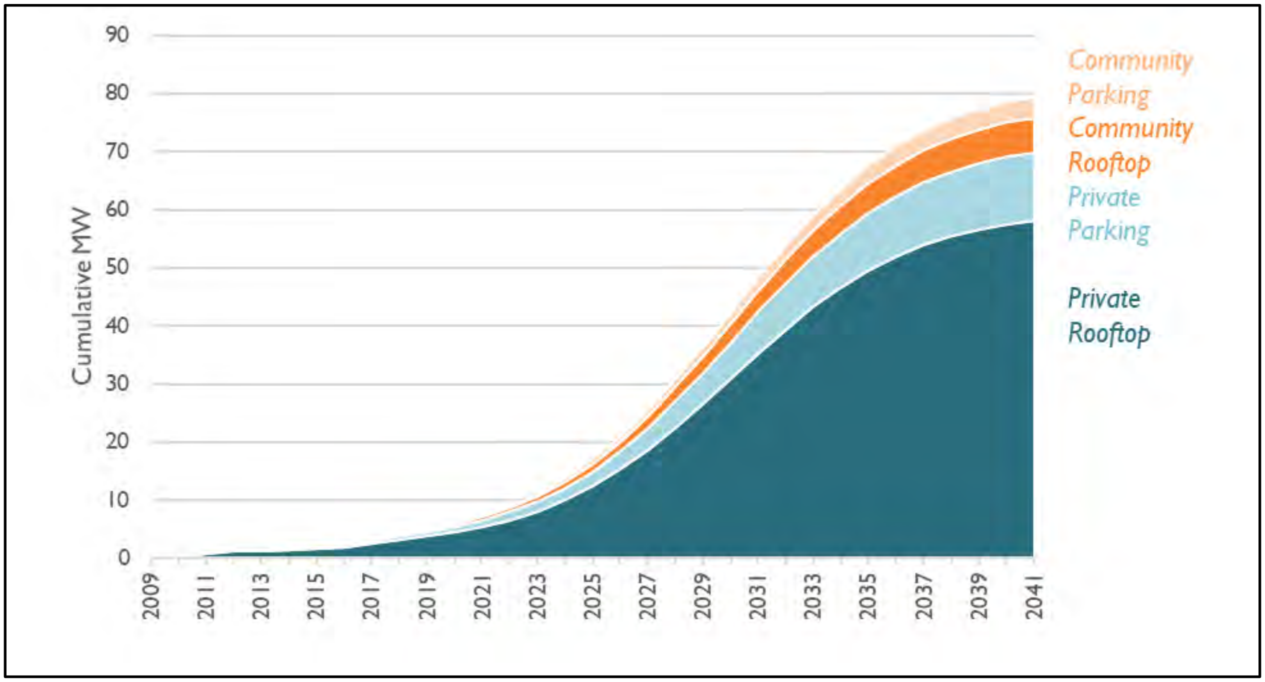


Figure 40. Ward 2 High projection solar potential by installation type

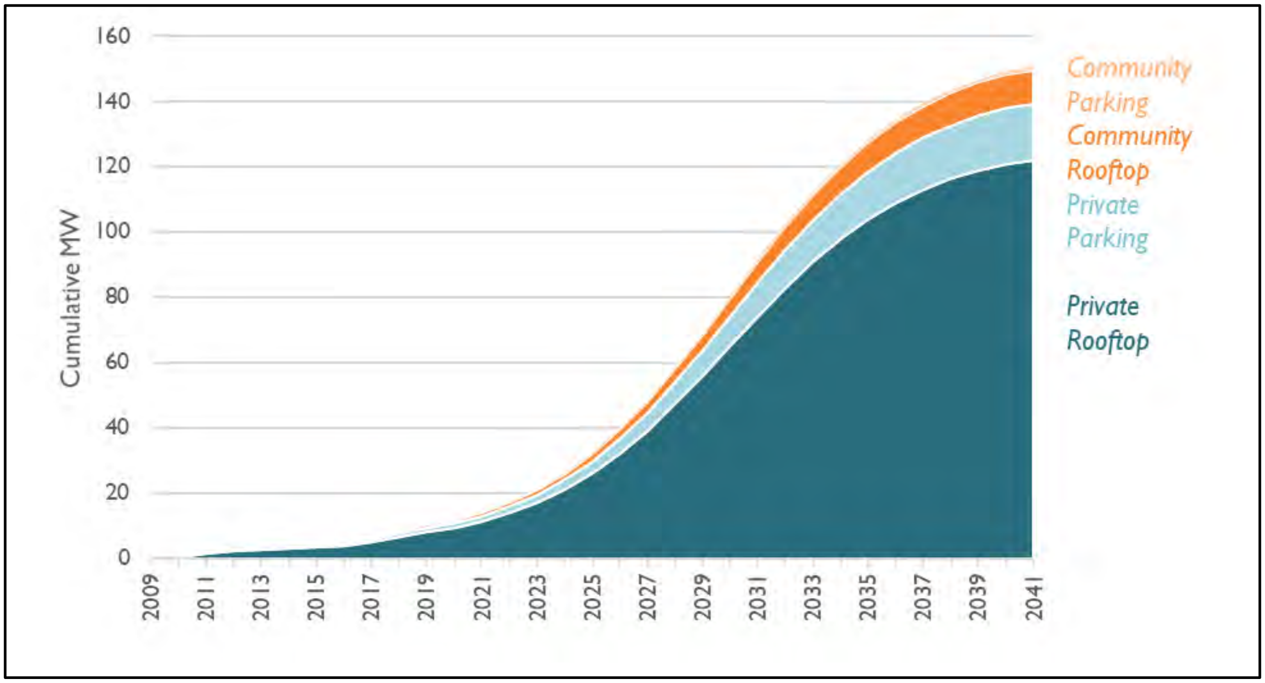


Figure 41. Ward 3 High projection solar potential by installation type.

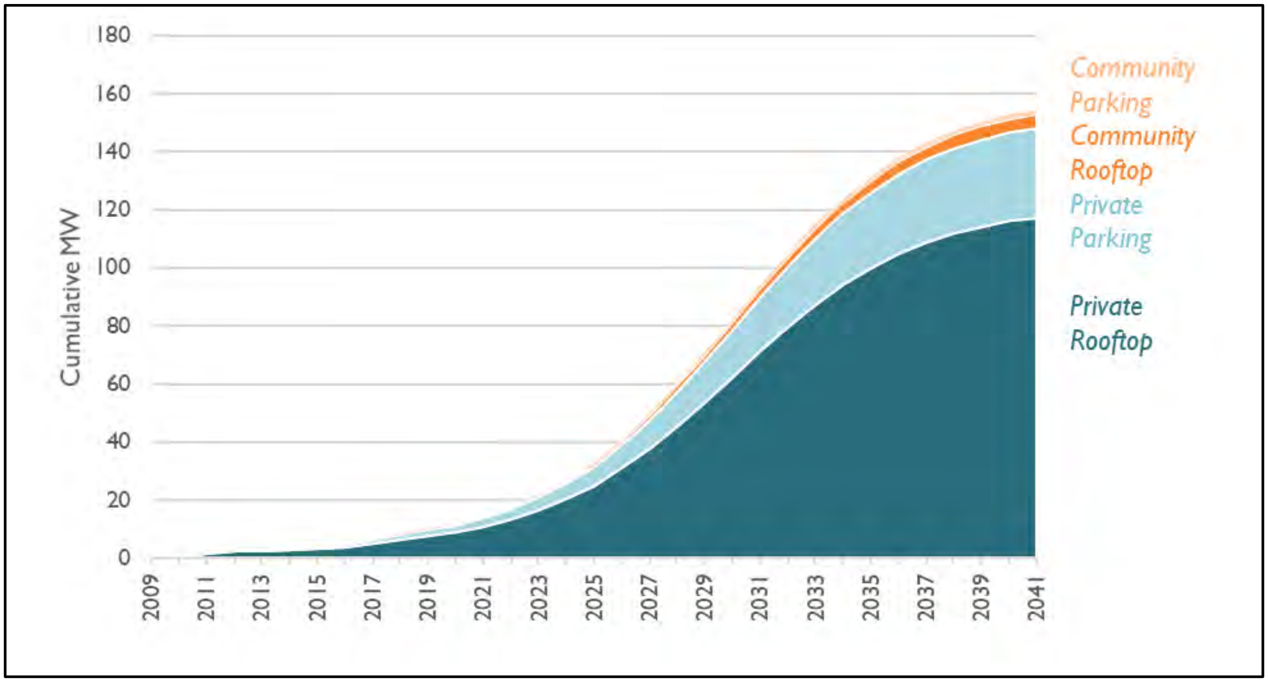


Figure 42. Ward 4 High projection solar potential by installation type.

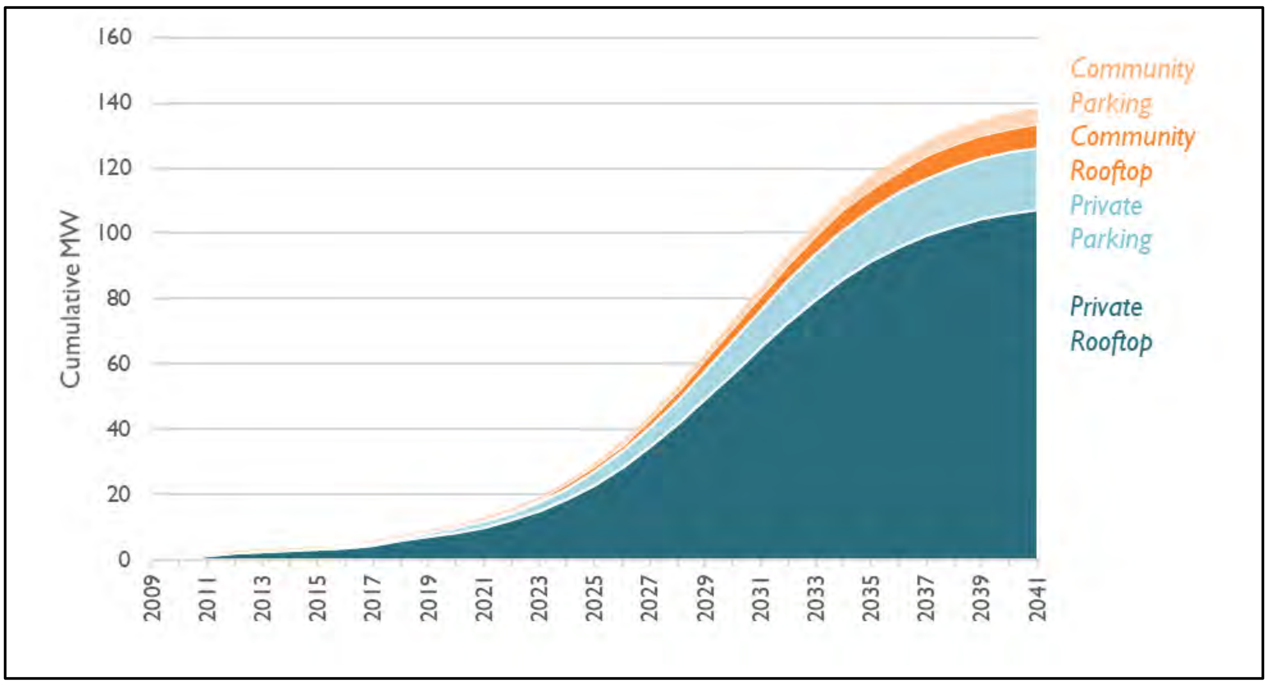


Figure 43. Ward 5 High projection solar potential by installation type.

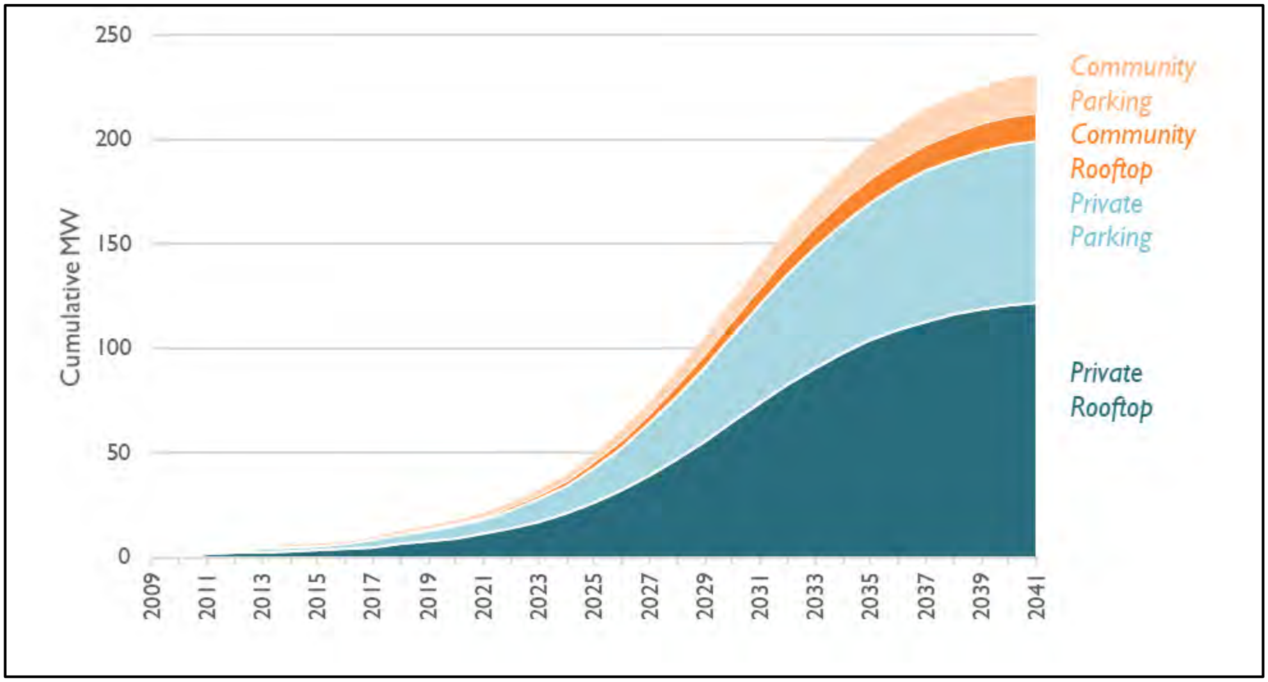


Figure 44. Ward 6 High projection solar potential by installation type.

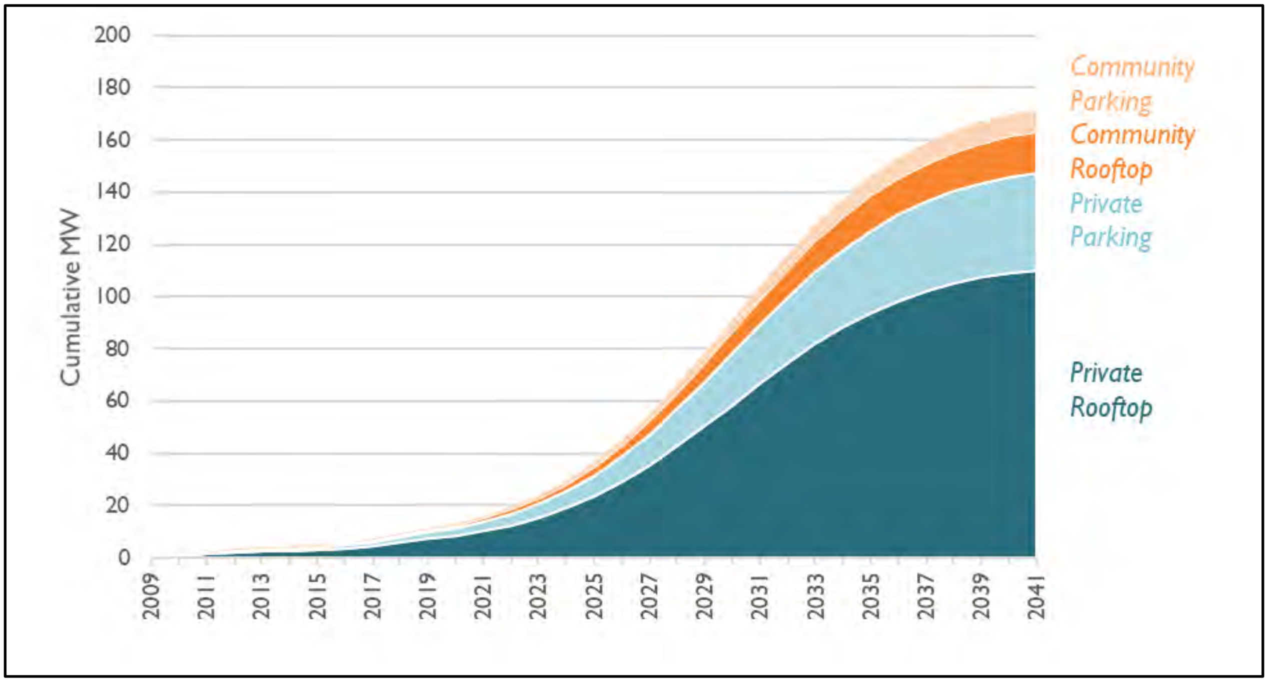


Figure 45. Ward 7 High projection solar potential by installation type.

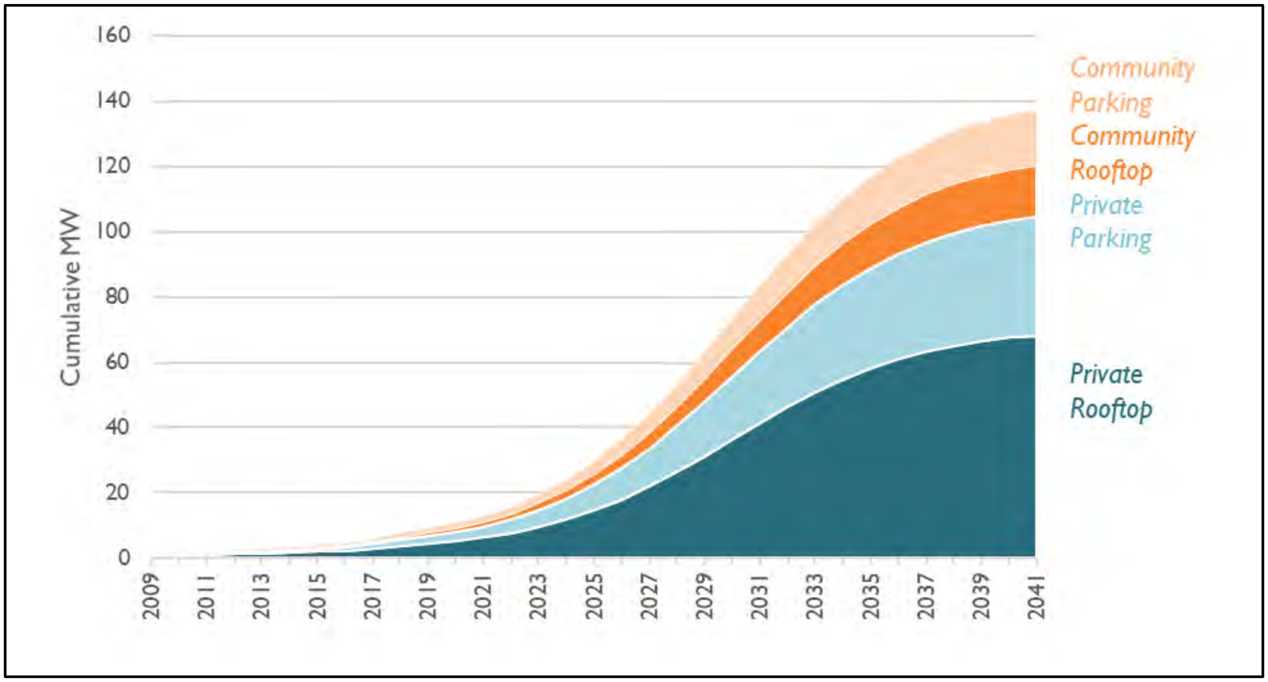
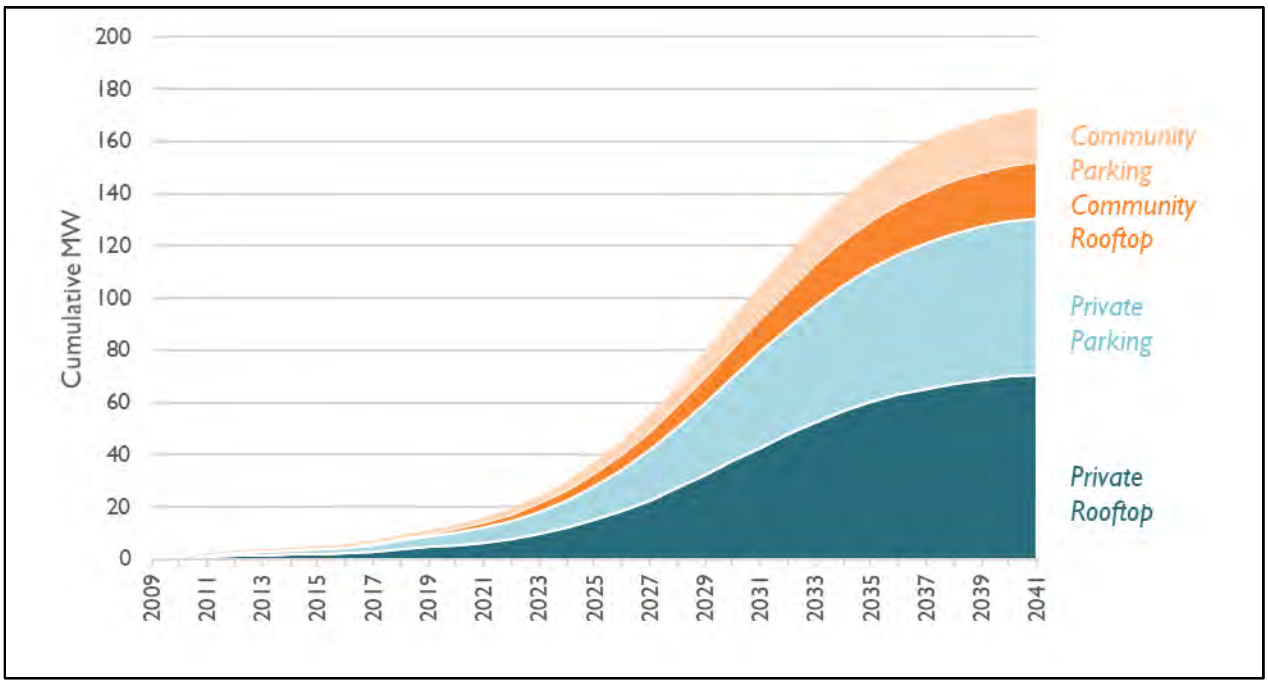


Figure 46. Ward 8 High projection solar potential by installation type.



Source: For Figure 39 - Figure 46, Synapse calculations with GIS data from Open Data DC (http://opendata.dc.gov/).