ELECTRIFY DC

Knowledge is POWER

How to Accelerate Renewable Energy Adoption through Transparent Data, Processes and Regulation

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by

ELECTRIFY DC

with

Synapse Energy Economics, Inc.

Redwood Energy

for the DC Department of Energy and Environment

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Executive Summary

The District of Columbia is at a pivotal moment in its clean energy transition. To meet the District's goals and the requirements of the Local Solar Expansion Act, local solar energy production will need to increase by at least 11% per year over the next 17 years.[1] Although so far the District has been able to meet yearly targets, the forecast based on current applications for solar projects shows a decrease in solar installations over the next seven years. Keeping up with the required growth will require transforming the District's electric grid to accommodate hundreds of megawatts of more local capacity. This report, prepared for the District Department of Energy and Environment by Electrify DC in collaboration with Redwood Energy and Synapse Energy Economics, responds to the DC Council's directive to assess the grid's hosting capacity[2] and identify solutions to accelerate the adoption of Distributed Energy Resources (DER)[3] while addressing systemic challenges. Throughout the development of this report, Pepco collaborated by providing representative data, participating in technical meetings, and responding to requests for clarification and factual information regarding hosting capacity.

To better understand hosting capacity and interconnection issues, Electrify DC gathered solar complaints from the Office of the People's Council (OPC), surveyed 315 DC residents, conducted three case studies, and conducted a dynamic hosting capacity analysis.

Key Findings

This study identifies two mutually reinforcing impediments to the District-mandated growth in renewable energy. On one hand, District residents, as the ultimate decision-makers in DER adoption, often lack access to the reliable information, transparency, and guidance necessary to confidently pursue installing solar and battery storage systems. On the other hand, Pepco does not appear to be well positioned to support widespread DER integration due to limitations in its grid infrastructure, operational systems, and administrative processes. Pepco has acknowledged the need for improvement, stating that it is seeking to adopt new technologies to better accommodate DERs, and states that currently there are "no restricted feeders in the District."

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[1] Synapse Energy Economics, *Future of Solar PV in the District of Columbia: Feasibility, Projections, and Rate Impacts of the District's Expanded RPS* (2020), 12.
[2] The capacity (generally expressed in kilowatts) of the existing grid or grid segment to accept the electrical power produced by a DER without requiring major upgrades to the distribution system or negatively impacting grid reliability and power quality.
[3] Small-scale units of local generation connected to the grid at the distribution level. Examples include solar arrays and home battery storage systems.

Interconnection Barriers Deter Solar Adoption

Multiple sources confirm that residents seeking to install solar encounter high interconnection fees, delays, and administrative hurdles.[4]

Between 2019 and 2024, OPC handled 102 consumer complaints about solar applications.[5] Most complaints involved unexpected and high interconnection fees, ranging from $2,000 to $104,000. Others involved delays in the interconnection process and administrative hurdles.[6] This data does not include cases where residents were unaware of OPC's assistance or chose to not seek help.

While based on a relatively small sample size of 315 District residents, the survey found that more than 15% of homeowners who installed solar reported experiencing interconnection issues. This figure may underrepresent the full scope of the problem, as some challenges are handled directly by solar installers without the homeowner's awareness. Three case studies by Electrify DC, news reports,[7] and several formal cases brought to the Public Service Commission of the District of Columbia (DC PSC),[8] confirm that unexpected costs, delays, and administrative hurdles have deterred solar adoption.[9]

Pepco's Hosting Capacity Map Does Not Meet the Needs of DC Residents or Developers

Pepco's current hosting capacity map,[10] instead of providing detailed, real-time data at the bus or customer level, only offers static, feeder-level data, based on minimum load and thermal rating, which estimates only thermal capacity at the feeder level and lacks the precision and updates needed for effective planning by residents and developers at the secondary voltage and sub feeder levels.[11] As a result, residents and installers have no way of determining whether solar installations are going to be possible without incurring additional cost.[12,13,14]

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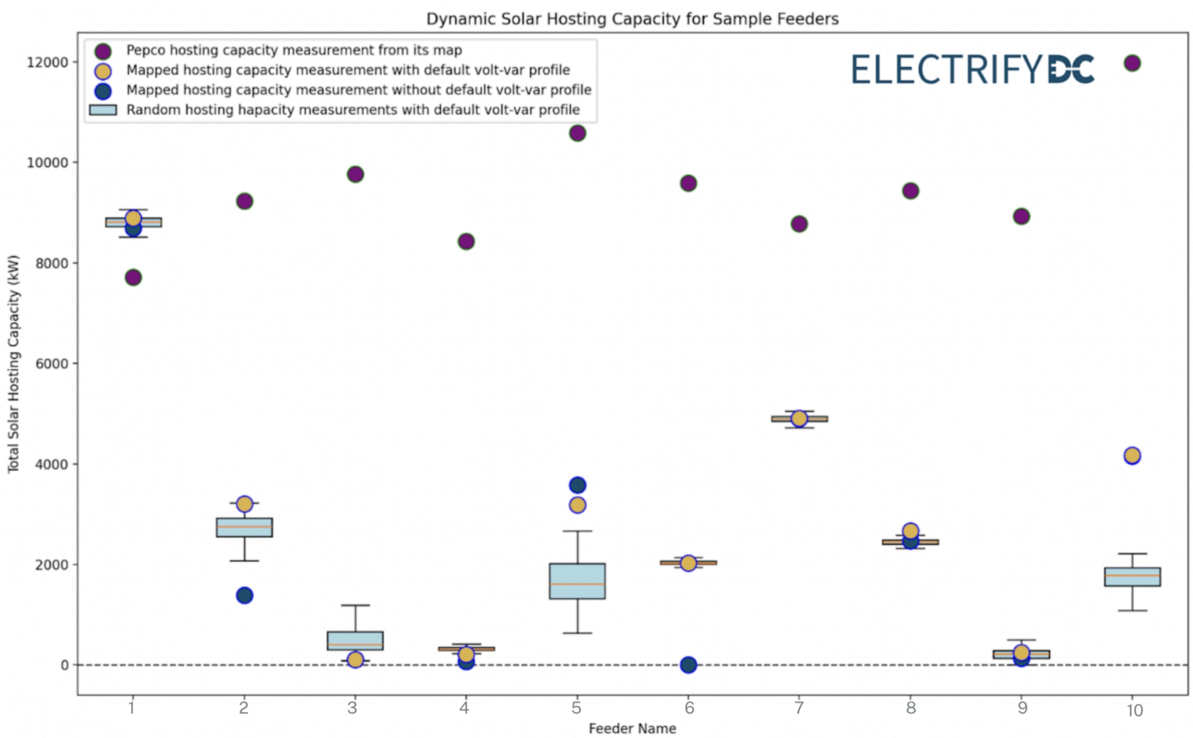
[4] Pepco states that other issues, such as the high proportion of renters in DC, also limit adoption.
[5] Pepco noted that there were approximately 16,000 interconnection applications during that time span, and 5,590 in 2024 alone as a reference point for comparing these complaint figures. However, it is important to remember that most unhappy customers do not end up filing complaints. Get Mindful, "Customer Service Stats That Matter: Part II" (2013), Accessed July 2025.
[6] Office of the People's Counsel, *OPC Solar Interconnection Report* (2024).
[7] Washington Post. "Fees from Pepco Put Solar Panels Out of Reach, D.C. Residents Say," (2022).
[8] See *Investigation into the Implementation of Interconnection Standards in the District of Columbia,* No. 1050 (D.C. Public Service Commission). See also *Investigation into Community Renewable Energy Facility Practices in the District of Columbia*, No. 1171 (D.C. Pub. Serv. Comm'n).
[9] *Reviewer Comment:* Pepco has argued that developer issues also contribute to deterred solar adoption.
[10] Pepco, "Hosting Capacity Map" (2025).
[11] Pepco, "Technical Conference Compendium" (2025), 27.
[12] Pepco believes that its proposed changes to the DC Small Generator Rules would remove many interconnection issues faced by residential customers and make hosting capacity maps less important.
[13] Public Notice on Formal Case No. 1050, RM40-202201-E, ET2023-1, (D.C. Pub. Serv. Comm'n Apr. 11, 2023).
[14] DC Department of Energy and Environment, "Comments in Response to the April 11, 2023 Public Notice on Formal Case No. 1050, RM40-202201-E, ET2023-1" (2023).

Pepco has stated its current hosting capacity map reflects feeder-level data for both residential and commercial installations based on minimum daylight load and thermal rating calculations. Pepco concedes that these calculations are not adequate to identify individual transformers that have reached their capacity for DER installations, and that as a result, residents and developers may be unaware of significant work and associated costs that may be required to accommodate a solar installation. Pepco has stated that as a result, residents and installers should use the Hosting Capacity Map as an initial indication that installation of a DER may be accomplished without a needed system upgrade.

Pepco's hosting capacity map measurement v. Electrify DC's dynamic hosting capacity measurement for each of the ten feeders analyzed



Based on Pepco's measurement, all ten feeders analyzed could fit an average residential PV installation for every single customer on that feeder. Electrify DC's dynamic hosting capacity measurement, however, shows a much lower hosting capacity, with three of the ten feeders essentially at capacity.

Dynamic hosting capacity analysis

Electrify DC has developed a highly configurable tool that automates dynamic hosting capacity analysis by leveraging advanced modeling libraries to exercise granular control over individual feeder components. Using this tool, Electrify DC conducted more than a thousand time-series power flow simulations with parameters similar to those used during the solar interconnection process, over a 24-hour period representing the worst-case scenario, defined *by peak solar irradiance[15] and minimum bus-level load profiles specified by Pepco[16]. These simulations were performed on ten representative feeders provided by Pepco, evaluating hosting capacity both with and without the inverter limits established by Pepco in compliance with IEEE 1547-2018.[17]*

Pepco could adopt this tool or develop a similar automated dynamic hosting capacity solution to efficiently produce hosting capacity maps with actionable customer-level data[18] that address the current gaps which leave residents and developers unaware of potential upgrade requirements.

Pepco Does Not Have Access to the Necessary High-Resolution Data

Pepco was unable to provide high resolution time series data stating that it is burdensome to collect and maintain such high-resolution data. Although Pepco is investing in some elements of smart grid planning like high-resolution telemetry demonstrating its awareness that further visibility into the grid is needed, its investment is limited to only network feeders.[19] At a more fundamental level, Pepco has also stated they do not maintain asset metadata like the age and model for individual grid components like transformers, hindering the ability to accurately model and assess the reliability of key grid components.[20] The absence of both high-resolution operational data and key asset metadata underscores the critical need for investment in real-time monitoring to be able to avoid blind spots during grid operation. Smart grid planning and investment is urgently needed to operate the grid safely, conduct accurate analyses, and increase DER adoption.

Pepco Does Not Account for Battery Storage in Their Hosting Capacity

Electrify DC found that Pepco does not take into account behind-the-meter batteries when analyzing hosting capacity. Pepco has stated they only account for behind-the-meter batteries when analyzing hosting capacity if the batteries are capable of increasing the minimum daytime load on a feeder.[21] However, batteries are used to increase hosting capacity by off-loading peak load and storing excess solar generation. Measuring and encouraging energy storage presents an opportunity to increase hosting capacity and enhance grid flexibility.

[15] *See* Figure 7 in Appendix B for ideal peak solar profile over 24 hours
[16] *See* Figures 5 and 6 in Appendix B for minimum bus-level load profiles provided by Pepco
[17] *See* Figure 8 in Appendix B for the PHI required inverter profile
[18] Pepco has stated this is a potential future state use. New Haven, Connecticut has a hosting capacity map that provides actional customer-level data without compromising confidential customer information. *See* UConn/CTDEEP, Esri, HERE, Garmin, NGA, USGS, NPS. *UI Interconnection Feasibility Map* (last modified October 24, 2024.)
[19] Electrify DC requested time series data in seconds or minutes and was informed by Pepco that it does not collect data at that rate. Pepco provided hourly load data for the sample feeders.
[20] Pepco email to Electrify DC and DOEE teams, March 13, 2025.
[21] Pepco has stated that they have no way to ensure that a battery is not adding to load and drawing power during peak times.

District Residents Need and Want to Know More

Electrify DC's survey found that residents' demand for solar is strong with over 86% of responders who did not yet have solar expressing interest in it. More than one in three respondents want to know how they can become net producers of energy and sell it back to the grid which indicates consumers are moving towards becoming "prosumers."

Recommendations

To address these challenges and enable the District to meet its clean energy goals, this report proposes the following actions:

1. Develop Comprehensive Grid Codes
   While Pepco states that they currently follow IEEE-1547-2018, DCMR Chapter 40 and internal utility standards to ensure the reliability and safety of the grid for interconnection, Electrify DC's analysis of Pepco's data revealed a more fundamental need for change. Hosting capacity, though valuable, is ultimately a limited internal metric that alone cannot fully support the scaling of DERs. To truly support DER integration, the DC PSC in collaboration with Pepco should implement robust, forward-looking grid codes[22] that prioritize system inputs and outputs rather than specific technologies.
2. Require Smart Grid Planning and Investment
   Pepco must upgrade its grid monitoring systems to include high-resolution telemetry and advanced distribution management capabilities. These investments will enhance situational awareness and support greater DER integration.[23]
3. Incentivize Battery Adoption
   To maximize hosting capacity and improve grid flexibility, incentives for behind-the-meter (BTM) batteries should be expanded and the grid interconnection process streamlined. Educational campaigns are needed to raise awareness about the benefits of battery storage among District residents.
4. Modernize Hosting Capacity Maps
   Pepco should develop dynamic, customer-level hosting capacity maps that are automatically updated based on approved solar connections and known network changes and make the map available to residents and developers. To assist Pepco in this, Electrify DC is making the code it developed to conduct the dynamic hosting capacity analysis available as open source.
5. Streamline Interconnection Processes
   The DC PSC should establish clear guidelines for interconnection timelines, cost transparency, and accountability measures for Pepco. Automation and advanced

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[22] Grid codes are technical specifications or set of rules that govern the connection, operation, and maintenance of facilities connected to an electricity grid. These facilities can include electricity generation plants, consumers, or other networks. The primary purpose of a grid code is to ensure the safe, reliable, and efficient functioning of the electric system.
[23] Pepco has stated they have high resolution telemetry for larger systems (above 250kW). Based on this, it seems Pepco could, at a minimum, estimate high resolution telemetry for smaller systems through localized weather forecasting in areas of high solar penetration.

technologies like automated hosting capacity analyses should be leveraged to simplify application processing.

6. <u>Enhance Public Education</u>
   Collaborative efforts by DC PSC, DOEE, and Pepco should focus on educating residents about their role in the clean energy transition through initiatives including demonstration sites, public service announcements, utility bill inserts, and community events.

Conclusion

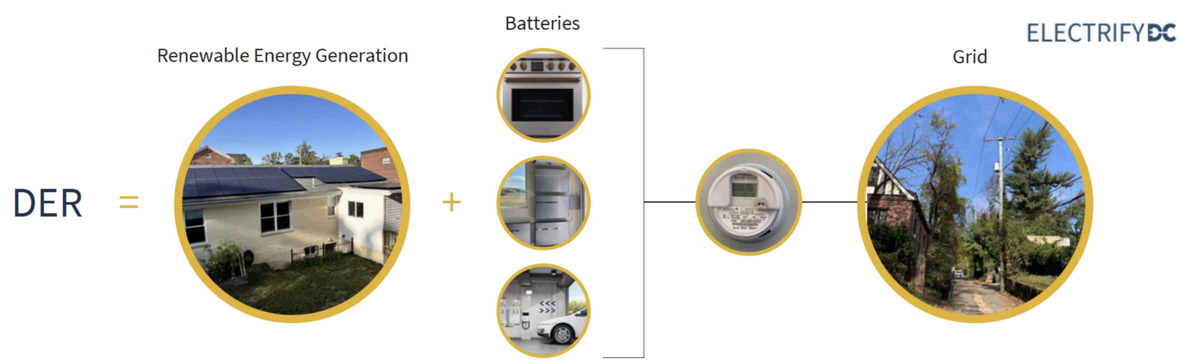
The District has a once-in-a-generation opportunity to reimagine its electric grid as a dynamic platform for clean energy innovation. By adopting the recommendations outlined in this report, the District can position itself as a national leader in renewable energy integration.

This report provides a roadmap for achieving these goals while considering technical, regulatory, and social challenges. With bold action from policymakers, utilities, and community stakeholders, the District can accelerate its path toward a sustainable energy future.

Introduction

The traditional model of utility operations, where power flowed one-way from generators to consumers, has been upended in the District by the installation of over 200 MW[24] of distributed solar power over the past decade, essentially a medium-sized power plant built across the District. Now that electricity consumers are "prosumers" (producer-consumers), they depend on the local distribution grid to provide different services than they previously required as passive consumers. The emergence of distributed energy resources (DER), such as solar photovoltaic (PV) and batteries as major contributors to the electric system that are located within Pepco's distribution system, presents new challenges to the Public Service Commission of the District of Columbia (DC PSC) as Pepco's regulator.

Figure 1: DER Overview



Distributed Energy Resources (DER): Small-scale units of local generation connected to the grid at the distribution level. Examples include solar arrays and home battery storage systems.

One challenge is that District residents have a growing expectation that they will be able to participate in the supply of energy to themselves and their neighbors. The District's legislated goal to supply 15 percent of electric energy from solar PV located in the District reinforces this belief. It is further bolstered by Federal Energy Regulatory Commission (FERC) Order 2222, which PJM Interconnection (PJM) plans to implement starting in February 2026.[25]

FERC Order 2222: removes the barriers preventing DERs from competing on a level playing field in the wholesale electricity markets.

[24] Renewable Energy Portfolio Standards: A Report for Compliance Year 2023 (D.C. Pub. Serv. Comm'n May 1, 2023), i.
[25] PJM Interconnection, L.L.C., PJM Proposed Compliance to FERC Order No. 2222 (Feb. 1, 2022).

The PSC plays an important role in enabling this participation and ensuring that Pepco provides adequate services to residents who wish to supply energy. This is especially the case, as Pepco currently lacks explicit incentives to accelerate the adoption of solar within the District. Although the District energy suppliers must meet the targets set by the Renewable Energy Portfolio Standards, as the administrator of the District's Standard Offer Service (SOS), Pepco is not allowed to own or otherwise benefit from solar infrastructure within the District. While Pepco can recover operations costs associated with processing solar applications, it only earns a return for its investors by investing in distribution infrastructure upgrades.[26]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DIVE BRIEF

Hawaiian Electric offers new incentives to customers with rooftop solar and battery storage

The company says it is streamlining programs for rooftop solar users to help the state meet its clean energy goals, but some customers could see smaller financial benefits.

Published April 3, 2024

By Patrick Cooley

Local solar PV can both cause and help to avoid or defer grid upgrades. In 2022, the Hawaii Public Utility Commission required the Investor Owned Utility (IOU) Hawaiian Electric to reopen net energy metering and pay for home solar plus battery systems in order to meet a legislature-determined 2025 date to close Hawaii's last coal power plant. The program was a huge success, reducing evening peak demand on Oahu by 17MW[27] in two years and enabling an on-time coal plant shut down.

The District has a once-in-a-generation opportunity to change how it currently expands the grid's capacity to accommodate DERs. Instead of considering each new DER in a standalone fashion and addressing any issues that arise from its integration on an ad hoc basis, there is an opportunity to develop a pro-active DER integration strategy that forecasts potential issues and provides system-level solutions. Transitioning to a smarter 2.0 grid is necessary to allow for plentiful DER adoption to meet the District's net zero goals.

Furthermore, this transition also ensures the safety and reliability of the grid, while reducing future infrastructure costs deriving from network imbalances. Electricity demand in the District has traditionally been treated as a fixed reality that utilities can meet with ever increasing supply from PJM. However, the summer heat waves of 2025 reveal the limitations of that idea, as even PJM struggled to meet record peak demand and contain soaring electricity prices.[28,29] These challenges are likely to only intensify in the years ahead. By building a more dynamic grid—one

[26] Pepco has indicated a sensitivity to any insinuations that they might be resistant to interconnection.
[27] Canary Media, "Hawaii used rooftop solar to shore up the grid," (Jan. 18, 2024), accessed 2025.
[28] Reuters, "Electricity prices soar as US regional grids wobble from extreme heat," (June 25, 2025), accessed 2025.
[29] Energy Information Administration (EIA), "Electricity demand in the Eastern United States surged from heat wave," (June 27, 2025), accessed 2025.

that can adjust to changing circumstances and market realities—the District can enable a less-costly and more resilient system that works better for District residents.

A Statutory Mandate to Study Hosting Capacity

On April 21, 2022, the DC Council directed Department of Energy and Environment (DOEE) "to conduct a comprehensive study in FY 2023 of the District's electric grid's existing capacity on radial feeders to support distributed energy resources such as solar photovoltaic panels, such as those placed on the roofs of single- and multi-family homes in the District, and battery storage systems. To further this study, the Committee anticipates DOEE will be able to work within its existing authority to obtain the data necessary to complete this study from Pepco."[30,31]

Responding to this direction from the DC Council, DOEE awarded a grant to Electrify DC, which has worked with its partners Redwood Energy and Synapse Energy Economics to study the District's existing capacity within the context of the data on radial feeders, which was willingly provided by Pepco.

Radial Feeders: Feeders are the overhead or underground power lines that carry electricity from substations to end users. Radial feeders are a type of feeder configuration where each customer is traditionally connected to a single source of power coming from the utility.

Background Facts and Figures

The District of Columbia has passed one of the most aggressive Renewable Energy Standards in the country, mandating that by 2032 electricity suppliers must achieve 100% renewable power by aggregating renewable electricity and renewable energy credits (REC).[32] The Local Solar Expansion Act mandates that by 2041 at least 15% of the electricity consumed by the District must come from solar energy generated within the District.[33]

> "Our [solar] system was installed in January 2024 and seeing both our reduced PEPCO bill, estimated C02 reduction, and SRECs I couldn't be happier. We recycle, compost, use public transit and drive a Prius, but our solar panel installation has given me the greatest sense of contribution to a sustainable planet."

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[30] District of Columbia Office of Energy Act of 1980, D.C. Law 3-132. Authorized DOEE to require energy distributors such as Pepco to "file such reports, data, and forecasts as [DOEE] may require" for purposes of obtaining information relevant to the District's energy resources, supply and demand, and research and development.
[31] Committee Budget Report, *Council of the District of Columbia, Committee on Transportation and the Environment for Fiscal Year 2023* (2022), 87.
[32] *Renewable Energy Portfolio Standards Report* (D.C. Pub. Serv. Comm'n. May 2024), iii. Currently, there are 46 suppliers of electricity to the District.
[33] Local Solar Expansion Amendment Act of 2022, D.C. Law 24-314. D.C. Local Solar Expansion Amendment Act of 2022, D.C. Law 24-314 (2022).

The District consumes 9,879,714 MWh/year of electricity.[34] Despite uncertainties and differences in forecasts as to overall peak demand,[35] consumption is expected to grow at an average annual rate of 1.4% to 1.7% per year according to a study commissioned by Pepco.[36] In 2024, the total Renewables Portfolio Standard-certified solar capacity of 308.1 MW exceeded the estimated solar capacity of 247.7 MW required to meet the 3.65% solar requirement for 2024.[37] This includes 258.5 MW produced locally and an additional 49.6 MW produced by systems in PJM and adjacent states, plus Maryland systems on feeders serving the District.[38]

District residents' homes are responsible for 25% of the District's energy consumption.[39] Producing renewable energy on-site is an energy-efficient way to address that energy need.

In 2024, less than 14% of the District's 117,000 solar viable roofs had solar installations, pointing to great potential for solar expansion.[40,41] Additionally, rooftop solar is only one of the many solar and other renewable energy production tools available (see images below of non-roof-top arrays installed in the District). Technological innovation is increasing the DER options at the disposal of DC residents. Most DERs will require some injection into the grid. Therefore, the grid needs to have ample capacity to accept the injected power.

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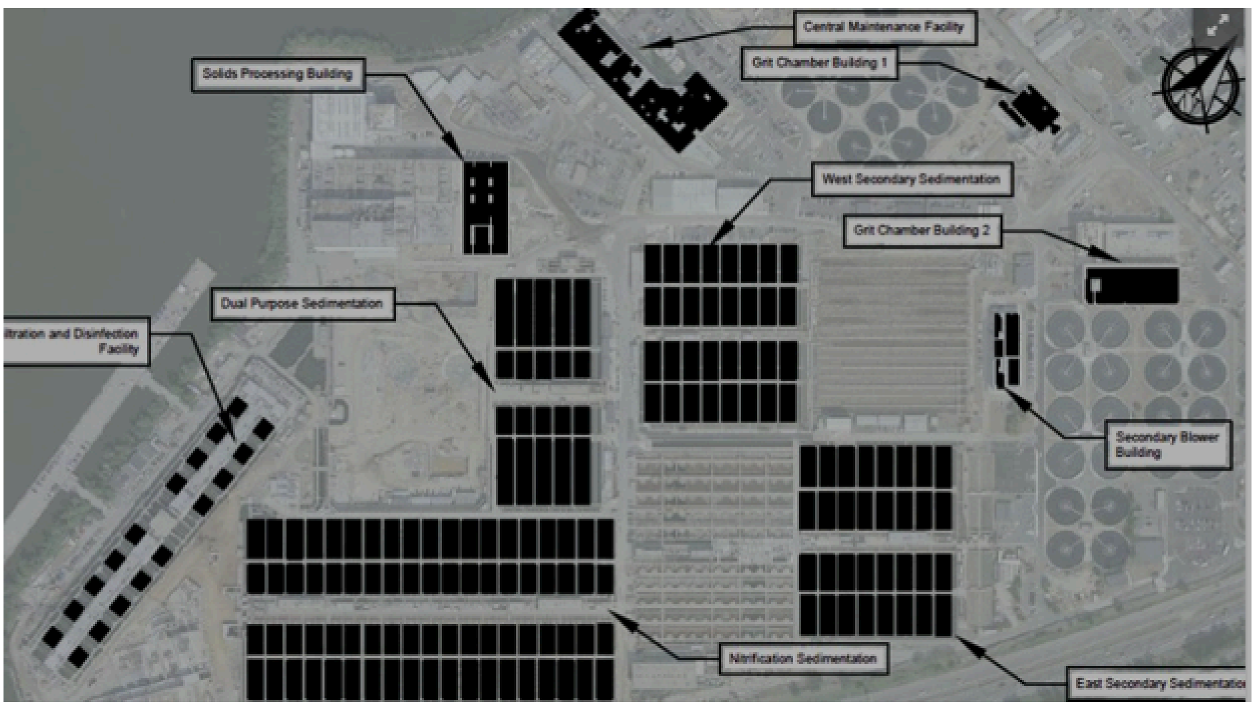
[34] Energy Information Administration (EIA), "Electricity State Profiles" (2023). 9,879,714 MWh Retail Sales (to ultimate customers) and 149,439 MWh Direct Use.
[35] District of Columbia Department of Energy and Environment, *Strategic Electrification Roadmap* (2023). In both the gradual and accelerated scenarios, which target 13% and 32% of the existing building stock respectively, there was no significant increase in overall peak demand.
[36] Brattle, *An Assessment of Electrification Impacts on the Pepco DC System* (2021).
[37] CleanEnergy DC Omnibus Amendment Act of 2018, D.C. Law 22-257
[38] "Renewable Energy Portfolio Standards Report" (D.C. Pub. Serv. Comm'n 2025), i.
[39] EIA, "District of Columbia Energy Consumption Estimates" (2022).
[40] PJM, "GATS" (data updated September 2024). 15,921 solar installations according to PJM Renewable Generators Registered.
[41] Google Project Sunroof (2018).

Figure 2: Vertical solar array on Nixon Peabody, LLP's building[42]

Figure 3: DC Water Blue Plains solar array[43]

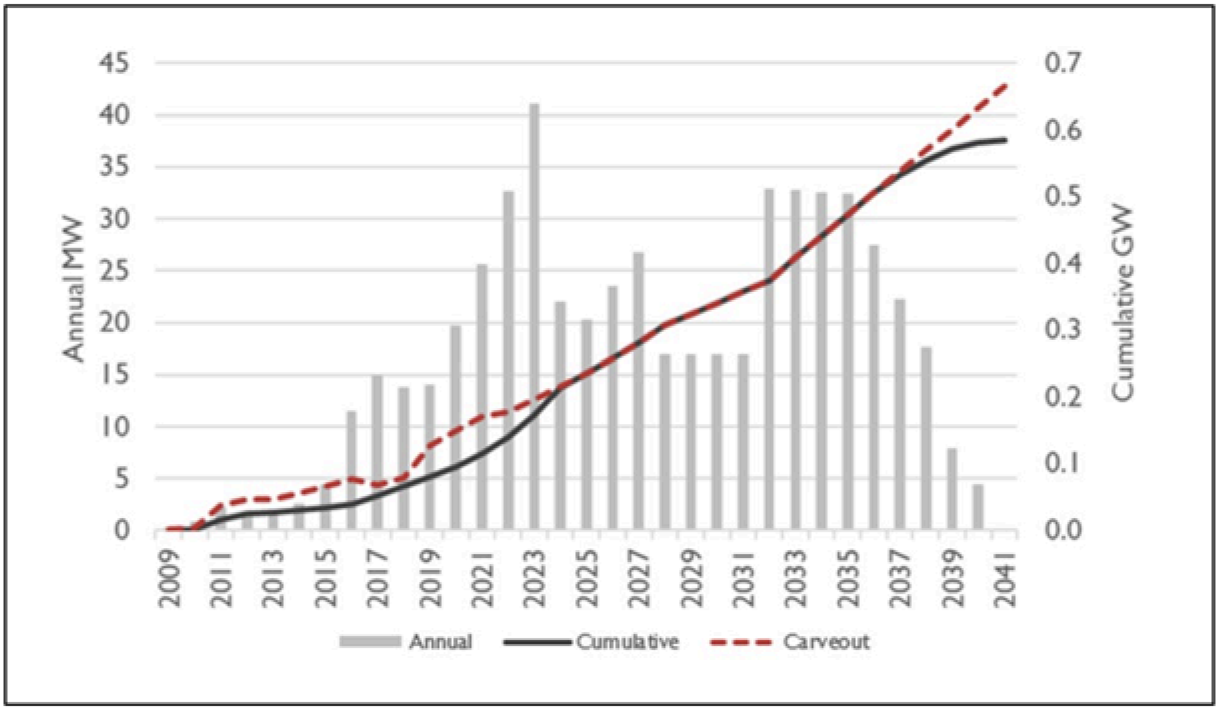


[42] The Washington Post, "[A D.C. Law Firm Looks to the Sun to Help Apartment Dwellers Pay Utility Bills]" (May 10, 2018.)
[43] Washington Business Journal, "[Poop and Power: DC Water pursues solar at Blue Plains]" (June 11, 2014.)

Accelerating Solar Adoption is Necessary, Feasible, and Benefits District Residents

To meet the District's clean energy goals and the requirements of the Local Solar Expansion Act, local solar energy production will need to increase by at least 11% per year over the next 17 years.[44] Although so far the District has been able to meet yearly targets, the forecast based on current applications for solar projects shows a decrease in solar installations over the next 7 years. Keeping up with the required growth will require interconnecting hundreds of MW more local capacity.

Figure 4: Estimated trends and legislated goals (carveout) for local solar production in the District.[45]



The District has been investing in solar for the past eight years through the Solar For All program, established in 2016. The federal Inflation Reduction Act has re-established a 30% tax credit for solar installations and provided additional funding for the District's Solar For All program.[46] Consumer attitudes towards solar are favorable, and solar installers are ready and able to install more solar.[47] Accelerating solar adoption is necessary, feasible, and has a number of corollary benefits for the District and its residents.

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[44] Synapse Energy Economics, *Future of Solar PV in the District of Columbia - Feasibility, Projections, and Rate Impacts of the District's Expanded RPS* (2020), 12.
[45] Synapse Energy Economics, *Future of Solar PV in the District of Columbia* (2020), 19.
[46] As of June 2025
[47] Pew Research Center, "How Americans View National, Local and Personal Energy Choices" (2024).

Generating power locally can act as a hedge against cost increases driven by PJM market dynamics (including interconnection queue issues, decreased capacity, and congestion) that the District has a limited capacity to control.[48] The District can manage its locational marginal pricing relationship within the PJM market by taking advantage of the local capacity for solar, batteries, smart thermostats, and other DERs to provide peak demand reduction.

Interconnection: The process of connecting DERs to the power grid. It involves technical, regulatory, and safety considerations to ensure the grid remains stable and reliable.

Moreover, generating power locally also helps protect residents from rising and increasingly unpredictable electricity prices. The median energy burden of Black households in the District of Columbia is 70% higher than non-Hispanic white households.[49] Accelerating solar adoption, especially in low-income neighborhoods, is critical to ensuring residential electrification is within reach of all District residents. The District can achieve this goal, by allowing residents to benefit directly from generation and therefore lower their energy burden.

> "Public Housing properties need to be included in the solar panel opportunities."
>
> Rhonda H., Ward 6

Finally, generating more power locally allows the District the resources to accelerate its policy goals related to renewable energy. These resources allow the District to anticipate how much of it should be produced locally to address ever more dire climate change forecasts.

Meeting DC's steadily rising annual renewable electricity goals will require addressing a range of issues.[50] In this study we look at administrative bottlenecks in the interconnection and permitting processes, lack of awareness among DC residents and installers about DERs, and some of the legal and regulatory barriers. One of the core challenges to improved interconnection, and also one of the key opportunities, relates to the District grid's hosting capacity.

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[48] This assumes economic feasibility during normal market conditions.

[49] A. Drehobl, L. Ross, and R. Ayala, "How High Are Household Energy Burdens?" American Council for an Energy-Efficient Economy (2020).

[50] *Renewable Energy Portfolio Standards Report 2024* (D.C. Pub. Serv. Comm'n 2025). Solar development is just barely keeping pace with REPS requirements. A 2022 local solar law raises the annual increment to about 45 MW, which is faster than recent development. (2023 added 43 MW). There is more solar installed now than required by the RPS, so there is some excess that will be eroded away. Additionally, as a result of the Healthy Homes Act, some systems outside of the DC and Maryland region will no longer be eligible for the local SRECs increasing the urgency around local solar adoption.

Hosting Capacity and Why it Matters

What is Hosting Capacity

Hosting Capacity: Represents the capacity (generally expressed in kilowatts) of the existing grid or grid segment to accept the electrical power produced by a DER without requiring major upgrades to the distribution system or negatively impacting grid reliability and power quality.

Hosting capacity can be measured for a whole feeder, but its local measurement at the point of interconnection is more relevant to determine whether a DER can safely be connected to the grid. Importantly, hosting capacity does not represent a limit on the amount of DERs that can be added to the distribution system; it represents how much capacity there is at a given moment in time before having made any changes or upgrades. Hosting capacity reflects the existing limits of the grid interface, which can be expanded with sufficient controls and on-site storage, for example, allowing more power to be generated on the grid than the initial hosting capacity suggests.

Hosting capacity varies daily and seasonally. It can be measured at a specific point in time or can be looked at dynamically. Dynamic hosting capacity is the foundation of analysis such as the National Renewable Energy Laboratory's.[51] It is based on quasi-static time-series simulation that considers the behavior of DERs, loads, and grid devices over time, and accounts for the fact that some instability is acceptable, for short periods of time and during a limited number of time points during the year.[52]

DC residents, or solar developers who are seeking to add DERs to the grid, look to Pepco's hosting capacity map to understand whether they might be able to interconnect at a reasonable cost.

Current Hosting Capacity Map

Currently, Pepco publishes a searchable hosting capacity map for all radial feeders in the District (Hosting Capacity Map).[53] The data provided to consumers is a static snapshot in time based on normal thermal rating and the net minimum daytime load.[54]

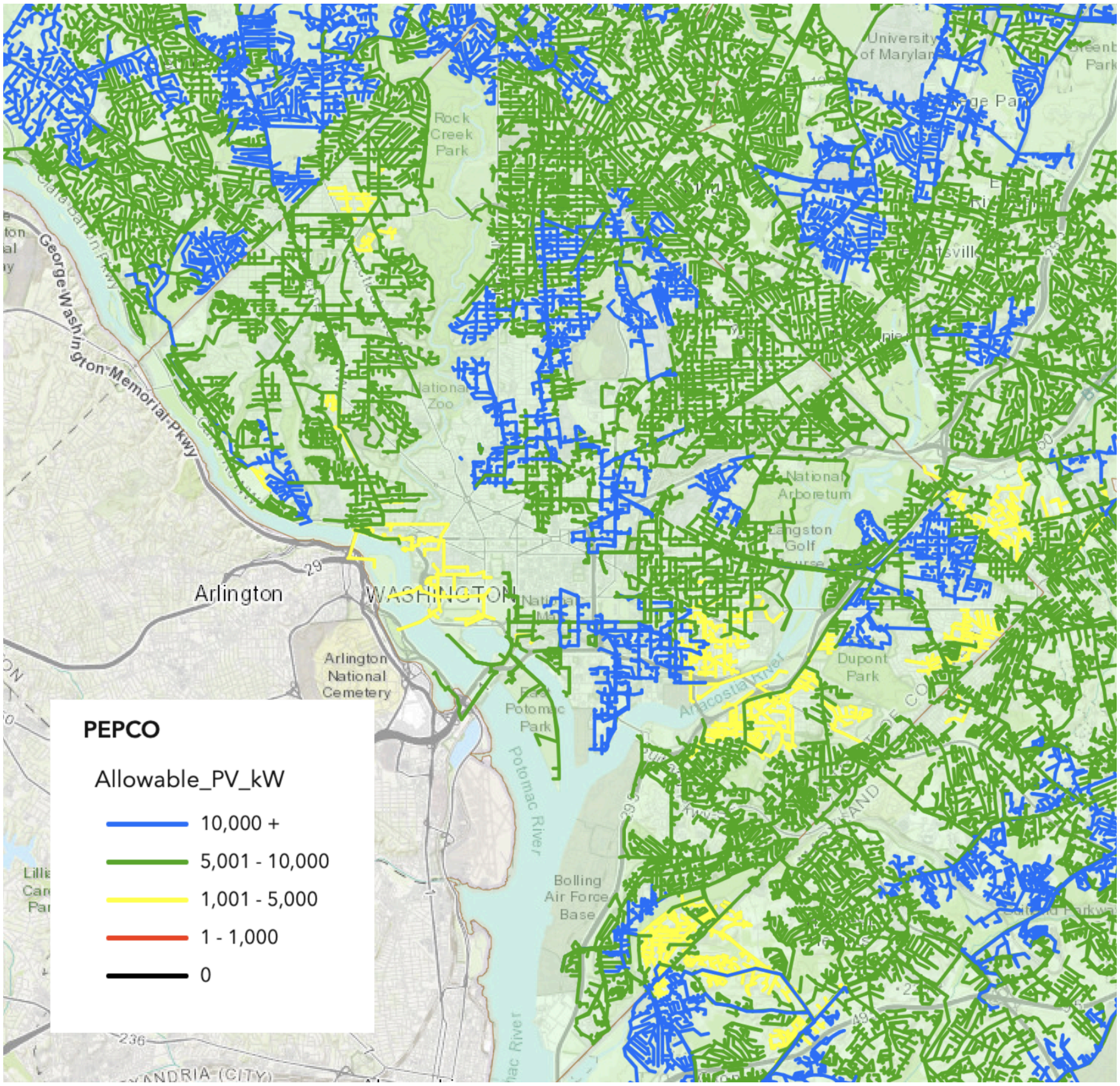
Loads: The amount of electrical power consumed by devices connected to the grid.

[51] NREL, "Advanced Hosting Capacity Analysis" (2025).
[52] Cadeo Group, "Maximizing Distributed Energy Resource Adoption with Hosting Capacity Analysis" (2024). An example of an instability that is acceptable for a short period of time or number of times per year (also known as transient instability) is a temporary or recoverable voltage drop or rise.
[53] Pepco, "Hosting Capacity Map" (2025).
[54] Pepco, "Technical Conference Compendium" (2025), 27.

The static nature of the information and the lack of bus-level specificity makes the data provided not actionable. The caveat Pepco adds to its Hosting Capacity Map ensures that residents and businesses cannot rely on it for planning and investing in DERs: “Although the values are meant to provide the user with a general idea of availability, space on the desired feeder is not guaranteed and/or may change at any time. All applications for interconnection will still require a full review and may also require additional interconnection costs.”[55] If the Hosting Capacity Map were a dynamic tool including data at the bus-level updated regularly, then customers would have actionable data and the tool would provide a better indication of potential challenges to interconnect due to a known lack of capacity.

[55] Pepco, “Hosting Capacity Map” (2025).

Figure 5: Hosting Capacity map published by Pepco indicating that (as of March 10, 2025) the vast majority of District feeders have between 5,001 and 10,000 of allowable PV kW in capacity[56]



The Hosting Capacity Map shows that the vast majority of District feeders have ample capacity to interconnect additional DERs without the need for infrastructure upgrades that would trigger charges to the consumer.

[56] Pepco, "Distribution Feeder Hosting Capacity" (2025).

However, we know that interconnection, together with its high fees, administrative barriers, and delays, has been an issue for many consumers.[57] This assertion is supported by reporting and several formal cases brought to the PSC, including Formal Cases 1050 and 1171.[58,59,60]

To better understand hosting capacity and interconnection issues, Electrify DC analyzed Pepco's data, gathered solar complaints from the Office of the People's Council (OPC), surveyed 315 DC residents, and conducted three case studies.

In response to Electrify DC's queries, the OPC issued a memorandum on interconnection complaints.[61] The memorandum states that from 2019 to Q4 2024, the OPC processed 102 consumer complaints related to solar applications. Among the interconnection complaints processed by the OPC, most complaints were due to high and unexpected interconnection fees, ranging from $2,000 to $104,000, followed by delayed interconnection timeframes and administrative barriers (requests made by Pepco related to DC Municipal Regulations). Most of the complaints originated from Ward 5, followed by Wards 3, 4, and 7. OPC notes that this data "only reflects resolutions sought and completed using OPC's assistance," and therefore, does not include interconnection issues where residents did not know to reach out to OPC, or for other reasons did not avail themselves of OPC's assistance.[62]

Additionally, Electrify DC's survey found that over 15% of homeowners that responded to the survey who installed solar had issues with interconnection. However, this percentage might be higher, as residents are often unaware of interconnection issues handled by the solar installer on their behalf.

Although Pepco reports not having denied interconnection to DC residents or residential or commercial installers, the presence of interconnection issues has prevented solar-seeking customers from moving forward with their plans (see Ed and Allen's case studies). Where there is sufficient dynamic capacity, interconnection should be relatively inexpensive and straightforward.

Allen's Solar Installation Challenges

Allen faced significant challenges in his effort to install a solar PV system on his Ward 4 home, after Pepco imposed a $35,000 interconnection charge for system upgrades, including a new transformer and pole. Despite multiple requests to Pepco and an appeal to the DC

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[57] Pepco states that hosting capacity is not a proxy for fees or administrative costs, and that it instead may simply provide some level of proxy for grid upgrade costs at the primary voltage level.
[58] Washington Post, "Fees from Pepco Put Solar Panels Out of Reach, D.C. Residents Say" (2022).
[59] *Investigation into the Implementation of Interconnection Standards in the District of Columbia*, No. 1050 (D.C. Pub. Serv. Comm'n).
[60] *Investigation into Community Renewable Energy Facility Practices in the District of Columbia*, No. 1171 (D.C. Pub. Serv. Comm'n).
[61] Office of the People's Counsel, *OPC Solar Interconnection Report* (2024).
[62] According to Pepco, the Company received 5,590 applications in 2024.

PSC which upheld Pepco's right to charge the upgrade fee, the financial burden proved insurmountable, leading to the cancellation of Allen's contract with the solar installer.

In addition to the project no longer being economically viable, unclear ownership and maintenance responsibilities for the new utility pole to replace an unmarked utility pole, located on a five-foot strip of grass between a neighboring church and Allen's home, added legal unknowns. This case reflects a broader challenge of imprecise utility infrastructure ownership. This reinforces the need for better maintenance of key asset metadata so that Pepco is aware of the locations and state of their infrastructure and so that users can have access to a data rich actionable hosting capacity map that can provide an indication of such potential issues.

Allen's case highlights significant barriers to residential solar adoption due to unexpected infrastructure costs and regulatory complexities.

(Photo of utility pole not on Pepco's map, provided by the homeowner.)

Hosting Capacity Varies Depending on Which Parameters Are Used

On its Hosting Capacity Map, Pepco states that "Hosting capacity is not an exact science. Results shown may understate the hosting capacity and results will be revisited in the future." While hosting capacity is a parameterized measurement, meaning it can vary depending on the specific parameters used in the model, it is possible to measure it more accurately than Pepco currently does or makes available to the public. This variability has led to frustration, as highlighted in the Formal Case 1050 Technical Conferences, where concerns were raised that Pepco's hosting capacity maps did not align with local hosting capacity measurements taken during the interconnection process.[63]

[63] Pepco, "Technical Conference Compendium" (2025), 27. The question asked was whether the current hosting capacity map or process identifies specific limiting criteria for hosting capacity and Pepco

Aligning Hosting Capacity Maps to Interconnection Process

Pepco's Hosting Capacity Map does not account for the full range of technical constraints evaluated during the interconnection process for solar applications. Unlike the Hosting Capacity Map, which considers only net minimum load and normal thermal rating, solar applications undergo a local power flow analysis at the nodal/bus level, incorporating factors such as voltage, thermal capacity, power stability, and inverter settings. Additionally, each application includes on-site measurements, as models do not always accurately reflect real-world conditions.

Pepco has noted it currently does not have the tools to conduct a hosting capacity assessment that reflects the local technical constraints considered during the interconnection process for residential solar applications. However, Pepco stated during the Formal Case 1050 Technical Conferences that it is in the process of investigating how it may be able to provide this information by investing in upgraded CYME versions and partnering with Atlas.[64]

During the Formal Case 1050 Technical Conferences, residents also requested Pepco transition to conducting a dynamic hosting capacity analysis rather than a static hosting capacity analysis.[65] A dynamic hosting capacity analysis performs a time series power flow analysis over the course of a whole year, while a static hosting capacity analysis performs a power flow analysis for a snapshot in time, like those performed in Hawaiian Electric's service territories.[66] The main drawbacks of a static or snapshot hosting capacity analysis are that, because it cannot fully capture grid device behavior or time series profiles, it often resorts to using inputs derived from worst case scenarios that have a low occurrence, such as all distributed solar systems operating at maximum output while the load is at its minimum. Pepco has stated that it is too burdensome to track the intra-day time-interval data necessary to conduct a dynamic

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responded that Pepco currently only identifies thermal limiting criteria for hosting capacity, but that Pepco is moving towards incorporating voltage on a locational basis. *Id.* at 27-28.

[64] Pepco, "Technical Conference Compendium" (2025), 27, 29.

[65] Pepco, "Technical Conference Compendium" (2025). The request to standardize modeling the inverter with its actual volt-VAR settings, in order to capture the true dynamic response of an inverter, is consistent with the methodology of a dynamic hosting capacity analysis (page 25). Fixed power factor adjustments provide only an estimate of reactive power contribution and do not replicate smart inverter behavior like voltage-dependent reactive power support or curtailment events.
The request to conduct a nodal level analysis is a core component of a dynamic hosting capacity study (page 27-28). Node-level evaluation captures local impacts of distributed energy resources, including voltage rise, thermal loading, and inverter response, which cannot be reflected in aggregated or feeder-level analyses.
The request to perform a long running time series simulation like the 8760 analysis which is a year-long hourly time series simulation exemplifies what is involved in a dynamic hosting capacity, where time-series simulations are required to be conducted upon at least a representative hourly series to capture the true operational variability of loads and DERs (page 29).
Therefore, the request to perform nodal level analysis, smart inverter settings modeling and standardization, and long running time series simulation is consistent with and directly supports the transition to a dynamic hosting capacity analysis, as defined by NREL and industry best practices.

[66] *Performance-based Regulation for the Hawaiian Electric Companies,* Docket No. 2018-0088 (Haw. Pub. Utils. Comm'n).

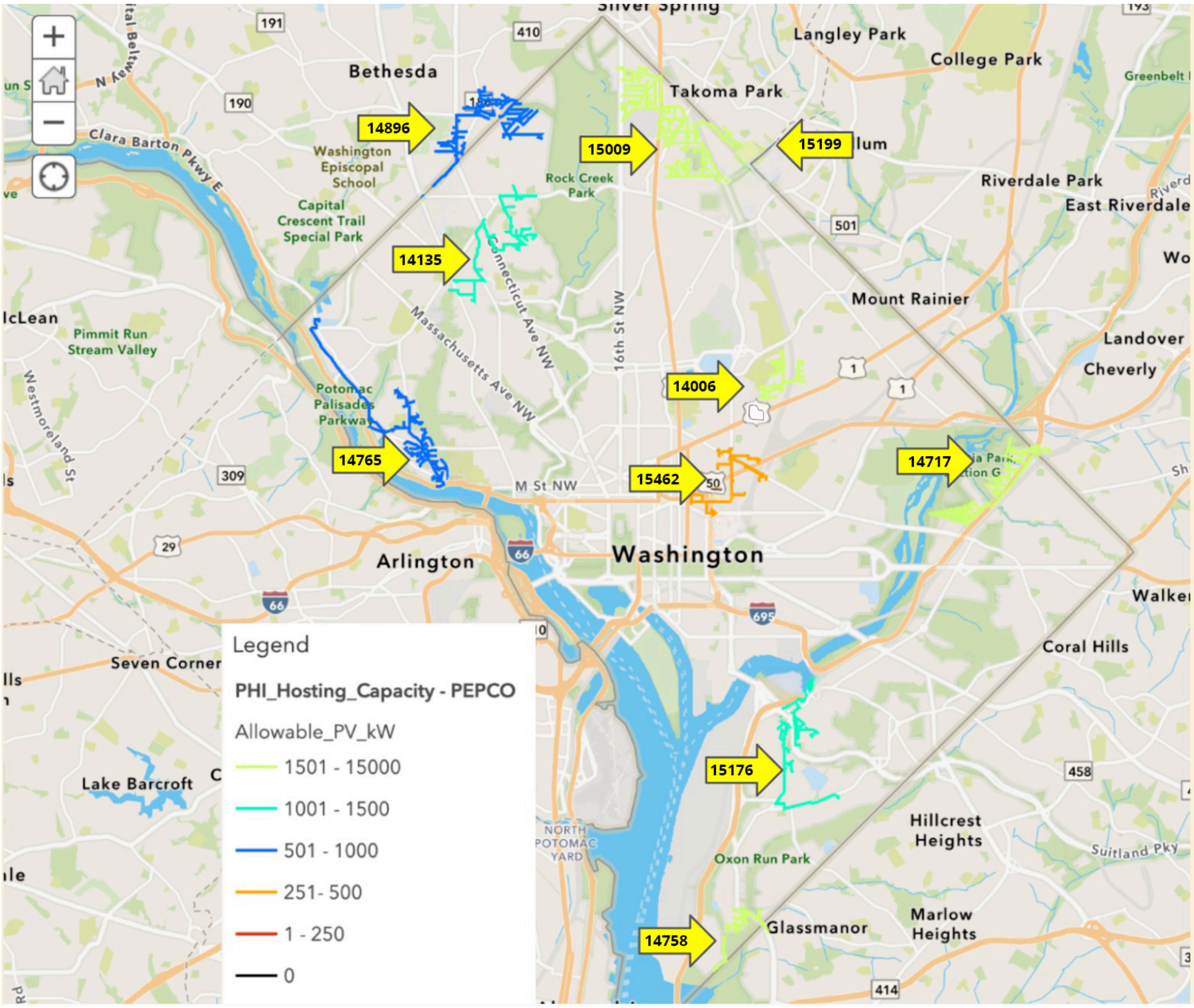
hosting capacity analysis, given the anticipated costs and need to outsource.[67] In order to evaluate whether it is possible to do a dynamic hosting capacity analysis, our team used power flow models to evaluate hosting capacity using data from Pepco.

Hosting Capacity Data, Modeling, Methodology and Results

The Electrify DC team asked Pepco, on behalf of DOEE, for data relating to all District radial feeders. Given the limited timeline of the study and Pepco's constrained resources, Pepco provided the requested information for ten of the District's approximately 765 feeders. According to Pepco, these ten radial feeders are representative of all the radial feeders in the District and therefore can be studied as a proxy for all other feeders. For the ten feeders provided, Pepco provided structural and time series data until the bus or node level, not until the end customer, meaning the modeling and time series profiles like load and solar were aggregated at the bus level. Therefore, Electrify DC has no visibility into secondary metering where equipment between the bus and the end customer may impose limitations that affect hosting capacity.

[67]Electrify DC, email message to Pepco, July 10, 2024. "Is Pepco providing hourly or even 5 minute solar generation data to PJM? If not, do you all foresee having to provide that data to PJM?"
Pepco, email reply to Electrify DC, July 10, 2024. "No. This is a major burden and services like this would have to be outsourced and the cost will more than likely exceed the benefit."

Figure 6: Map showing the 10 feeders for which structural data was provided by Pepco, and their available hosting capacity as determined by Pepco[68]



The team utilized CYME and primarily EPRI's OpenDSS to conduct a dynamic hosting capacity analysis for 10 radial feeders selected by Pepco as proxies for all the radial feeders within the District. The analysis was conducted using a time-series power flow analysis in OpenDSS, incorporating similar parameters used in the solar interconnection process—voltage and power stability, thermal and short circuit capacity, protection device statuses, and inverter settings. By analyzing hourly load data from a representative 24-hour period provided by Pepco and individually scaling solar generation systems according to their generation profiles, the team was able to determine the local hosting capacity at each bus or node.[69,70]

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68 Pepco, [Distribution Feeder Hosting Capacity](#) (2024), with 10 feeders highlighted.
69 Electrify DC checked for thermal overloading while conducting its analysis.
70 Unfortunately, despite Electrify DC's requests for seconds or minutes, no higher temporal resolution than hourly load data was provided by Pepco.

Dynamic Time Series Power Flow Analysis using OpenDSS

Although the team had access to Eaton's CYME tool, Electrify DC chose to conduct the hosting capacity analysis using Electric Power Research Institute's (EPRI) OpenDSS tool.[71] OpenDSS is used by industry leaders including the National Renewable Energy Laboratory (NREL), FERC's engineering staff, and many Institute of Electrical and Electronics Engineers (IEEE) authors. It allows for time series simulations in various resolutions, and allows the user to directly interface with circuit elements using simple lines of code in Python. Each feeder and corresponding circuit element is treated as a flexible scalable object, which allows hosting capacity to be analyzed locally rather than on a global feeder level scale.

Data Preparation

The original feeder model data was provided in a dictionary format (sxst) only accessible within CYME. The data was converted to ASCII or text based files using CYME's database import functions. The NREL's open source library Distribution Transformation Tool (DITTO), was used to convert the modeling format from Eaton's CYME to EPRI's OpenDSS format.

SCADA: Supervisory Control and Data Acquisition systems collect and analyze data from various points in the power system, including substations, power plants, and transmission lines, by collecting real-time data to optimize performance and respond to dynamic conditions

AMI: Advanced Metering Infrastructure that records customer consumption hourly or more frequently and that provides for daily or more frequent transmittal of measurements over a communication network to a central collection point

The original time series data provided contained both SCADA data at the feeder head level and AMI data with hourly load at the nodal level. Each bus contained the following hourly data: the kVA rating for each transformer, the phase, and the kW measured. The feeder level time series data was mapped to each relevant facility id which was present in the load id at the nodal level.

The AMI time series data contained missing values for certain nodes, where neither the number of customers nor the hourly load appeared reliable. To address these gaps, load profiles were generated by sampling from a Gaussian distribution created from the existing data for each hour, ensuring statistical consistency. Since loads with different phase numbers exhibit distinct statistical characteristics, the data was first filtered by phase count before generating the distributions. This approach preserved the unique load patterns associated with each phase configuration while providing realistic imputed values.

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[71] *See* Section A in the Appendix for the unbalanced power flow analysis conducted in CYME without DER integration, which establishes the baseline state of the provided feeders.

Transformer: Devices that transfer electrical energy between two or more circuits through electromagnetic induction. They are used to increase (step-up) or decrease (step-down) voltage levels.

Transformer impedances and reactances were provided for relevant feeders with voltage regulation devices. Solar profile data for the District was obtained from the National Oceanic and Atmospheric Administration.

Kron reduction was performed on the line reactance and resistance matrices to have a symmetrical matrix for each phase (three phase four wire). Kron reduction is performed as part of steady state assumptions for hosting capacity studies.

Time Series Power Flow Analysis Parameters

To understand how hosting capacity varies depending on certain parameters, multiple time series power flow analysis with DER integration were performed:

1. A Monte Carlo time series power flow analysis for a 100 solves was conducted over a 24-hour period, using **random load allocation** while ensuring compliance with thermal ratings, voltage limits, and power stability constraints (similar to Pepco's review during the solar application process).[72] PV systems are assigned at the nodal level and then scaled to respect constraints. This probabilistic approach enables a comprehensive evaluation of grid performance under varying load and generation conditions and aligns with NREL's description of a dynamic hosting capacity study as a quasi-static time-series simulation.[73] PV Systems are integrated with inverters using the default volt-var profile mandated by Pepco.[74]
2. A single time series power flow analysis with **mapped load allocation** over 24 hours constrained by thermal ratings, voltage and power stability (similar to Pepco's review during the solar application process). PV systems are assigned at the nodal level and then scaled to respect constraints. PV Systems are integrated with and without inverters using the default volt-var profile mandated by Pepco.

Electrify DC utilized historical data provided by Pepco for the mapped load allocation approach. In contrast, the random load allocation method generated data based on this historical dataset, introducing stochastic variations to better reflect real-world scenarios. It should be noted that exact parameter selection and constraints considered for Pepco's solar application process are

[72] *See* Section B in the Appendix for details around the difference between random load allocation and mapped load allocation.
[73] NREL, *Advanced Hosting Capacity Analysis* (2025).
[74] Pepco, "Pepco Acceptable Inverters" (2024). Default volt-var profile under document PHI Distribution Utility - Utility Required Profile (DU-URP)

not communicated to the general public and there is a lack of clarity about what specifically is being measured on-site.[75]

Results

Singular PV systems, representing the aggregate generation at each bus, were added to each bus for all the feeders provided. An acceptable system size for each node was converged upon by iteratively decreasing or increasing the system size by observing if the solution converged, reported any thermal overload violation, and if voltage stability limitations were respected at each bus. The total hosting capacity for a feeder was derived from summing the local hosting capacity across all the nodes of a feeder.[76]

Figure 7: Acceptable voltage rise measured at each bus for sample feeder

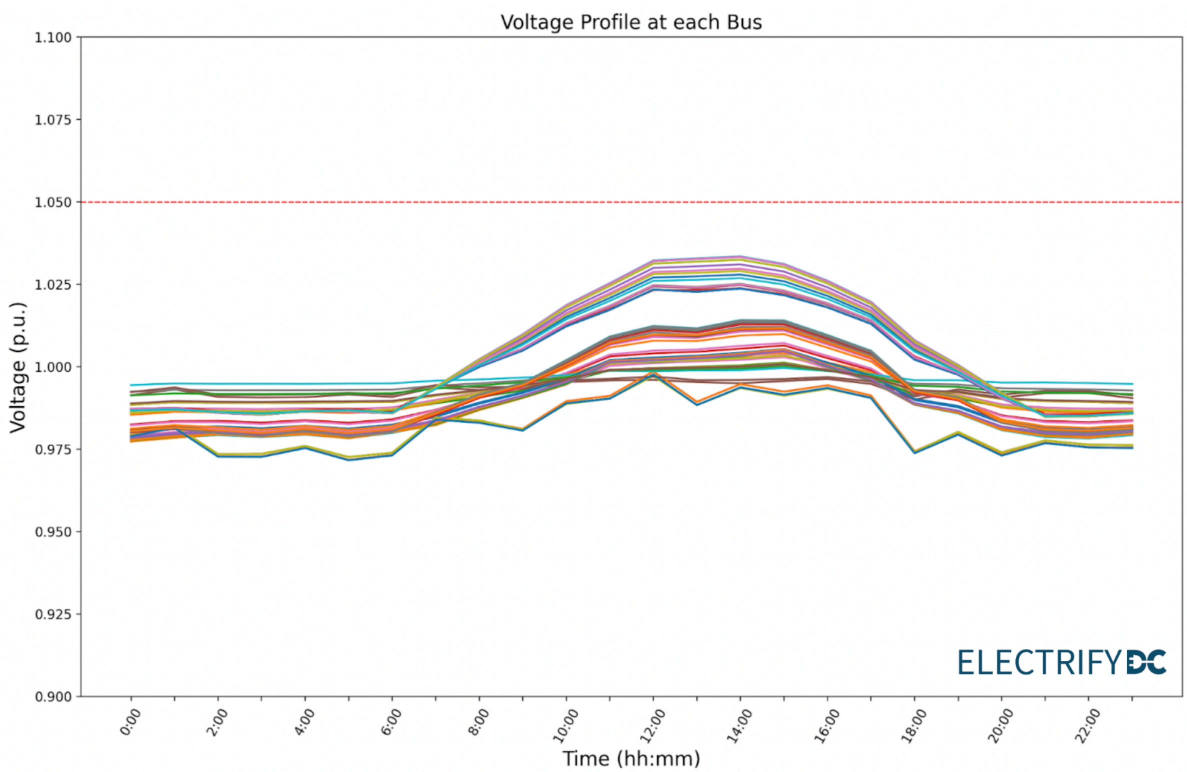
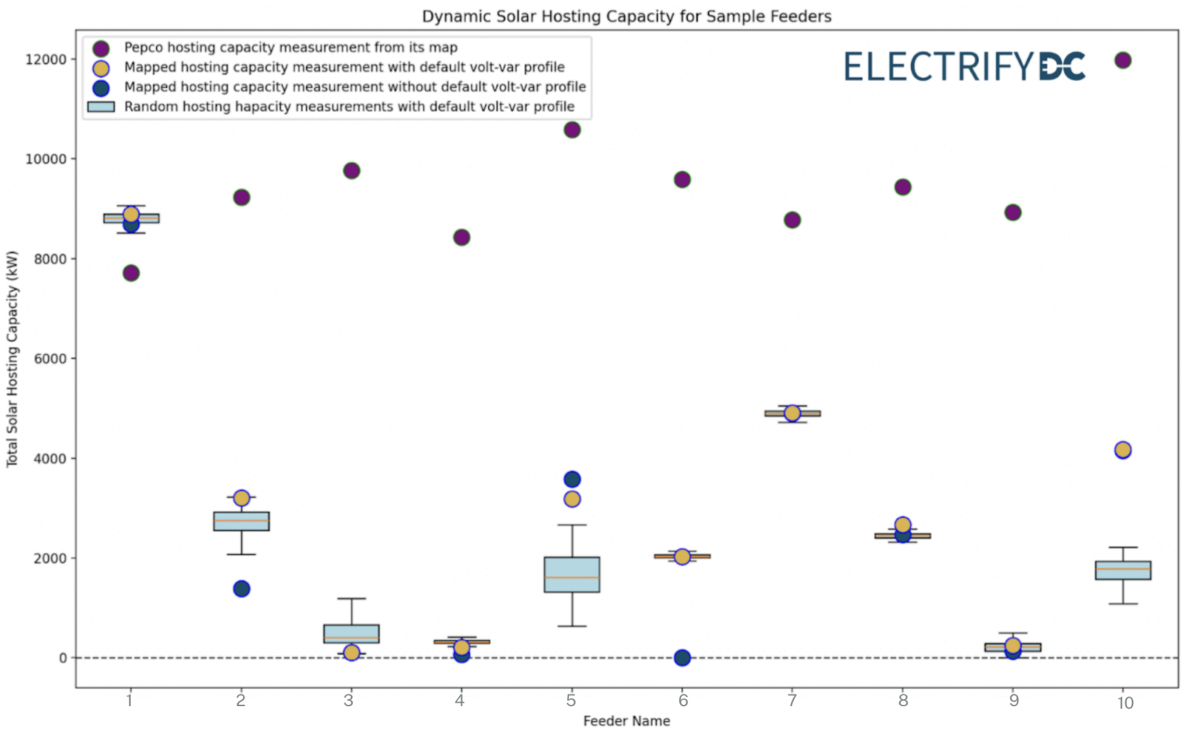


Figure 7 illustrates the voltage magnitude measured at each bus for a sample feeder. It can be observed that the voltage remains below the maximum limit of 1.05 per unit, ensuring compliance with operational constraints.[77] Additionally, no irrecoverable faults occur, as the voltage magnitude never drops to zero, which would otherwise disrupt power flow at the affected bus. This voltage profile was deemed acceptable for evaluating our results while scaling the PV

[75] *Investigation into the Implementation of Interconnection Standards in the District of Columbia*, No. 1050 (D.C. Pub. Serv. Comm'n).
[76] *See* Section C in the Appendix for description of the iterative algorithm used to maximize solar hosting capacity.
[77] In OpenDSS, 1.05 per unit (pu) means that the voltage at a particular node or bus is 5% higher than the nominal (base) voltage.

system. Furthermore, a noticeable correlation exists between peak generation periods and voltage increases, indicating that voltage rises concurrently with peak PV generation.

Figure 8: Graph showing dynamic hosting capacity for each feeder



For nine out of ten feeders, the hosting capacity measurement provided by Pepco on its Hosting Capacity Map is significantly higher than the dynamic hosting capacity measurements with or without inverter settings calculated by Electrify DC. The dynamic measurement of three of the ten feeders shows the feeders are essentially at capacity. To put this into context, the number of customers for these ten feeders ranges from 307 to 1276. The size of an average PV installation, according to the data provided, is 4.5 kW. By Pepco's hosting capacity measurement, assuming the hosting capacity at each individual bus is not an impediment, most of the 10 feeders could fit an average PV installation for every single customer. Of course, Pepco's Hosting Capacity Maps do not provide bus-level data so there is no way for consumers to be aware of any impediments. Electrify DC could have determined hosting capacity measurements for each customer if it had been given the feeder data between each bus and the customers mapped to that bus.[78] Assuming Pepco has the data between each bus and the customer, they should be able to offer an even more accurate hosting capacity measurement by incorporating secondary metering models.[79]

[78] Pepco agreed to Electrify DC's request for meter-to-meter data: bus to customer mapping. Electrify DC was able to use the meter-to-meter data to understand the number of customers being served by each bus and map it to the provided load profiles at the bus level to then model and scale the aggregated load accordingly. However, without the secondary metering data or even individual customer load profiles, Electrify DC was unable to accurately determine the hosting capacity at each house.
[79] Pepco has stated that residential hosting capacity will primarily be limited by the secondary conductor length run.

Pepco's measurement only considers the minimum load and thermal rating of the feeder. Electrify DC's hosting capacity measurement was derived as described previously by using different parameters depending on how the load was allocated and the consideration of the default inverter settings mandated by IEEE 1547-2018.[80,81,82]

The figures below show how hosting capacity differs depending on whether inverter settings are considered or not. Pepco should use this parameter to refine its hosting capacity measurement.[83] For example, the highlighted bus shows that the difference between a measurement with inverter settings and without is 22kW which in this case is a 20% increase in hosting capacity.

The figures below also show the variation in hosting capacity of different buses along a same feeder, which is why a global hosting capacity measurement for a feeder does not help customers assess whether they can install solar.

[80] Pepco, "Pepco Acceptable Inverters" (2024). Default volt-var profile under document PHI Distribution Utility - Utility Required Profile (DU-URP).
[81] IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces, IEEE Std 1547-2018 (2018).
[82] Although IEEE-1547-2018 doesn't mandate including inverter settings in hosting capacity analysis, Pepco abides by it, so it should be accounted for in their hosting capacity analysis.
[83] Pepco has stated that inverter settings would not increase the hosting capacity unless they changed their methodology to how they calculate hosting capacity.

Figure 9: Hosting capacity map showing local aggregate solar capacity with inverter employing default volt-var

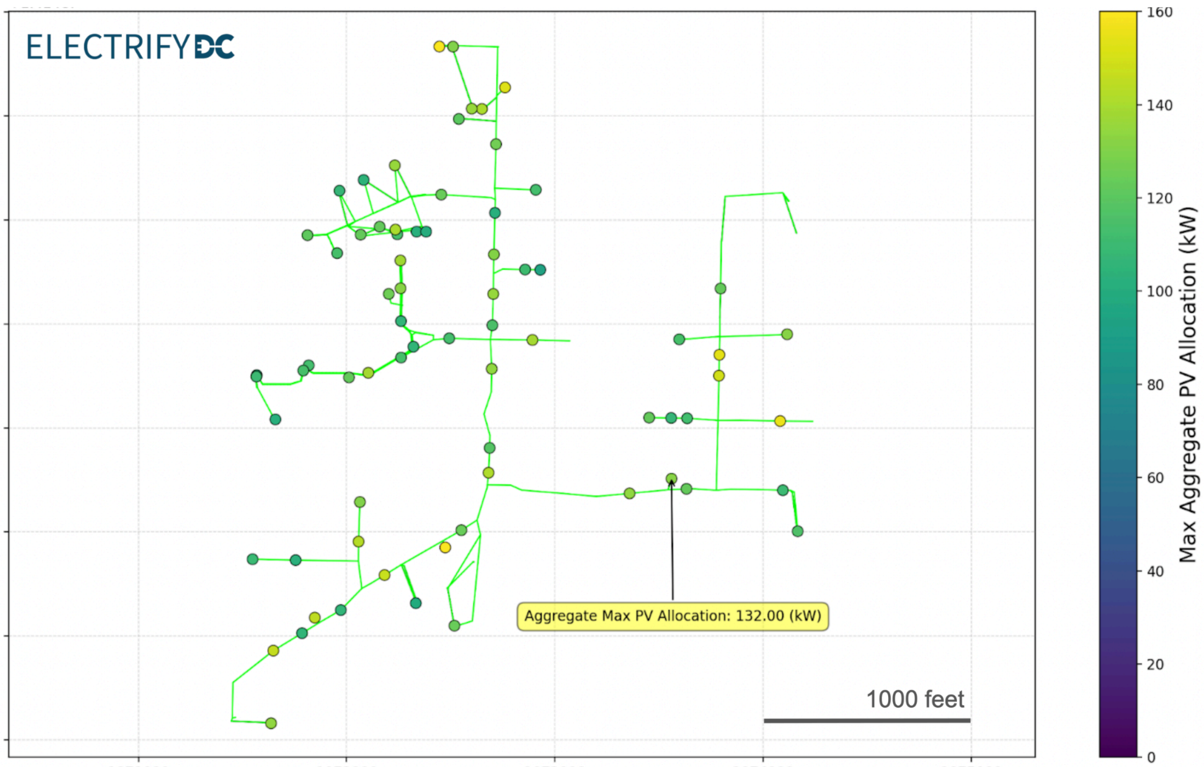
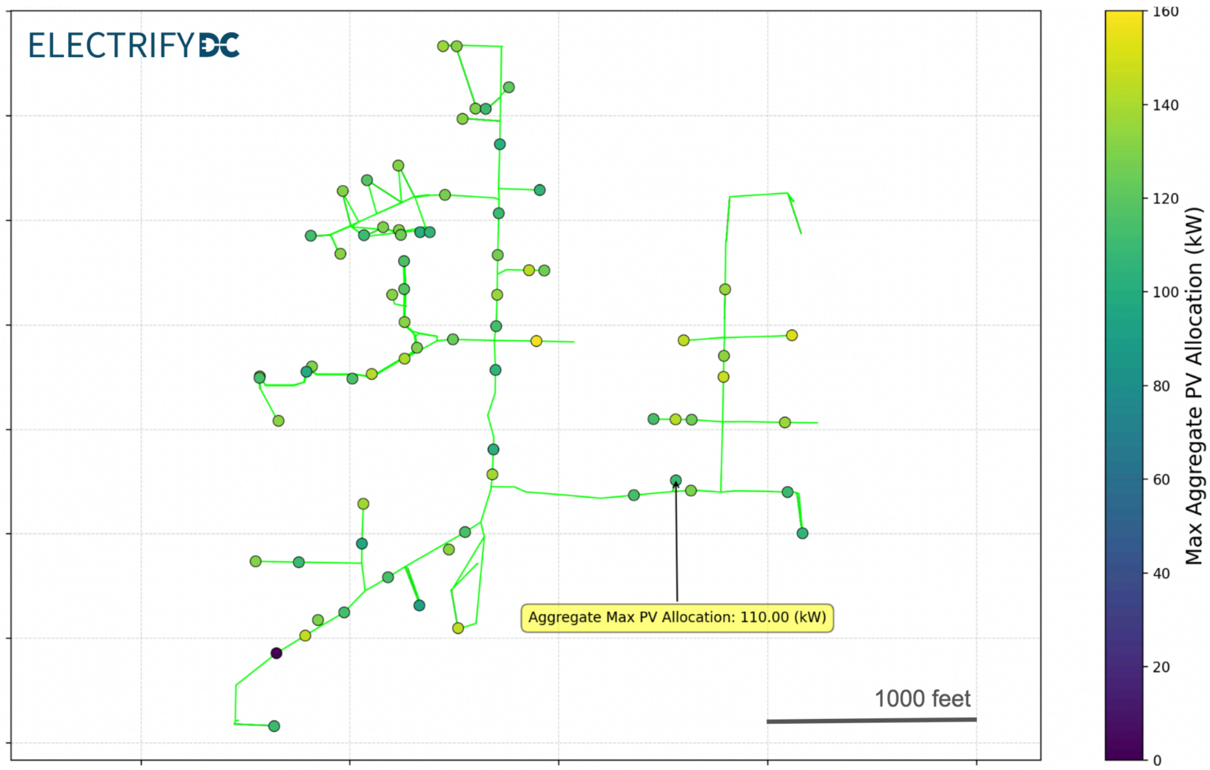


Figure 10: Hosting capacity map showing local aggregate solar capacity without inverter employing default volt-var



The purpose of this analysis was to show how hosting capacity changes based on parameter selection, how hosting capacity can be calculated for feeders at the nodal level, and how Pepco can update their hosting capacity maps to communicate realistic information to residents. IEEE 1547-2018 mandates that all DERs use inverters capable of curtailing power in response to disturbances. However, Electrify DC's analysis does not consider volt-watt or power curtailment settings, as Pepco determines these on a case-by-case basis depending on local feeder characteristics and the specific interconnection application.

Key Takeaways from Dynamic Hosting Capacity Analysis

Through its dynamic hosting capacity analysis, Electrify DC was able to conduct a time series power flow analysis capturing technical constraints such as bounding the voltage rise at each bus considered during Pepco's interconnection process for solar applications. The analysis shows that the hosting capacity measurement can greatly vary depending on what parameters are considered during the analysis. Because Pepco's analysis is constrained solely by minimum daytime load and thermal ratings, the hosting capacity appears significantly higher than when voltage stability and protection device statuses are also considered.

Pepco states "the Hosting Capacity map gives an indication of how much generation (expressed in kW) can be added to a feeder before the feeder reaches capacity or other limitations that reduce the reliability of service to electric customers on the feeder and that the results may understate the hosting capacity."[84] Although the maps are intended to give users a general idea of availability, they fail to achieve this goal. As previously stated, hosting capacity is a localized measurement specific to a customer's point of interconnection. Consequently, the values presented on Pepco's current Hosting Capacity Map do not accurately reflect how availability of capacity is assessed during the actual interconnection process for residential solar applications.

As stated previously, Electrify DC did not receive the requested secondary metering data from Pepco, despite the Non Disclosure Agreement in place, as Pepco deemed that information too confidential to disclose. Pepco did not flag any limitations from equipment between the bus and the customer that would impact hosting capacity at the customer level, bus level, and feeder level. Ultimately Pepco has this secondary metering data and would be able to provide residents with the most accurate and localized hosting capacity measurements.[85] The results of Electrify DC's analysis with limited data demonstrates that Pepco can and should be able to provide residents with an effective and actionable map.

To ensure consistency and transparency, Pepco must revise its standardized methodology for measuring hosting capacity so that it reflects the full potential of inverter-based resources, and ensure those changes are captured through their interconnection process and clearly communicate any significant changes.[86] For example, the measurements given by the Hosting Capacity Map for the 10 analyzed feeders, including the represented shape and stated capacity of some of them, changed significantly between September of 2024 and March of 2025, yet no mention is made of it by Pepco.[87] Hosting capacity should have a consistent definition to help customers understand its impact on their interconnection applications and to facilitate informed discussions on DER integration in the District. Beyond the basic definition, Pepco should provide on its website—and file with the DC PSC—a detailed explanation of the methodology, parameters, and software Pepco uses to calculate hosting capacity, and update these materials whenever its methodology changes.

[84] Pepco, *Hosting Capacity Map* (2025).
[85] Pepco has stated that hosting capacity for residential solar applications will primarily be limited by the secondary conductor length run.
[86] Pepco states they have and maintain a standardized methodology. However Pepco has stated both that they identify inverter operating settings as part of the DER analysis and that they do not consider inverter settings in their hosting capacity measurement. Accordingly, Electrify DC believes that Pepco should update their standardized methodology to reflect their interconnection process and the known nature of inverters.
[87] When given the opportunity to address this change, Pepco offered no additional context.

Maximizing Existing Hosting Capacity while Increasing Situational Awareness

Currently, Pepco states it does not maintain the data showing the specific infrastructure, age, and condition.[88] Improving Pepco's understanding of its basic distribution system equipment is paramount, as highlighted in the FC 1050 comments and the Advanced Inverter Working Group meeting for comments from Pepco on the need to do field verifications because of unreliable data quality on its system assets.[89,90,91] In addition to better understanding its basic distribution system equipment, in order to maximize the existing hosting capacity of a feeder while maintaining grid reliability, it is critical for Pepco to understand and respect a feeder's local behavior under default settings and operation. Even in 2016 nearly a decade ago, NERC stated in its Long-Term Reliability Assessment that many utilities lack sufficient visibility of DERs.[92] This lack of visibility could present certain issues for bulk power system reliability, including a lack of situational awareness.

Situational Awareness: A utility's ability to monitor, analyze, and respond to real-time grid conditions. This includes tracking power flows, voltage levels, equipment status, and DER operations to ensure grid reliability and stability.

NERC has defined situational awareness as "ensuring that accurate information on current system conditions is continuously available to operators."[93] Although Pepco maintains static data on DER installations, including their physical and electrical location, capacity, type, and capabilities, it does not maintain high-resolution DER telemetry data. According to their SCADA and AMI data, Pepco currently collects data from the substation and buses along the feeder at an hourly rate. However, collecting high resolution telemetry data provides operators with real-time visibility and situational awareness of behind-the-meter (BTM) generation.

As previously stated, hosting capacity is a representative measurement or model of the grid's ability to accommodate distributed generation and may not always reflect real-time or site-specific conditions. Situational awareness tools—such as AMI, SCADA systems, and real-time telemetry from inverters—enable utilities to assess hosting capacity and system

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[88] "[W]e do not have information related to the second request because we do not maintain a central repository for the age/model of equipment." Pepco, response to an Electrify DC data request, March 13, 2025.
[89] Pepco, *Technical Conference Compendium* (2025), 28, accessed March 31, 2025.
[90] *Advanced Inverter Working Group Meeting Minutes*, (D.C. Pub. Serv. Comm'n, Feb. 6, 2025) accessed March 31, 2025.
[91] The missing pole from case study "Allen's Solar Installation Challenges", on page 17.
[92] North American Electric Reliability Corporation (NERC), "2016 Long-Term Reliability Assessment" (2016), viii.
[93] North American Electric Reliability Corporation (NERC), "Real-Time Tools Survey Analysis and Recommendations" (2008), 9.

conditions in real time rather than relying on a previous estimate.[94] Enhanced situational awareness allows utilities to better anticipate potential hosting capacity violations and forecast their impact on grid performance over time. By leveraging these tools, utilities can proactively prevent issues such as voltage fluctuations and thermal overloading, ensuring stable and reliable grid operations.

Ultimately increased DER integration introduces more variability into the grid as power generation fluctuates with weather conditions like cloud cover. As system conditions can significantly change over one hour, FERC has recommended that operators receive on-line data of generation in at least one minute increments.[95] With higher DER penetration, real-time situational awareness becomes essential for accurately assessing system conditions and maintaining grid stability.

High Resolution Telemetry Lays the Foundation for the Future

DERMS: DER Management System is a form of energy management software that can manage multiple DERs by communicating with smart inverters to optimize their operation based on grid conditions.[96]

Investing in high resolution telemetry enhances grid situational awareness while laying the foundation for a DER Management System (DERMS). Pepco has invested in the Remote Monitoring System (RMS) to enable greater visibility and accommodate more DERs in the system.[97] However, this investment has been limited to low-voltage network feeders and does not include radial feeders. Although Pepco has expressed uncertainty about how much additional DER capacity will be supported as a result of its investment in the Remote Monitoring System.[98] Pepco has stated that the Advanced Distribution Management System (ADMS) is essential in sustaining grid stabilization and mitigating fluctuations that can occur when additional demand is placed on the grid, whether through the adoption of additional DER interconnections or due to the continued increase in electrification in the District.[99] Pepco's investments and statements indicate that DERMS benefits both the generation and consumption of power on the grid.

ADMS: The Advanced Distribution Management System project deploys foundational DERMS

[94] Pepco states that these tools are currently in use in the analysis of DER applications. They also state that, aside from real-time telemetry from inverters, they are not able to access AMI and SCADA systems until after the system is built.
[95] Distributed Energy Resources - Technical Considerations for the Bulk Power System, 162 FERC 61,127 (2018).
[96] Pepco statement on DERMS: "A DERMs should be capable of dispatching DERs by priority with the intent of flexibility interconnecting those DERs or utilizing those DERs as non-wires solutions to alleviate load driven grid constraints. Furthermore, a DERMs shall be capable of providing locational and time value compensation to DERs to replace net metering."
[97] Formal Case No. 1176, Exhibit DCG A-13 (D.C. Pub. Serv. Comm'n 2024).
[98] Formal Case No. 1176, 47 (D.C. Pub. Serv. Comm'n 2024).
[99] Formal Case No. 1176, Exhibit DCG (A)-13. RESPONSE TO DCG DATA REQUEST NO. 9 QUESTION 2 (D.C. Pub. Serv. Comm'n 2024).

capabilities like DER visualization, DER estimation, DER forecasting, and DER monitoring and DER control.

DERMS enables utilities to exercise distributed control over DERs across the grid. IEEE 1547-2018 mandates that smart inverters support secure, two-way communication with utilities and grid operators.[100] While smart inverters already provide voltage regulation and frequency control, they can be further leveraged by dynamically adjusting set points in response to real-time grid conditions. Adopting protocols like IEEE 2030.5, DNP3, or SunSpec Modbus can allow for PV systems to be dispatched similarly to conventional power plants via API or web based signals.[101]

If Pepco can monitor the grid at a high enough frequency, it can treat DERs as dispatchable assets, responding to system events such as voltage fluctuations and thermal loading. This functionality helps maximize hosting capacity, by providing real-time situational awareness, forecasting potential hosting capacity violations, and actively controlling inverter set points to balance generation and demand. For example, if excess solar generation risks overloading the system, set points can be adjusted to curtail output. Conversely, an energy storage system can be dispatched to meet a sudden power demand. An approach like DERMS enhances grid reliability and enables greater DER integration without requiring costly infrastructure upgrades.

Energy Storage Provides Control Over Balancing Supply and Demand

DERs that generate power like PV systems are normally referred to as passive generation assets because they must be integrated with smart inverters, DERMS, or energy storage to become dispatchable grid-supporting resources. Integrating PV systems with energy storage systems (ESS) and power control systems allows for utilities using DERMS to actively shift energy generation to meet energy demand by storing curtailed power for dispatch during forecasted power demands.[102]

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[100] Pepco has expressed concern over needing to implement direct controls in a DERMS system like the ability to turn off a DER. Pepco has also expressed concern over needing to estimate potential curtailment periods for applicants but have noted that batteries may be able to be used to reduce curtailments if sited close to the generating DER.

[101] DERMs can be designed to implement direct or indirect control by a utility. Pepco has expressed concern over implementing a DERMs system that exercises direct control over DERs on the grid. First, DERMs can be designed to exercise indirect control over multiple assets where each DER is incentivized to perform certain grid operations on a periodic basis like voltage or frequency regulation through changing its power output- this is similar to market operators sending market signals that a power plant responds to. In the market scenario and DERMs scenario the operator is not responsible for sending a signal to each asset rather it publishes a signal that assets can choose to subscribe to and hence participate in regulating the grid. Here Pepco is not responsible for controlling each asset. Second, if Pepco chooses to exercise direct control over assets on the grid when necessary, these commands can be sent via API requests or topic publications. Solar installers are able to set up web based communication on commonly used inverters like SMA to receive these commands or subscribe to such topics.

[102] Power control systems are a primary way for DERs to meet their limited generation profiles. IREC News & Press Releases, "Milestone Decision by California Regulators Approves the Use of DER Schedules to Avoid Interconnection Upgrades" (March 21, 2024), accessed March 31, 2025.

ESS: Energy storage systems or battery based systems can store or charge energy from renewable sources or from the grid and then release or discharge it when needed.

Hybrid systems, such as a solar and energy storage system (PV-ESS), can integrate at a single point of interconnection through a single inverter. Sharing a single inverter allows for power flow to be directly managed between the solar array and ESS without incurring power losses through DC to AC conversion.[103] The smart inverter can manage the charging and discharging of the ESS while optimizing the energy generated by the solar panels.

Even without the integration of DERMS, integrating solar PV systems with ESS alleviates hosting capacity issues at the local level by storing the excess power generated that would likely be curtailed.[104]

Solar curtailment: the intentional reduction or restriction of electricity generation from solar photovoltaic (PV) or solar thermal systems. This occurs when the amount of solar energy produced exceeds the capacity of the grid to absorb or distribute it effectively. Curtailment is typically implemented to maintain grid stability and prevent damage to infrastructure, and it results in wasted energy and lost revenue. When batteries are included in the context, solar curtailment also refers to situations where excess solar energy cannot be stored because battery storage systems have reached their capacity or are unavailable.

Smart inverters treat all integrated systems equally, meaning a connected battery cannot discharge if solar power is being curtailed. Inverter set points take precedence over both the battery and solar power flows and ensure that outflow at the point of interconnection remains within the local hosting capacity limits.

Although smart inverters will curtail excess power generated by a solar PV system, it does not allow for residents to take advantage of larger installations. For example, if a resident is able to generate 10 kW but their local hosting capacity limits them to export a maximum of 6 kW, the inverter will curtail the excess 4 kW. However, by installing a large enough ESS alongside the solar PV system, the excess power (4kW) can be charged to the battery, while the 6kW of solar generation can flow into the grid. If the battery is full, the inverter will curtail the solar generation to ensure that the power exported does not exceed the hosting capacity limit.

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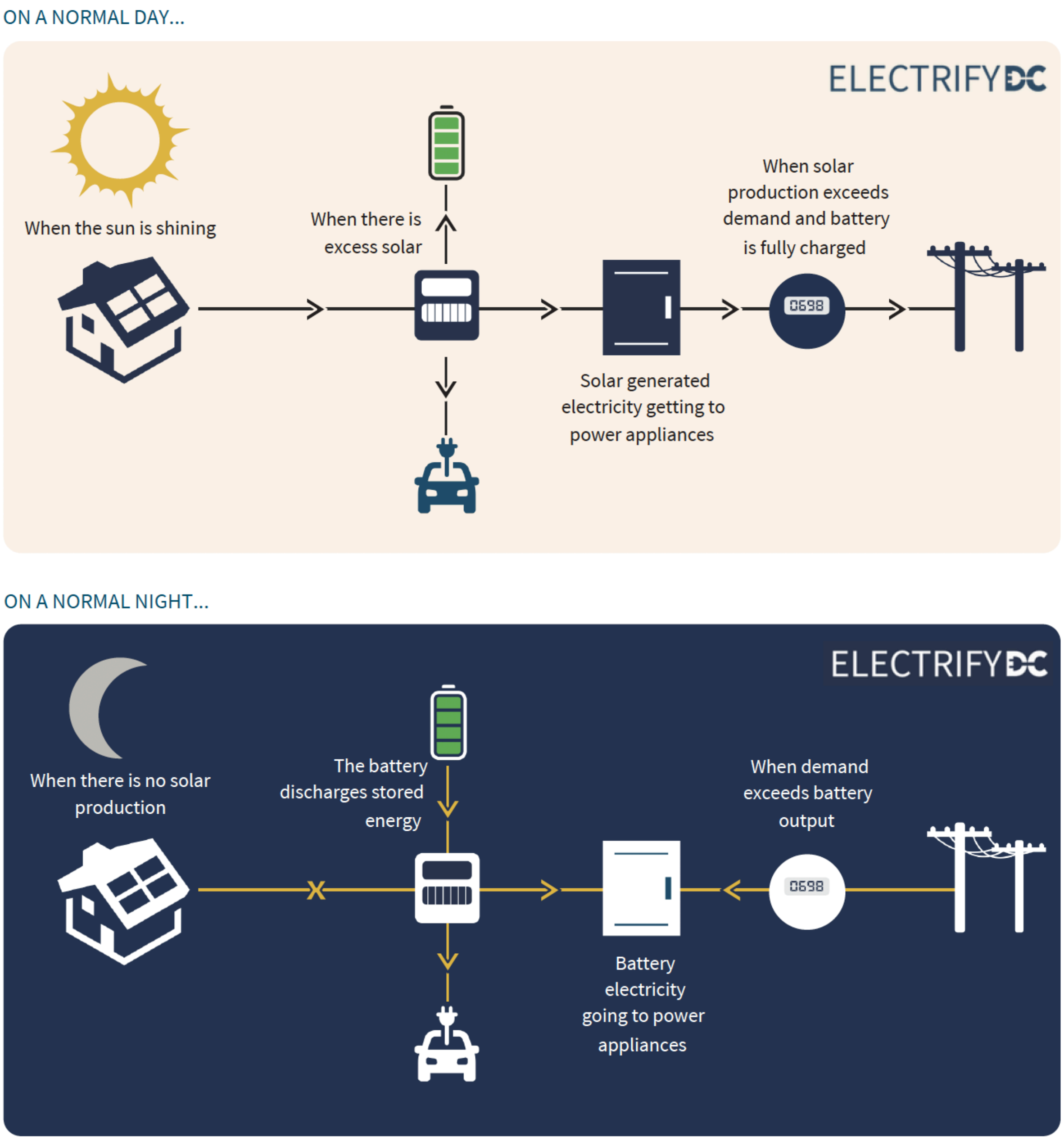
[103] Inverter design is a customer choice. Pepco's interconnection rules in DC (per DCMR 15-40, the Small Generator Interconnection Rules) categorize DER systems based on their electrical connection point—not each inverter device – meaning customers are able to choose how their systems are designed behind the meter.

[104] Pepco has expressed concern that DERMS would be needed to ensure that it can control DERs behind the meter, for example ensuring that curtailed solar power is flowing from PV to battery. However, DERMs are not meant to control assets behind the meter. DERMs are meant to send the appropriate signal to any system where the smart inverter can then exercise control to ensure it remains in compliance with its point of interconnection. Pepco's compliance with IEEE 1547-2018 ensures that DERs are interconnected with a smart inverter. Refer to SMA's smart inverter solution for residential batteries and solar systems: *SMA Energy Solution.*

Figure 11: Residential batteries store curtailed solar, preventing both wasted energy and excess power injection



This integration of PV systems and ESS allows residents to maximize their solar generation potential, reduce wasted energy, and comply with local hosting capacity limits. In Electrify DC's correspondence with Pepco, Pepco stated that batteries are not included in hosting capacity measurements. The inclusion of a battery system alongside a solar installation is currently not considered to alleviate local hosting capacity limits. This is likely due to difficulties in modeling the power flow analysis and understanding how best to capture a “worst case scenario” for a hybrid system in line with Pepco’s static hosting capacity measurement.

Investing to Migrate to a Dynamic Hosting Capacity Measurement

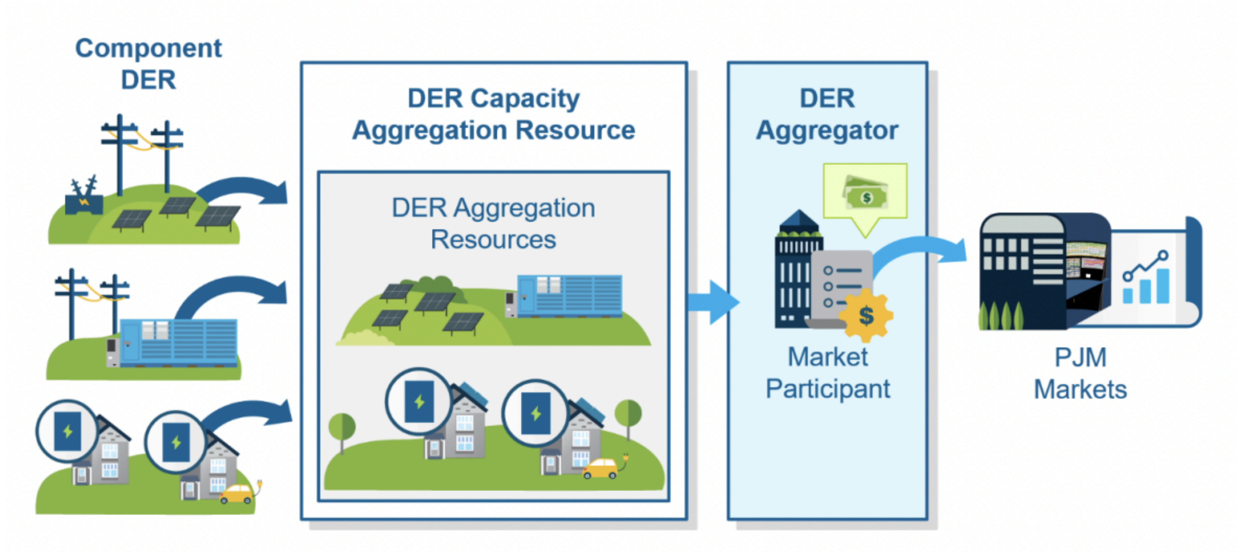
In order to realistically include batteries in the hosting capacity measurement, Pepco will have to move towards a dynamic hosting capacity measurement that can take into account inverter control, ESS integration, and DERMS to reflect their own planned investments (ADMS). The team recommends that Pepco transition to automating their power flow analysis for hosting capacity by utilizing industry software that supports scripting languages, such as EPRI’s OpenDSS with Python. This approach would enable the automation of workflows through cloud-based software infrastructure.

Pepco should also consider requesting approval for investments to modernize its software architecture. This migration would enable automated power flow analysis contained in cloud functions (triggered by network changes to feeders or approved solar applications) and facilitate the aggregation of high-resolution telemetry data. Investing in software and data science would allow Pepco to alleviate the manual workload of processing solar applications, including conducting local power flow analyses and determining inverter set points, each time a new application is submitted.

Pepco and the DC PSC should be motivated to make these investments into Pepco’s software infrastructure to facilitate the District's migration to comply with PJM’s proposed implementation of FERC 2222 slated to go into effect February 2026. PJM has proposed a new “DER Aggregator Participation Model” that will allow component DERs like rooftop residential solar to aggregate across a single pricing node to form a DER Capacity Aggregation Resource of at least 100kW and at most 5 MW to participate under a DER Aggregator in the PJM Markets.[105,106]

[105] PJM Interconnection, L.L.C., Data Miner, *Pricing Nodes* (2025).
[106] PJM Interconnection, L.L.C., *Order No. 2222 Compliance Filing of PJM Interconnection, L.L.C.* (2022), 5.

Figure 12: PJM's proposed DER aggregator participation model[107]



According to PJM's proposed implementation of FERC 2222, Pepco will be required to make changes to its utility operations to allow for PJM dispatch of DER Aggregators and determine when PJM dispatch must be overridden for its own grid operations. The proposed model does not prohibit Pepco from forming its own DER Aggregation Resources and participating as a DER Aggregator.[108] PJM has designated state and local regulators, such as the DC PSC, to oversee these operational relationships and adjudicate disputes between the DER Aggregator and local distribution utilities like Pepco.

In line with high resolution telemetry recommendations, DER Aggregators will be required to provide high resolution telemetry data at the resource level through forecasting (±2%) to PJM or real time readings of component DERs for the market they are participating in. Under this model, DER Aggregators will be required to participate in at least the Capacity market meaning a resolution of at least 1 minute is required.[109]

[107] PJM Interconnection, L.L.C., *Order No. 2222 Compliance Filing of PJM Interconnection, L.L.C.* (2022), 5.
[108] PJM Interconnection, L.L.C., *Order No. 2222 Compliance Filing of PJM Interconnection, L.L.C.* (2022), 15.
[109] PJM Interconnection, L.L.C., *Order No. 2222 Compliance Filing of PJM Interconnection, L.L.C.* (2022), 60.

Figure 13: PJM's telemetry requirements per market[110]

MARKET		TELEMETRY	ACCURACY
Capacity		1 minute data	+/-2%
Energy Only	<10 MW	No real-time telemetry required	
	≥10 MW	1 minute data	
Regulation		2/10 second data	
Reserves		1 minute data	

PJM has expressed concern that jurisdictions may not be able to comply with the requirements by February 2026 and has requested an extension till February 2028 to FERC. However, several jurisdictions within PJM and the Exelon family, like New Jersey and Atlantic City Electric, have already convened with their regulatory commissions to discuss how to comply with PJM's implementation of FERC 2222.[111] Although outside of PJM, New York's utilities under NYISO held a stakeholder session in 2022 to determine the necessary software architecture changes for compliance with a similar DER Aggregator Model, which also has comparable telemetry requirements.[112]

Implications of PJM's Proposed Implementation of FERC 2222 on Net Metering

Net metering was originally developed because analog meters on typical homes and businesses were incapable of handling any more sophisticated tracking of volume, direction, or time of electricity consumption. Net metering credits customers by counting the kilowatt-hours that flow into the building and charge the customer for that amount. This allows for any surplus generation from the DER to be used by the grid.[113]

The District of Columbia's § 34-1518 on Net Metering limits residential systems subscribing to Net Metering to have an individual system capacity limit of 1 MW.[114,115] However there is no limit for the total amount of solar that can participate in net metering across the District.[116] The absence of aggregated net metering in the District has raised concerns, in comparison to Maryland, which allows for aggregate net metering.[117] However, PJM's implementation of FERC

[110] PJM Interconnection, L.L.C., *Order No. 2222 Compliance Filing of PJM Interconnection, L.L.C.* (2022), 60.
[111] PJM Interconnection, L.L.C., New Jersey Board of Public Utilities, *DER Aggregator Participation Model: Overview* (2025).
[112] Joint Utilities of New York, "DER Real-Time Telemetry: Distribution Utility Solutions" (2022).
[113] Travis Bradford, "The Energy System: Technology, Economics, Markets and Policy" (2018).
[114] Council of the District of Columbia, *§ 34–1518. Net metering* (2013).
[115] EnergySage, "How does Potomac Electric Power Company (Pepco) net metering work?" (2024).
[116] EnergySage, "How does Potomac Electric Power Company (Pepco) net metering work?" (2024).
[117] Solar United Neighbors, "Net metering in Maryland" (2024).

2222 may help address these concerns, as it requires DER aggregation across multiple utility points—not only within a single residential building but across a pricing node—to meet the 100 kW threshold.

To comply with FERC 2222, net metering programs and regulations promulgated by the Commission will need adjustments to accommodate component DERs that participate in both net metering and market programs, ensuring that aggregation does not lead to double compensation concerns.[118]

Stephen's unexpected $20,000 charge and frustrating delays

"A couple other neighbors had gotten solar panels and I read how DC is an uniquely well-suited place for solar and SRECs," said Ward 3 resident Stephen who in March of 2022, after thorough research and discussions with several solar installers, selected one who designed his array and submitted installation plans to Pepco. Mistakenly assuming the plans had been approved, the installer proceeded with installing the panels on Stephen's roof before Pepco officially signed off on the project.[119] Weeks later, Pepco informed the homeowner that additional upgrades to their electrical lines were necessary to accommodate the solar output. This unexpected requirement came with a price tag of $20,000.

Frustration mounted as the homeowner navigated through months of back-and-forth negotiations with both Pepco and the installer, while his new solar panels sat unused on his roof. The homeowner engaged with OPC and participated in a lengthy and ultimately unproductive mediation process with the DC PSC. Despite presenting evidence and data, the mediation failed to provide a resolution suitable for the homeowner who was deemed liable for the full upgrade cost.

Pepco offered the option to install a smaller system, but the homeowner was set on a full installation. Ultimately, the solar installation company agreed to cover $15,000 of the $20,000 upgrade cost, with the homeowner paying the remaining $5,000. The District missed out on roughly a year of solar generation.

[118] PJM Interconnection, L.L.C., Order No. 2222 Compliance Filing of PJM Interconnection, L.L.C. (2022), 41.
[119] Pepco attributes this issue to installer error.

District Residents' Experience and Knowledge

"What is the truth about the return on investment for the owner for installing solar panels on their house? Sounds too good to be true where it is 'free' to install solar panels on a house; there's no such thing as 'free'"

Ward 7 Resident

To understand local experiences and knowledge around hosting capacity, DERs, and grid interconnection, Electrify DC conducted a survey of 315 DC residents promoted across a broad array of channels.[120]

The survey asked a minimum of 35 unique questions between two primary tracks, one for homeowners and one for renters, which diverged in relevant questions about solar and installation experiences. Sixty out of the 315 respondents chose to provide additional feedback which provided insights on the solar and electrification experiences and opinions of residents.

Demographics

In addition to collecting information on whether respondents owned or rented their homes which was necessary to present them with questions relevant to them, the survey collected basic demographic information on age, income range, race and ethnicity, gender, as well as household size and type. Three fourths of respondents are homeowners, with renters making up the rest. This higher-than-representative proportion of homeowners (in the District, homeowners make up between 40 to 45% of households) is likely a factor in the overrepresentation of White and more affluent respondents.[121] The higher-than-representative proportion of homeowners may also be a factor in the fact that, although respondents are well distributed across wards, Ward 4, which has the highest percentage of homeowners, is overrepresented among respondents and Ward 8, which has the lowest percentage of homeowners, is underrepresented. Although this underrepresentation of renters does not affect the results of the survey, as responses by homeowners and renters were analyzed separately, it might be indicative of renters' feelings towards solar as something that does not concern or benefit them enough to want to engage in a survey about it.

Of the 315 respondents, 48% reported having installed or being in the process of installing solar. Respondent self-selection might have led to more respondents familiar with DERs than what is normal for DC, as only 14% of District viable roofs have solar installs.

[120] Pepco has expressed reservations about the survey results.
[121] In DC, White residents account for 39% of residents and 51% of homeowners. In this survey they account for 64% of all respondents and 68% of homeowners respondents: United States Census, "Black or African American Population in Washington, D.C.," accessed 2025

Key Findings

- ➔ At least 11% of respondent homeowners had troubles with interconnection.[122]
- ➔ 86% of respondent homeowners who do not have solar considered installing it.
- ➔ Income does not seem to make a difference in adoption rates or knowledge.
- ➔ 79% of respondents who installed or are installing solar are using the rebates.
- ➔ 50% of respondent homeowners who installed solar but did not install a home battery cited cost of home batteries as an impediment to installation.
- ➔ 46% of respondent homeowners who did not install a home battery indicated that they did not understand the benefits of installing a home battery.
- ➔ Respondents self-report low knowledge about DERs, hosting capacity and the grid in general.
- ➔ 75% of respondent homeowners and 83% of respondent renters want to know more about DERs.
- ➔ Over 35% of all respondents want to know how they can become net producers of energy and sell it back to the grid.
- ➔ Renters want to find out more about community solar potentially joining the solar adoption movement
- ➔ Among respondents, many reported being unclear about how solar co-ops work and are structured, if co-ops are less expensive, and, for those respondents who already have DERs, if a co-op arrangement would be possible and/or advantageous.

"Would [Electrify DC] like to present to the community about the ins and outs of installation?"

ANC Commissioner in Ward 4

Most Frequently Cited Barriers to Solar Installation

Among homeowners who did not install solar, most frequently cited barriers to solar installation are:

- ➔ **Upfront Costs**: Many respondents believe that the initial investment is a barrier, even when considering long-term savings.
- ➔ **Roof Incompatibilities**: Issues with roof condition, shape, and location were raised as an obstacle. Several respondents mentioned needing roof repairs or replacements before installation, while others raised tree cover and structural incompatibility as hindrances.
- ➔ **Lack of Knowledge**: Approximately half of respondents expressed uncertainty about the solar installation process, available tax incentives, had SREC confusion, and questioned the long-term benefits and maintenance costs. A few mentioned not knowing anyone with solar, which may contribute to low solar adoption rates.

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[122] In several cases, residents are unaware of issues because the solar installer manages much of this process. Future surveys should include solar installers.

- ➔ **Regulatory and Permitting Issues**: Historic property regulations, condo association rules, and complex permitting processes were mentioned by multiple respondents as obstacles. This likely creates a feedback loop between lack of knowledge about exceptions and apprehension of navigating permitting and approval processes.

"The roof is not currently in need of repair or replacing, but I have thought that it might be best to do that step first prior to moving ahead with solar panels"

Erica M., Ward 6

How Survey Findings Inform Hosting Capacity Considerations

The findings provide several takeaways regarding hosting capacity and the challenges and opportunities for increasing DER adoption. Although there are clear interconnection challenges experienced by some residents, and upfront costs are a significant deterrent for solar and battery installations, there is high interest and latent demand for solar adoption with 86% of responding homeowners who do not have solar considering installation, 77% of all respondents expressing interest in learning more about these topics, and over 35% of respondents wanting to know how to become net producers of energy and sell it back to the grid.[123]

These results hint to a District population healthily ready for DERs, regardless of roof ownership or condition. By addressing these barriers and leveraging the expressed interest in DERs as suggested in this report's recommendations, DC PSC, DOEE and Pepco can significantly expand hosting capacity while fostering a more resilient and sustainable energy grid.

Regulatory Context

As Pepco's regulator, the DC PSC works for the best interest of the District as a whole, and should require Pepco to capture and enable the benefits that DERs can provide (as well as minimizing any costs they cause).

The DC PSC is not alone in addressing the challenge of growing DERs–regional wholesale markets are also being forced to adapt. FERC Order 2222 sets rules for customers with DERs, DER aggregators, local distribution utilities (Pepco), and regional transmission operators (PJM).[124] In order to comply with FERC Order 2222, Pepco needs to both ensure that it is enabling DERs that wish to participate in the PJM markets to interconnect, and identify what grid upgrades may be required. Pepco also must establish appropriate metering and telemetry processes to enable aggregators to participate in PJM's markets. Actions that Pepco and the

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[123] While Pepco concedes that the survey data indicates high interest among respondents who don't have solar, they have expressed concerns about potential income bias.

[124] Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators, Order No. 2222, 172 FERC 61,247 (2020).

DC PSC must take to comply with Order 2222 are consistent with the methods and vision for improved hosting capacity, and thus interconnection, described in this report. Adopting the recommendations of this report would make Order 2222 compliance more straightforward. In line with PJM's proposed implementation of FERC 2222, the DC PSC will serve as the regulatory authority to hold Pepco accountable for enabling interconnection and facilitating market participation of residential DERs within the District.[125]

After a year and a half, Ed moves on

In April of 2021, Ed's family decided to install solar panels on their Ward 5 home to contribute to clean energy, to benefit from the District's financial incentives, and to join their neighbors who had successfully just done the same. In June, Ed joined a co-op that worked with the installer he had chosen and signed a contract with that installer using their financing. Several months later, in November, Pepco notified Ed that the planned nine-kilowatt system would require a costly upgrade to a 50-kilowatt transformer. The interconnection charge presented was $7,600, adding unexpected financial strain to the overall project cost, which was around $40,000.

In March of 2022, Ed asked OPC for assistance. With their help, he registered a complaint with the DC PSC which led to an unsuccessful mediation with Pepco and the installer. In June, with the assistance of OPC, Ed requested a formal hearing with DC PSC. Pepco dropped the cost to $6,700. In September of 2022, Ed received another letter from Pepco reducing the cost to $2,400. "As Pepco lowered charges, the explanations didn't make sense. It seemed to be 100% due to our pushback–in essence a negotiation." Ed added, "People shouldn't have to haggle over these charges."

Ultimately, while the interconnection charge was now manageable, Ed decided to cancel the solar installation due to an upcoming move. Ed felt the process was arbitrary, lacked transparency and consistency, and highlighted systemic issues with Pepco's pricing methodology.

[125] PJM Interconnection, L.L.C., Order No. 2222 Compliance Filing, Docket No. ER22-962-000, at 10 (Feb. 1, 2022).

Key Recommendations

While one might expect a report on hosting capacity to primarily recommend improvements in measurement, procedures and data transparency, our analysis reveals a more fundamental need for change. Hosting capacity, though valuable, is ultimately a limited internal metric that alone cannot fully support the scaling of DERs. While enhancing hosting capacity analysis accessibility would address some issues highlighted by the OPC Memorandum and Electrify DC's case studies and survey, a paradigm shift towards comprehensive grid codes is necessary to truly transform the energy landscape.

As Pepco shifts from serving customers to serving prosumers, adopting recommendations in the following areas will accelerate solar deployment and decrease frustration for District residents and installers:

1. Grid Codes: Developing robust, forward-looking regulations to guide DER integration
2. Smart Grid Planning and Investment: Modernizing infrastructure to support increased DER adoption
3. BTM Battery Incentives: Encouraging energy storage solutions to enhance grid flexibility
4. Customer-Facing Hosting Capacity Maps: Enhancing transparency and accessibility, including refined hosting capacity information
5. Interconnection Process: Streamlining, leveraging machine learning and better aligning the hosting capacity maps
6. Public Education: Empowering residents to understand and participate in the clean energy transition

By focusing on these interconnected aspects, rather than solely on hosting capacity, the District can create a more resilient, efficient, and sustainable energy ecosystem that fully leverages the potential of DERs.

Develop Comprehensive Grid Codes

Grid Code: technical specification or set of rules that governs the connection, operation, and maintenance of facilities connected to an electricity grid. These facilities can include electricity generation plants, consumers, or other networks. The primary purpose of a grid code is to ensure the safe, reliable, and efficient functioning of the electric system.

While Pepco has been developing grid codes and interconnection standards over the years, and complies with all relevant Commission and industry standards, these efforts have often been shaped by the limitations of existing technologies and legacy systems. The Public Service Commission (DC PSC) should take a more proactive leadership role in guiding the development of grid codes that are holistic and technology-agnostic—focused on desired system behaviors and outcomes rather than the capabilities of currently deployed infrastructure. By adopting flexible and standardized grid codes, the DC PSC can ensure faster adaptation to emerging renewable energy technologies while maintaining system stability and reliability.[126]

Rather than emphasizing hosting capacity, which is an internal measurement of grid or feeder performance, Pepco—as the system operator—should prioritize understanding its system requirements. This includes developing interconnection standards and establishing a robust automated process for approving interconnection applications based on modeling and simulation results for proposed projects.[127] The DC PSC and Pepco can collaborate with technical bodies such as IREC (Interstate Renewable Energy Council) or ESIG (Energy Systems Integration Group) to create viable grid codes that address the dynamic capabilities of new technologies without requiring frequent updates every time Distributed Energy Resource (DER) technologies evolve or the grid configuration changes.[128,129] These grid codes should encapsulate the interactions between new systems and the existing grid infrastructure, ensuring seamless integration.

While PJM's standards focus on transmission-level grid codes, distribution codes are left to individual states. The DC PSC can look to states like Texas, which have successfully implemented state-wide distribution grid codes, as a model for creating effective and scalable frameworks.[130] Given the complexity of implementing and maintaining grid codes, it is essential that the DC PSC leads this process in collaboration with experts such as IREC and ESIG.

Grid codes should still account for feeder-specific characteristics. For example, metrics like short circuit ratio or local hosting capacity can provide valuable insights into a feeder's strength and sensitivity, which are critical when integrating DERs. To achieve this, Pepco must have a thorough understanding of its grid—its components' interactions, the influence of system states (e.g., excess power generation versus consumption), and conditions required for stability.

Cities and Independent System Operators (ISOs) have often updated their grid codes in response to rapid adoption of bidirectional devices like batteries. These devices serve dual roles as market participants and tools for alleviating grid stress by dynamically absorbing or releasing power to meet energy demands and hosting capacity limits. Recognizing this trend, Pepco and the DC PSC should focus on developing grid codes that address three key categories: Generation Devices, Load Devices, and Bidirectional Devices.

We recommend initiating this process in summer 2025 with a target completion date by mid-2026. A working group approach—similar to ERCOT's process for updating its grid codes—should be adopted to ensure stakeholder engagement and incorporation of best

126 IRENA, "IRENA Grid Codes Renewable Systems" (2022), 11.
127 Pepco states that these efforts are underway.
128 Pepco has expressed concerns about how accountability and liability will be distributed in ways that ensure system safety and reliability.
129 ESIG, "ESIG ERCOT Technical Workshop" (2025). Collaboration between ESIG and ERCOT.
130 ERCOT, "ESIG EPRI ERCOT Task Force" (2022).

practices. This effort is particularly critical as the District powers the nation's capital, positioning itself as a leader in modernizing grid infrastructure to support renewable energy integration.

Require Smart Grid Planning and Investment

The DC PSC should require Pepco to present a clear plan for upgrading controls and monitoring for the grid and BTM assets over the next five years, as part of the new Integrated Distribution System Plan discussed in Formal Case No. 1182.[131] This will provide greater insights about what grid upgrades might be required to handle increased loads from electrification, and what is going on at the feeder levels at smaller time intervals. Integrated planning will enable more proactive investment in the final grid and will avoid iterative replacement.

The DC PSC should require Pepco to account for the age, as well as the capability, of its grid assets, as it plans and executes grid upgrades. Where possible, Pepco should plan for the grid it's going to need and replace assets with that grid in mind, before they are old enough to require replacement. Incremental capacity, added at time of replacement, is generally much more cost effective than retrofitting or revisiting to add capacity, when capacity has been consumed. The DC PSC could consider the model of a recent Colorado law[132] that allows the utility to proactively invest in greater capacity assets, if planned as part of an approved comprehensive distribution system plan. Pepco may need more capable software platforms to conduct this planning while supporting our other recommended actions.

Incentivize Behind the Meter Battery Adoption

Given the importance of BTM batteries in easing hosting capacity issues, the need for accelerating battery deployment, and the District residents' lack of familiarity with batteries, we recommend that DC PSC require Pepco to conduct consumer education. Pepco, in collaboration with DOEE, can provide education about consumer batteries including the most appropriate way to incentivize the purchase and installation of BTM batteries, and PJM can set a capacity target of at least 3 kWh (available through 2032).[133] This would be supplementary to the federal 30% tax credit for eligible battery storage systems.

Additionally, DOEE should look for opportunities to expand access to storage alongside Solar for All and the Affordable Home Electrification Program and Affordable Housing Retrofit Accelerator programs, administered by the DC Sustainable Energy Utility under contract with DOEE. However, it should be noted that PJM's implementation of FERC 2222 will allow any type of DER, including batteries, to participate in wholesale capacity markets, by aggregating

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[131] In the Matter of the Investigation into the Implementation of Integrated Distribution System Planning for Electric Utilities, No. 1182 (D.C. Pub. Serv. Comm'n 2024).
[132] Colorado Law SB 24-218, Modernize Energy Distribution Systems (2024).
[133] U.S. Department of Energy, *Making Our Homes More Efficient: Clean Energy Tax Credits for Consumers* (2022).

with any other DERs under a single pricing node, enabling battery owners to recover financial investments through an additional revenue stream.[134]

Modernize Hosting Capacity Maps

The DC PSC should require that Pepco develop a dynamic hosting capacity map based on analysis that uses a parallel structure to that used by Pepco for its interconnection assessment. This will improve the Hosting Capacity Map's usefulness as an indicator for solar developers and consumers. This map should be publicly available, user-friendly, with actionable information that all residents, solar installers, developers, and other stakeholders can rely on to determine if they can add DERs (and what dynamic restrictions those DERs would need to operate under) without the need for additional steps. As discussed in the hosting capacity analysis findings above, this map should account for the ability of battery storage to provide voltage support as well as limit problematic injection. Given the dynamic nature of DER integration, the map should be updated frequently enough, via automated processes, to remain useful. In addition to minimum load and thermal rating, the map should include local power flow analysis at the customer-level, incorporating, at a minimum, factors such as voltage, thermal capacity, power stability, inverter settings and on-site measurements, geospatial data, and using models to forecast both current and future hosting capacity.

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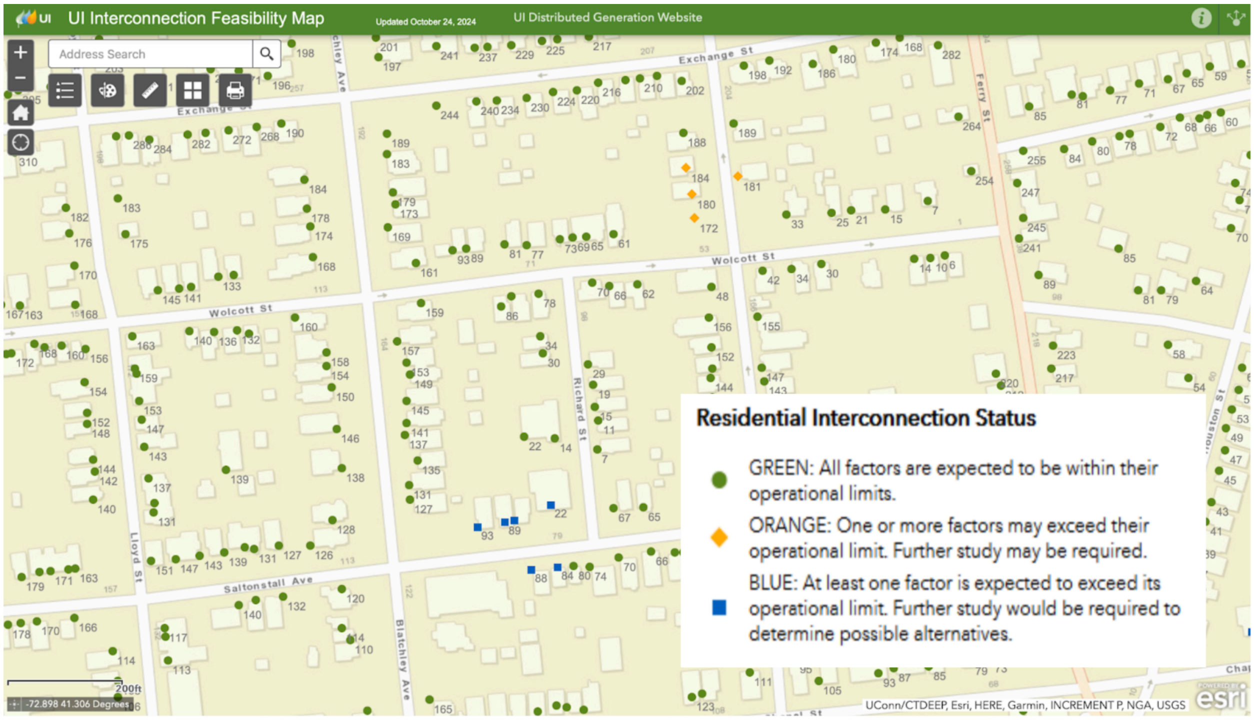
[134] PJM Interconnection, L.L.C., *Order No. 2222 Compliance Filing of PJM Interconnection, L.L.C.* (2022), 36.

Figure 14: UI Interconnection Feasibility Map showing customer-level data on hosting capacity[135]



Results from Electrify DC's survey could inform aspects of this customer-facing tool. Additional focus groups should be run to ensure the information provided is not only accessible and understandable by District residents, but also results in an overall better consumer experience.

Streamline Interconnection Process

The DC PSC should set clear expectations for an improved interconnection process. It should look to the example set by the Hawaii Public Utility Commission's Performance Based Regulation process for interconnection process improvement, which set clear performance mechanism for the Hawaii electric utilities to meet.[136] These performance measures have resulted in measurable improvements in interconnection timelines by the utilities.[137] The DC PSC should also hold Pepco accountable for excessive costs and delays that undermine the economic viability of clean energy investments for homeowners and other stakeholders, who

[135] Map by Connecticut utility UI showing that customer-level data on hosting capacity is being published without raising confidentiality issues: UI Hosting Capacity
[136] State of Hawaii Public Utilities Commission, "Performance-based Regulation (PBR) for the Hawaiian Electric Companies (Docket No. 2018-0088)," accessed 2025
[137] Letter to Chair and Members of the Hawai'i Public Utilities Commission, "18-0088 – Performance-Based Regulation Hawaiian Electric Companies' Revised PIM," accessed 2025

are moving in the right direction in meeting the clean energy goals of the District.[138] Regular audits of interconnection processing should be mandated and penalties should be imposed for non-compliance with the DC PSC's expectations. A clear accounting of why an upgrade is needed, with more itemized detailing from Pepco, is needed for both the solar installers and the customers. While solar installers may need more technical details, customers may need simpler cost breakdowns. We hereby incorporate, by reference, the recommendations of Interstate Renewable Energy Council (IREC), detailed in a recent blogpost from IREC on interconnection challenges in DC.[139] In the long-term, as DER penetration increases, the interconnection process should evolve towards streamlining interconnection applications leveraging advanced technologies (e.g., automation, AI-based grid management). Additionally, DC PSC will need to intervene where the timeframes set by PJM's proposed implementation of FERC 2222 are exceeded.[140]

Enhance Consumer Education

The education of District residents about their role in the clean energy transition is vital, as they are the ultimate decision makers on residential solar and battery adoption. Homeowners, renters, and, importantly, installers and other home renovation contractors require clear and actionable information from trusted sources to take action and participate in the District's energy future. The DC PSC, DOEE and Pepco each have a role to play in educating District residents about what they can do to help meet and exceed the District's clean energy goals. The DC PSC can increase regulatory clarity and mandate education on the part of our utilities. DOEE can provide additional information about environmental benefits, incentives and programs relating to solar and, in the future, batteries. Pepco can clearly communicate the technical steps to solar installation, net metering, battery installations, and demand response programs. This education on wholesale market participation incentives is mandated by FERC 2222. Other companies in the Exelon family have already convened on how to best make this information available to consumers.[141,142]

Electrify DC recommends the following education initiatives.

Demonstration Sites

Exploiting the power of social imitation, the DC PSC should sponsor one demonstration site in each of the 131 neighborhoods of the District, along the lines of Electrify DC's Demonstration Homes, where early adopter homeowners open their homes to their neighbors for community

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[138] Pepco asserts that the DC PSC should also have more insight into the costs and timelines associated with interconnection, as well as how those factors impact the economic feasibility of clean energy investments.
[139] IREC, *Persistent Interconnection Challenges Risk DC's Clean Energy Goals* (2024).
[140] PJM Interconnection, L.L.C., Order No. 2222 Compliance Filing, Docket No. ER22-962-000 (Feb. 1, 2022).
[141] N.J. Bd. of Pub. Utils., Order No. 2222 Technical Conference — Presentation Materials (Jan. 17, 2025).
[142] Pepco notes that while the DCSEU is currently funded and mandated to provide energy efficiency programs and customer education in this region, Pepco is not.

events.[143] During these Open House events, participating homeowners can explain how the solar systems on their roofs and the batteries on the side of their buildings work together to reduce their energy burden and decrease the 25% of emissions that come from the District homes, and, most importantly, how they took advantage of incentives, financing and government programs to do so.

> "I understand that it is the future of electric generation. [...] But no one is passing the word. [...] And this is the time to get on the "bandwagon" to save and improve one's property at the same time."
>
> Thom, Ward 4

Public Service Announcements

With the help of the District's communication infrastructure, DC PSC should run a public education campaign across local TV stations and social media to inform residents about the goals of the District and how residents can help meet those goals while benefiting from the programs and incentives available and improving their resilience from a changing climate. The "scrollytelling" format, originally proposed by Electrify DC to share the results of this study, is a storytelling format in which visual and textual elements appear or change as the reader scrolls through an online article or information, making it a visually appealing way to engage and educate the general public.[144] Messaging should be informed by the results of Electrify DC's survey to identify

Inserts in Utilities Bills

A tried and true way to educate consumers is through bill inserts. DC PSC should mandate that Pepco and Washington Gas add inserts in their bills explaining how and why home electrification is key to the clean energy transition, how installing solar on every suitable roof protects residents from the vagaries of electricity prices, and practical information on how to install solar, add home batteries, and benefit from programs and incentives to do so. Such inserts should be designed by Pepco, with input from DC PSC and DOEE.

Homeowners/Renters' Hub

Hosted on DC PSC, DOEE, Pepco, DCSEU or Electrify DC's website, the homeowners/renters' hub would provide centralized online resources on technical guidance, financial incentives, and step-by-step guides to permitting/interconnection for installing DERs.[145] The hub would offer different resources depending on income and ownership status to avoid customer frustration.

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143 Electrify DC, "Demonstration Homes" (2025).
144 Built on the Vev or the Shorthand platform depending on several considerations including which integrates best with DOEE and DC PSC's websites.
145 Electrify DC, "Regional Electrification Working Group Initiatives" (2025).

"I'm a renter who has looked a ton into trying to get solar installed where I rent. It is really difficult to navigate the website and to find out if I qualify for anything. It seems like most programs are only available to homeowners. Would love there to be more available for renters since we make up such a big part of DC."

Kara B., Ward 1

Large Public Event

Free consumer-facing fairs are important for residents to be able to touch, see, interact face to face with vendors, hear from experts, participate in hands-on workshops, etc. Electrify DC obtained validation of the need for consumer-facing education events like the Healthy Homes Fair from the attendance to last year's event and from several respondents to the survey. DC PSC and DOEE should double down on their support for this event and provide funding to ensure its sustainability.

"I think it would be helpful if DOEE were to conduct a "solar fair" where trustworthy experts from DOEE could give info about ways to obtain solar and financial incentives, and then have vendors there to talk about specifics. I think many people would be interested in getting trustworthy information (vs. marketing pitches) and are both early adopters and have money to invest in their homes which they own. It would help to see more solar installations in the neighborhood as an incentive for others to learn more."

Chuck E., Ward 3 (ANC Commissioner)

Contractor List

According to Electrify DC's survey, half of homeowners who installed solar had issues with the professionals installing it. Educating District residents on how to select reputable contractors and being able to point them to a list of vetted installers with customer ratings and price ranges for services would improve consumer experience and accelerate solar deployment.[146] The District would lead the region by addressing the need for a contractor list, which was identified as a critical initiative by the Residential Electrification Implementation Working Group.[147]

"Too many salesmen knocking on the door. Some of them are very, very pushy. Each company offers something different: pricing, etc. It would be nice to be able to compare one to the other."

Ward 5 resident

[146] Tech Clean California Website, accessed March 31, 2025.
[147] Electrify DC, "Regional Electrification Working Group Initiatives" (2025).

Suggested Future Studies

Analysis of Remaining Feeders

The DC PSC should require Pepco to conduct a dynamic hosting capacity analysis of the remaining feeders at a local level to assess where management software, controls, monitoring, and other smart grid planning elements are warranted to support DER interconnection and increased hosting capacity.

Performance-Based Regulation

The DC PSC should build on its consideration of performance based regulation to incentivize investment in monitoring, energy management software, and newer technologies to increase DER adoption.[148]

Pepco's Ownership of Batteries

The DC PSC should conduct research on regulatory ownership models for batteries on the distribution system, as most other jurisdictions allow utility-owned batteries. This will mainly be a definition exercise as batteries in this context would have the functionality of capacitor banks to provide grid operation stability when needed based on energy demand and generation.

Analysis of Loads and Optimal Siting

The DC PSC should direct Pepco to research how residential sector load profiles impact DER integration and hosting capacity, and explore optimal DER siting on feeders to maximize benefits, taking into account geographical location, load density, and network topology.

Conclusion

Maximizing the benefits of the clean energy transition requires action on the part of the DC PSC. In directing Pepco to invest in smart grid upgrades and data transparency, the DC PSC will strengthen the stability of the grid for future generations.

Following the lead of other jurisdictions near and far who are proving what is working in smart grid upgrades, the District can position itself as a leader in how to successfully transition urban centers into energy generating hubs. By increasing our independence vis-a-vis outside power generators, the nation's capital can take control of its security and resilience.

[148] RMI, "Examples & Lessons Learned from Performance-Based Rates in Practice," Cara Goldenberg and Gennelle Wilson (January 17, 2025)

Credits

About Electrify DC

Electrify DC is a District of Columbia-based nonprofit that works to make it easier, faster and more affordable to decarbonize all homes by educating communities, convening manufacturers and government agencies, and supporting the residential real estate market and the professions that serve it. Vanessa Bertelli, Romita Biswas, Christie Poimboeuf, Linsey Silver, Natasha Shields, Robert Shalett, and Ricardo Sheler have contributed to this report.

About Redwood Energy

Redwood Energy is a partnership and certified microbusiness with staff from diverse backgrounds. We are a collaborative, innovative design firm that has worked on more than 400 all-electric, solar powered apartment complexes, which was two-thirds of the all-electric apartments built in California between 2012 and 2019, and one-fourth of the Zero Net Energy residences built North American between 2012 and 2020. Sean Armstrong, Dylan Anderson, Romel Robinson, and Gary Goslin have contributed to this report.

About Synapse Energy Economics

Synapse Energy Economics is a research and consulting firm focused on the intersection of energy, economics, and the environment. Since 1996, we've provided rigorous technical, quantitative, and policy analysis to help public interest and governmental clients improve planning, policies, and decision-making in the energy sector. Asa Hopkins has contributed to this report.

Acknowledgements

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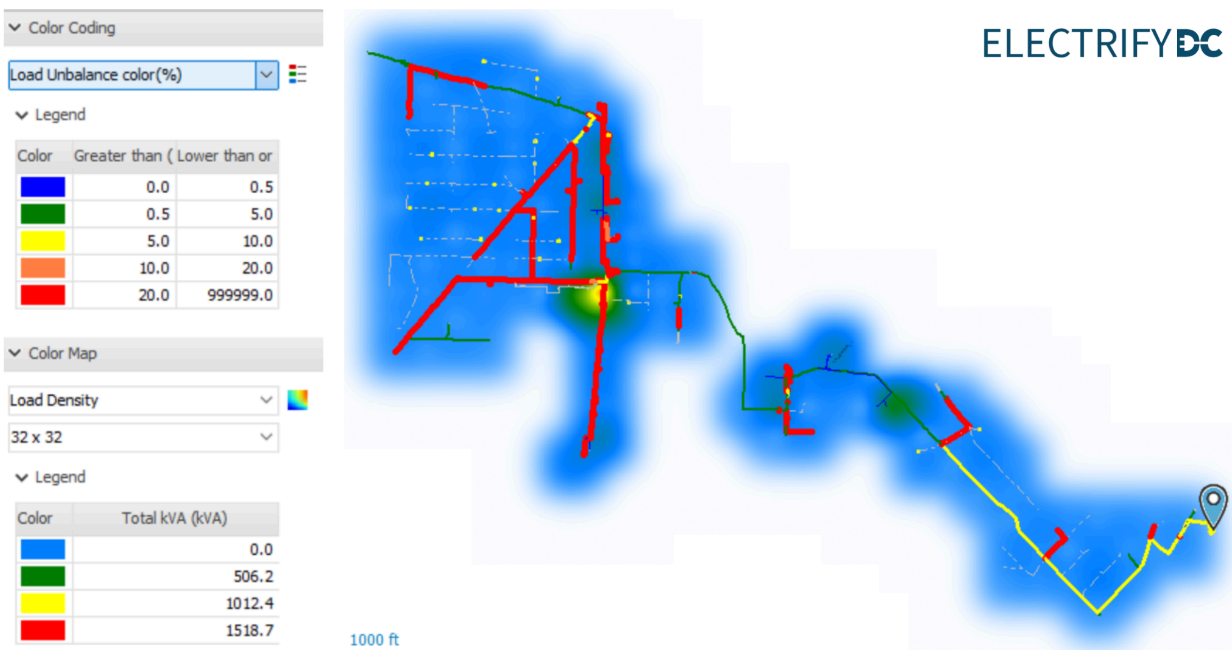
Technical Appendix

A: Baselining Radial Feeder Profile in CYME

The objective of conducting an unbalanced power flow analysis in CYME is to establish baseline feeder performance prior to the integration of DERs as no baseline or code was provided by Pepco. An unbalanced power flow analysis considers the natural unbalance that occurs due to variable single phase line placement and load consumption. Even if the structure is perfectly balanced, power is consumed by various loads with different profiles at any given time. CYME is currently used by Pepco to conduct power flow analyses.

Figure 1: Figure below shows load density and load unbalance percentage across a single feeder. Map pin represents the feeder head.



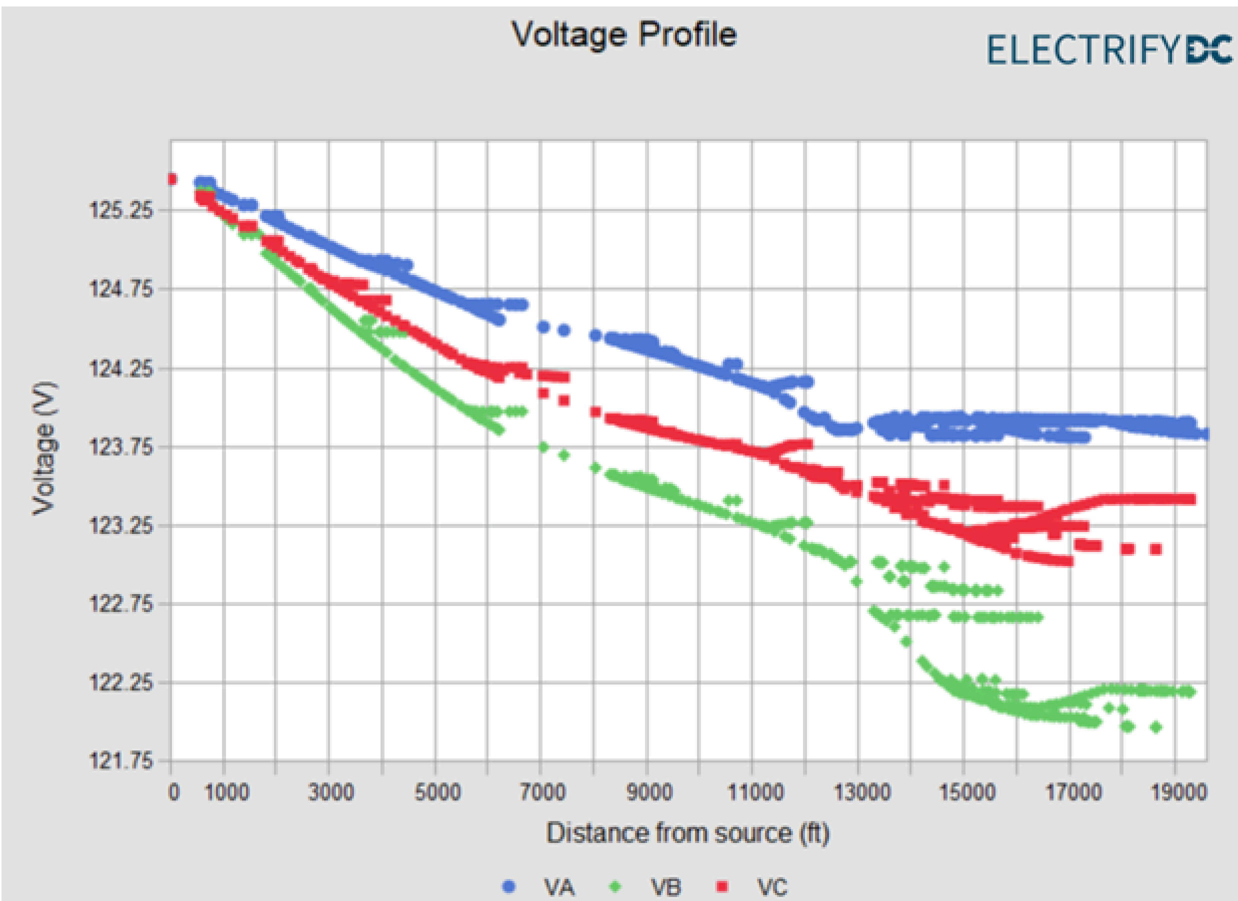
<u>Unbalanced PFA Results:</u>

The unbalanced power flow analysis has been scaled by feeder zones rather than applying a global scale. A global scale factor assumes that active and reactive power are unbalanced equally across the feeder. However, power factor changes across a feeder due to variable consumption patterns and network structure.

Power Factor: The ratio of real power (measured in watts) to apparent power (measured in volt-amperes). It is a measure of how effectively the electrical power is being used. A power factor of 1 (or 100%) indicates that all the power is being effectively converted into useful work.

The analysis was constrained by setting convergence parameters to 0.1% in volts and simulating for 60 iterations, with ambient temperatures ranging from [77 - 100]°F. The unbalanced power flow analysis revealed existing issues within each feeder including voltage sag, phase unbalance, and variation in power factor.

Figure 2: Voltage profile of radial feeder where Voltage A is 0 degrees phase, Voltage B is 120 degrees phase, and Voltage C is 240 degrees phase.



Voltage profile of radial feeder where Voltage A is 0 degrees phase, Voltage B is 120 degrees phase, and Voltage C is 240 degrees phase. It is observed the three voltage phases are different and become unbalanced almost immediately. Voltage drop is a function of both distance and current, and as power travels through a line, it gets further from the feeder head and encounters both resistance and reactance.

Phase unbalance is a common occurrence in low voltage feeders due to variation in load consumption across single phase connections. Phase unbalance is often observed as voltage sag during a power flow analysis with only load consumption. As the distance from the feeder head or originating substation increases, voltage phase unbalance intensifies, and the magnitude of each voltage phase decreases, resulting in voltage sag. It is critical for the voltage to be maintained at each point within a feeder. In older networks phase unbalance and voltage sag can significantly impact the performance and longevity of equipment.

Unbalanced Phase and Voltage Sag Impacts:

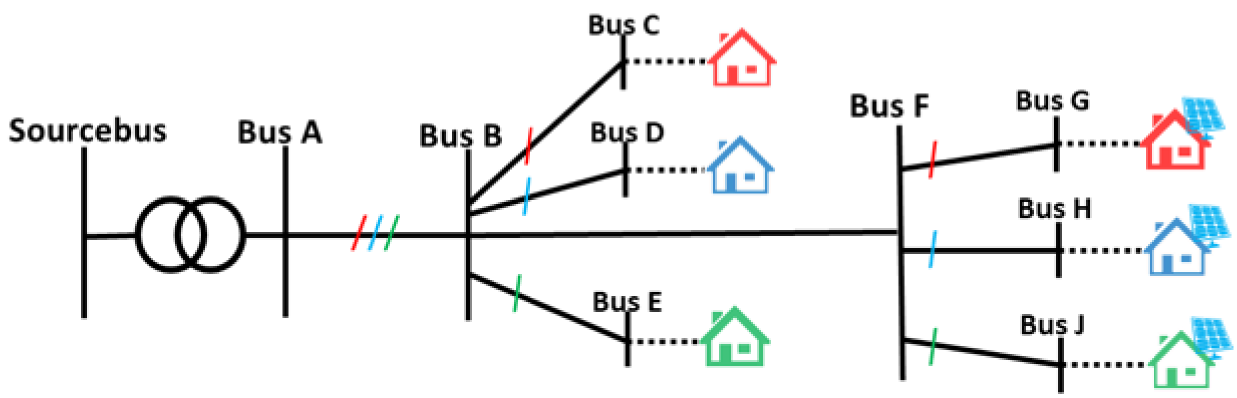
If loads on the three phases are not evenly distributed, it creates an imbalance, leading to overheating and excessive wear on transformers, switchgear, and circuit breakers. This continuous stress can shorten the lifespan of components as they operate beyond their optimal design conditions. To compensate for older infrastructure struggling to handle unbalanced loads, Pepco may need to perform more frequent upgrades to transformers, power lines, and distribution management systems. To prevent further reduction in equipment lifecycle, Pepco should consider deploying additional voltage regulation systems, grid forming inverter based systems, and energy storage systems to actively stabilize voltage and ensure grid reliability.[149]

Customers at the end of a feeder tend to experience greater voltage sag and therefore reduced power quality as power originating from the feeder head will encounter more resistance and reactance as it flows through the feeder. The ends of the feeder are more sensitive to voltage issues (rise or sag). In a balanced feeder, the ends of a feeder tend to suffer from hosting capacity issues because the excess power generated cannot be consumed by downstream loads leading to voltage rise issues commonly observed at the nodes or buses.

However in an unbalanced feeder experiencing voltage sag and phase unbalance, the integration of DERs towards the ends of the feeder can be used to achieve stable voltage levels and mitigate the effects of phase unbalance. Distributed power generation can help ensure that customers at the end of the feeder receive high quality power and help the feeder system remain balanced and stable.

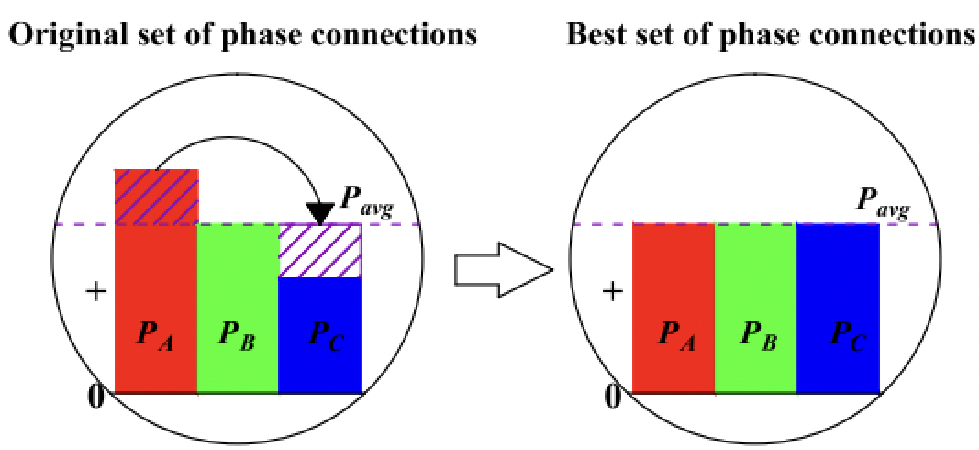
[149] To further assess issues in the specific equipment a harmonic analysis should be conducted to determine the long term impact of phase unbalance on these devices. DERs can mitigate these issues, by providing 0.8% to 3.1% more power where voltage sag is most prevalent locally.

Figure 3: PV placement across phases at ends of feeder for voltage balance[150]



In an unbalanced feeder, installation of PV should be prioritized on the phases that need balancing. By taking advantage of different phase connections, the voltage unbalance can be reduced. The total aggregated load demand of each phase determines the voltage sag, while the total aggregated generated supply of each phase determines the voltage rise. By rebalancing power generation onto phases with higher capacities, the overall PV hosting capacity can be maximized. Similarly phases that experience higher levels of power consumption and voltage sag, will benefit from additional PV generation. This rebalancing process across phase lines will allow PV hosting capacity to be maximized. For example in the voltage profile of the feeder shown above, phase B has the highest hosting capacity then phase A and finally phase C.

Figure 4: Phase rebalancing allowing for phase balance[151]



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[150] Nando Github, Tutorial-DERHostingCapacity-1-AdvancedTools_LV (2023)
[151] Science Direct, "Increasing PV hosting capacity with phase rebalancing in LV networks: A network-agnostic rule-based approach" (2024).

It should be noted as the ends of the feeder tend to be more sensitive, DERs with voltage regulation and active power curtailment should be deployed, and it is recommended that any power generation device be deployed with an energy storage system to distribute curtailed solar power during peak consumption hours when voltage sag will be more prevalent to support grid stability and provide high quality power to all customers.

B: Load Allocation Variation for OpenDSS Time Series Power Flow Analysis

B.1 Load Allocation

Random load allocation is a common approach in hosting capacity studies. In this analysis, the provided load data was used to stochastically distribute a load demand shape across the defined loads in the feeder data. To ensure statistical consistency, the AMI data for the peak day was first categorized into single-phase and three-phase load shapes. A Gaussian distribution was then generated from the historical data, sorted by the number of phases, to create representative load profiles. This method preserves the distinct characteristics of different load types while enabling a realistic and probabilistic assessment of system behavior.

Equation 1: Mean for sample load points across row

$$E(X) = \frac{\sum_{i=0}^{n-1} X_i}{n}$$

Equation 2: Standard deviation for sample load points across row

$$\sigma(X) = \sqrt{\frac{1}{n}\left[\sum_{i=0}^{n-1} X_i^2 - n * E^2(X_i)\right]}$$

Equation 3: Gaussian sample structure for load profiles to build a random profiles

$$\begin{pmatrix} hour\ 0 \\ hour\ 1 \\ . \\ . \\ . \\ hour\ 23 \end{pmatrix} = Number\ of\ Customers * Gaussian\ Sample \begin{pmatrix} load\ 0\ at\ hour\ 0, & load\ 1\ at\ hour\ 0, \dots, & load\ n-1\ at\ hour\ 0 \\ load\ 0\ at\ hour\ 1, & load\ 1\ at\ hour\ 1, \dots, & load\ n-1\ at\ hour\ 1 \\ & . & \\ & . & \\ & . & \\ load\ 0\ at\ hour\ 23, & load\ 1\ at\ hour\ 23, \dots, & load\ n-1\ at\ hour\ 23 \end{pmatrix}$$

Neither the power factor nor reactance power of each load was specified by the AMI data provided, however the power factor range is known from both the CYME analysis and the SCADA data provided at the feeder level. The power factor range [0.871 to 0.99] was chosen based on the SCADA data provided for each feeder head where both active power and reactive power for each phase was provided. Power factors were assigned stochastically along with the load demand shapes as OpenDSS requires both reactive and active power measurements.

Equation 4: Reactive power from active power and power factor

$$kVar = kW * tan(arccos(pf)),$$
$$where\ kVar = reactive\ power,\ kW = active\ power,\ pf = power\ factor$$

To perform mapped allocation, the facility ids of each bus was contained in the transformer or facility id in the feeder data, the load shape and AMI data could be accordingly mapped without performing random load allocation. The purpose of this mapping was to understand the true effects of the load consumption and power generation profiles locally without introducing any stochasticity. Power factors were assigned along with the load demand shapes. However, for buses missing load data, a random load profile generated from customer profile data for the feeder was assigned to the bus and given a customer number of 1. The buses that were missing load data coincided with buses where the number of customers was not known.

Figure 5: Residential Load Profiles Scaled by Number of Customers for Single Phase Loads

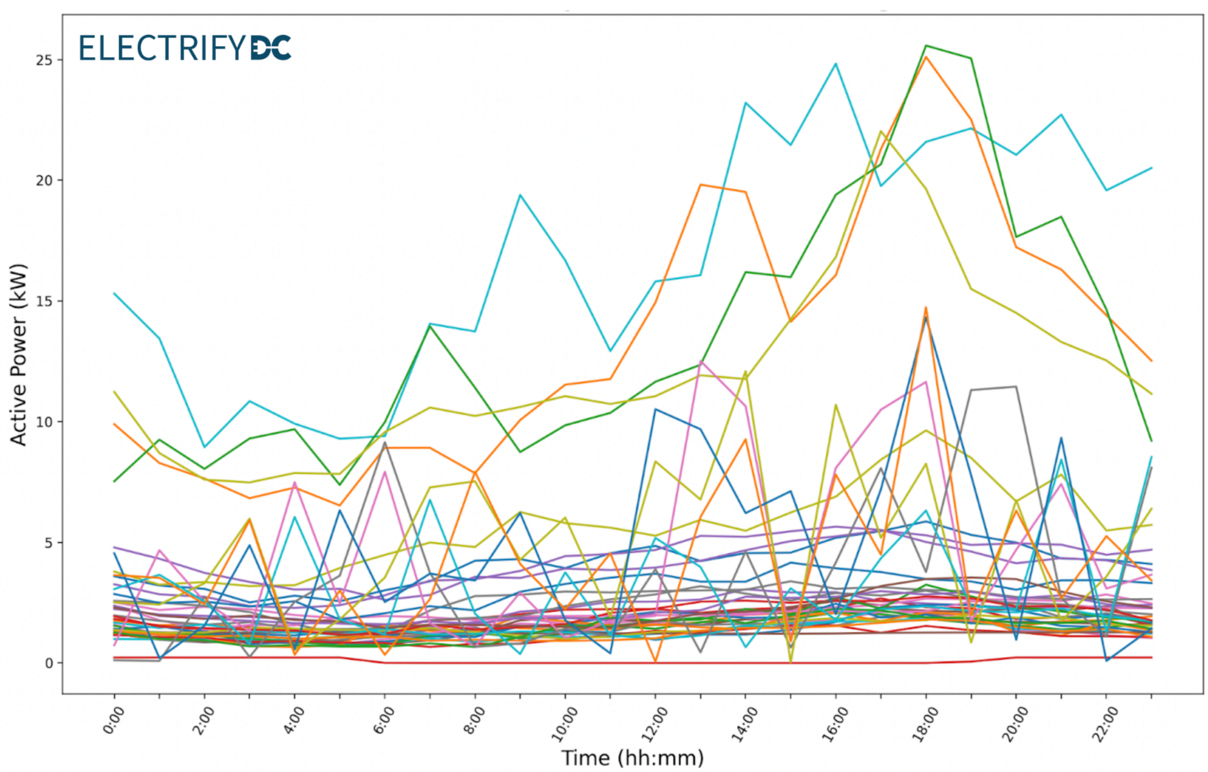
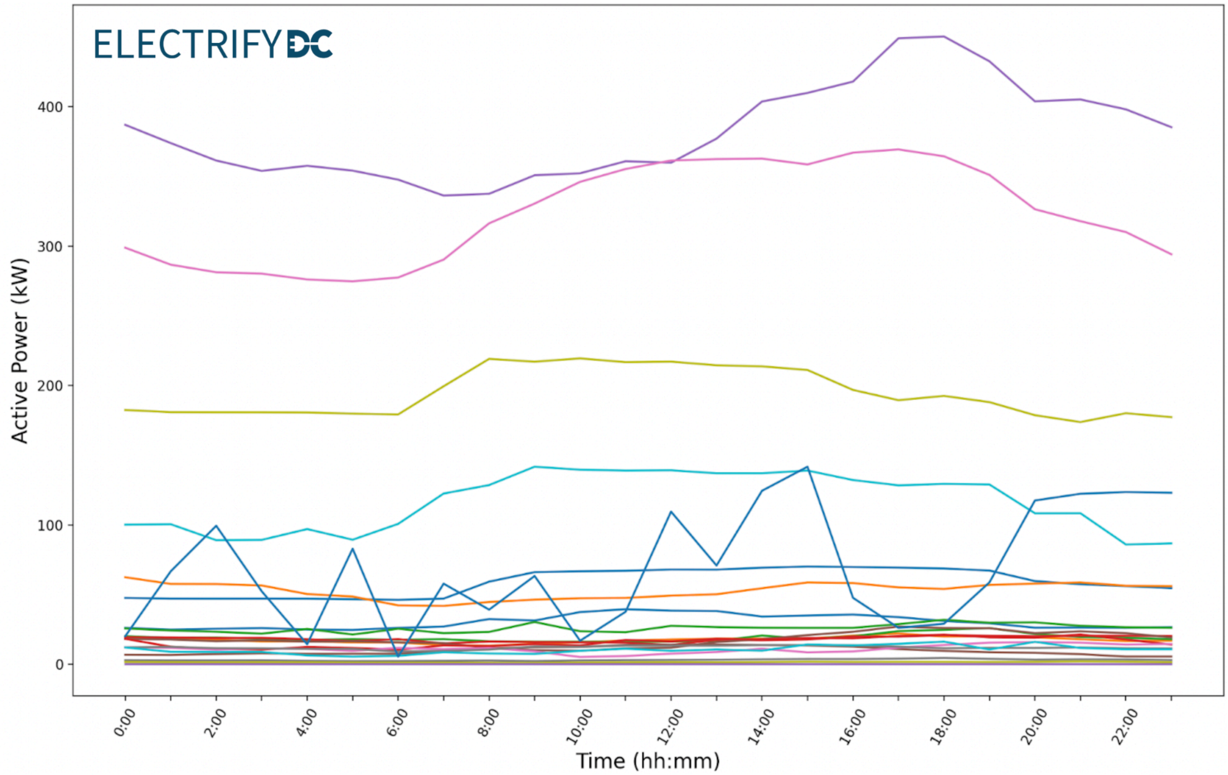


Figure 6: Residential Load Profiles Scaled by Number of Customers for Three Phase Loads



B.2 Solar Profile Data

To analyze the worst case scenario over 24 hours for hosting capacity, the solar profile for the day with the highest solar radiation was chosen June 20, 2024. The solar elevation determines solar radiation. It is assumed n - cloud cover is 0. When cloud cover is present it reduces the potential solar output.

Equation 5: Solar power generation

$$E = A * y * H * r,$$

$$where\ E = energy,\ A = area,\ y = efficiency,\ H = solar\ irradiation,\ r = performance\ ratio$$

Equation 6: Solar irradiance

$$H = R_0 * (1 - 0.75\eta^{3.4}),$$

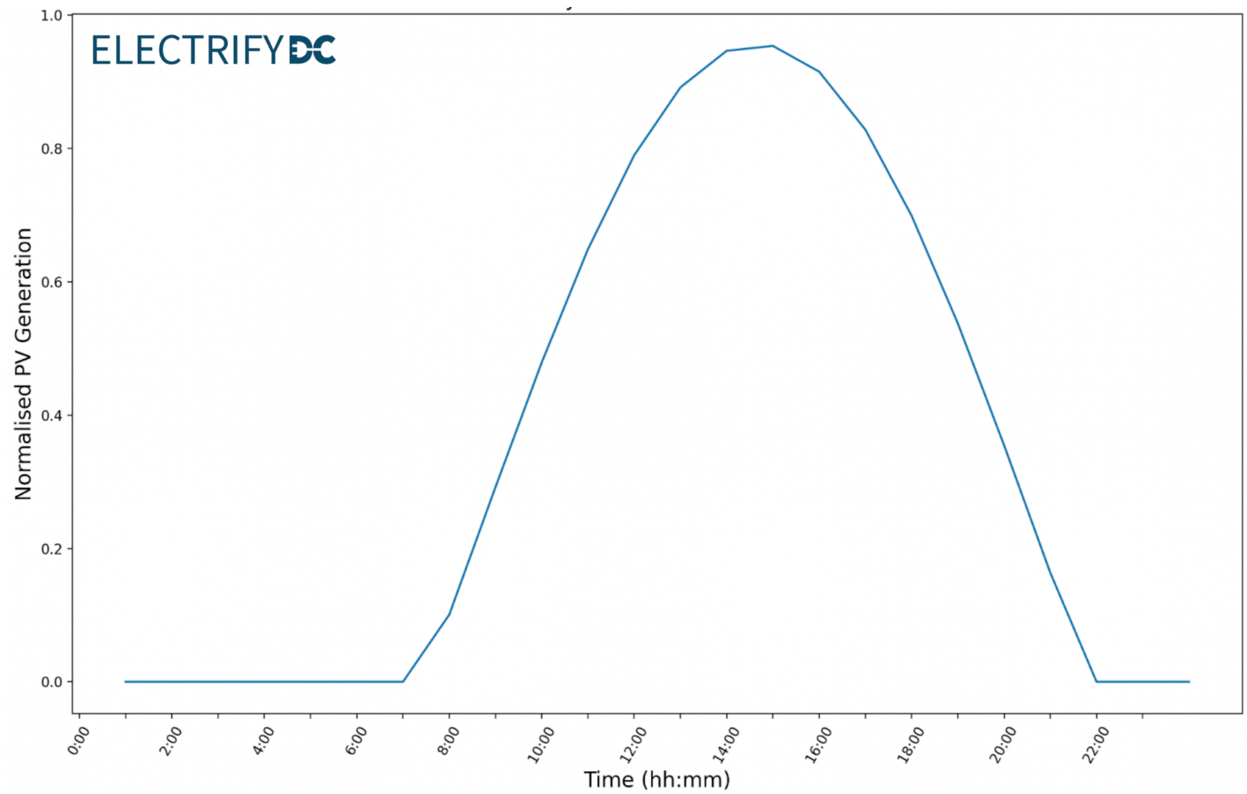
$$where\ H = surface\ solar\ radiation,\ R_0 = atmospheric\ radiation,\ \eta = cloudiness\ fraction$$

Equation 7: Clear sky insolation

$$R_0 = 990 * sin(\frac{\varphi_{tp} + \varphi_p}{2}) - 30,$$

$where\ R_0 = atmospheric\ radiation,\ \varphi_{tp} = time\ dependent\ angle,\ \varphi_p = seasonal\ phase\ angle$

Figure 7: Graph showing scaled solar radiation [0.0 → 1.0] for ideal peak solar day



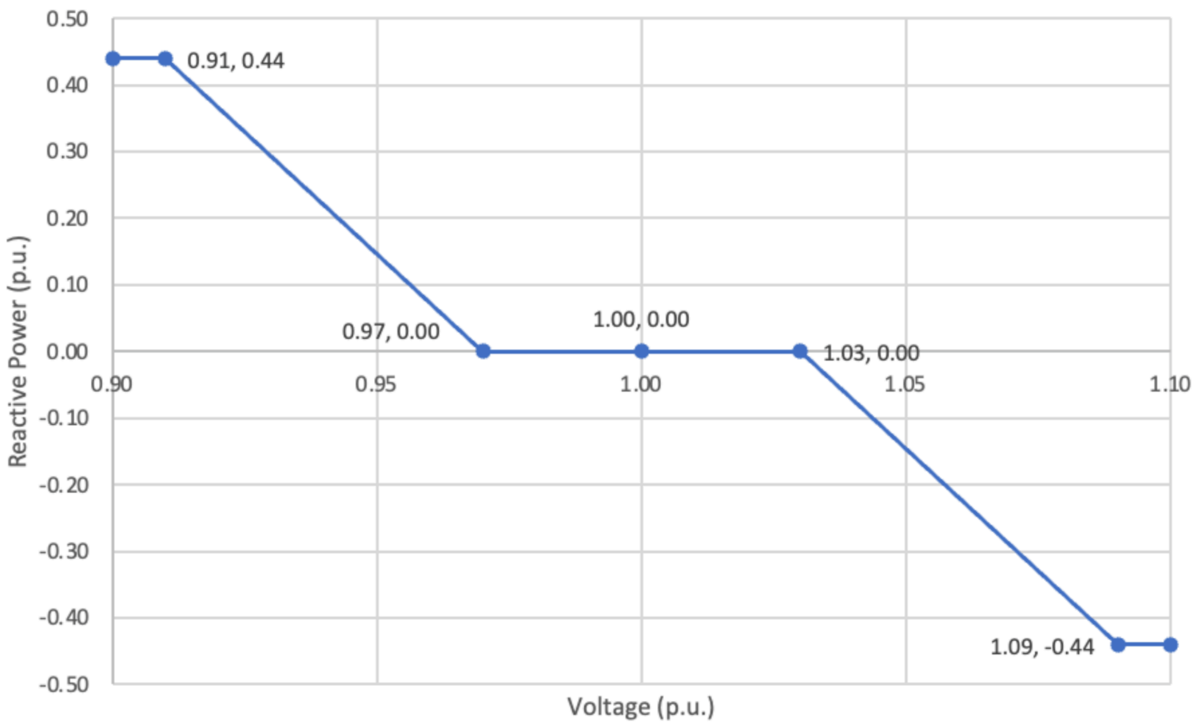
Notice that the solar radiation is close to 1 meaning the max solar irradiance or radiation possible. This solar profile chosen is to solve for the maximum solar power generation as there is no cloud cover. As pollution and wildfire smoke has been increasing in the region, the cloud cover has also been increasing.[152] Nonetheless, this solar profile was used to analyze the worst case scenario over a 24 hour period based on the maximum solar generation profile.[153]

[152] NASA Editorial Team, "NASA Study Untangles Smoke, Pollution Effects on Clouds" (2018).
[153] Yoram J. Kaufman and Ilan Koren, "Smoke and Pollution Aerosol Effect on Cloud Cover," Science 313, no. 5787 (2006).

B.3 Default Inverter Profile:

The default inverter profile used for simulating the power flow analysis is provided by Pepco. The inverter profile for volt-var was used to analyze hosting capacity with and without the utility defined default inverter settings.

Figure 8: PHI Smart Inverter Utility Required Profile[154]

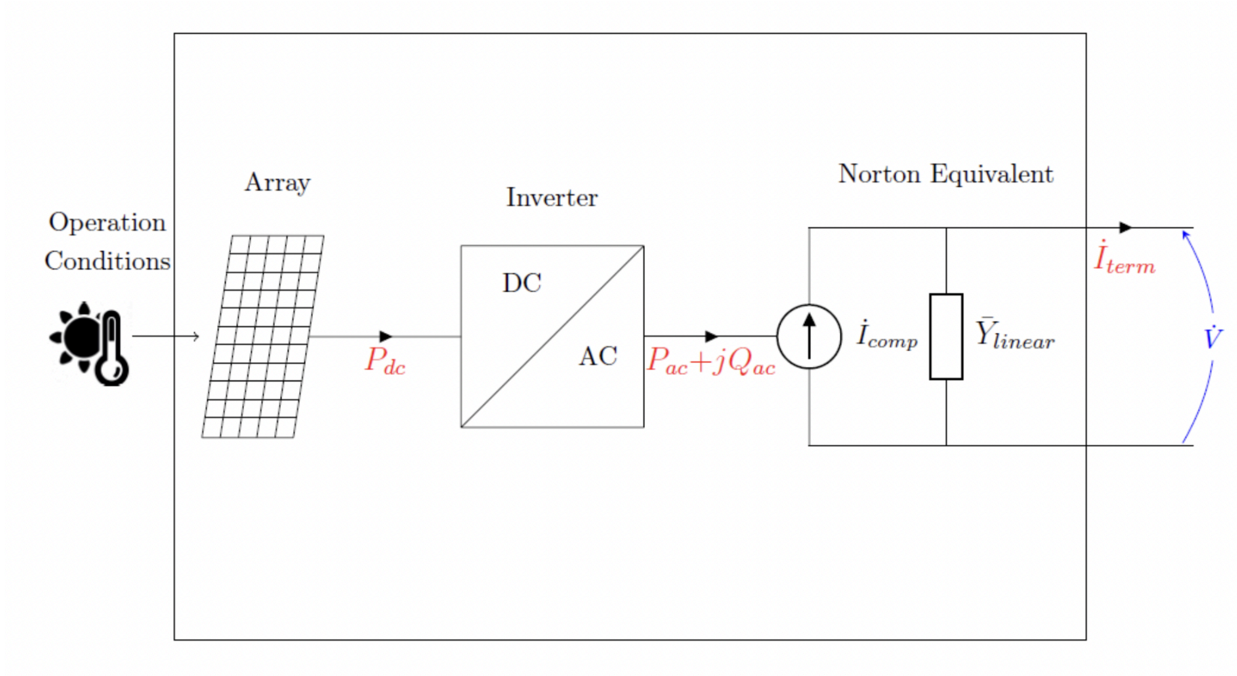


Inverters are required for any DER wishing to interconnect as they must convert DC power to AC. When simulating a power flow analysis in OpenDSS, the PV system comes with a default inverter if no other inverter settings are defined. The default inverter and PV system settings from EPRI are shown below. The hosting capacity analysis without defined volt-var settings from Pepco used the inverter from EPRI below.

The EPRI PV system model combines the photovoltaic (PV) array and the PV inverter. It assumes that the inverter is capable of tracking the maximum power point of the panel quickly (at least 1 second).[155]

[154] Pepco, "PHI Utility Required Profile," (2024), 6.
[155] EPRI, *OpenDSS PV System* (2024).

Figure 9: Block diagram of the OpenDSS PV System element model provided by EPRI[156]



C: Iterative Algorithm to Maximize Solar

C.1 Algorithm to maximize size of solar installation across a feeder:

1. Initialize Circuit with Load & PV Profiles
   a. Load existing profiles into the circuit model.
2. Run Initial Power Flow Analysis
   a. Simulate power flow with the current PV allocation.
   b. Determine if the system converges (i.e., stable solution is found).
3. Set PV Adjustment Parameters
   a. Compute the incremental reduction in PV power [delta_pv] per iteration.
   b. Initialize [max_pv_power_df] to store power outputs constrained by network limits.
   c. Compute the initial maximum PV capacity [max_pv].
      i. If buses are not within voltage limit bounds set to 0 otherwise leave as is
      ii. sum to get [max_pv]
4. Iterate to Maximize PV Hosting Capacity
   For each iteration (up to [maximize_pv_iterations]):
   a. Reduce the PV power range based on the iteration count.
   b. Adjust PV profiles accordingly

[156] EPRI, OpenDSS PV System, Figure 1 (2024)

        i. Generate random number between 0 and [pv_power_range] to increase PV profiles that are within voltage range and decrease PV profiles that are out of bounds
    c. Modify the circuit with these adjusted PV profiles.
    d. Run a new power flow analysis.
    e. Check if the system remains within operational limits (bounded simulation).
    f. If the simulation converges and remains bounded, update [max_pv].
        i. else if simulation converges check if buses are not within voltage limit bounds and set to 0 otherwise leave as is
        ii. sum to get [new_pv]
        iii. if [new_pv] greater than [max_pv] updated [max_pv_df] and [max_pv]
5. Return Final Maximum PV Capacity
    a. The result is the highest PV generation level that maintains power system stability.

Disclaimer

This report was prepared for DC's Department of Energy and Environment (DOEE) and is intended to be read and used as a whole and not in parts.

The projections provided in this presentation are necessarily based on assumptions with respect to conditions or events which may or may not arise or occur in the future. While we believe these assumptions to be reasonable for purposes of preparing our analysis, they are dependent upon future events that are not within our control or the control of any other person. Actual future outcomes can and will differ, perhaps materially, from those evaluated in these projections. No one can give any assurance that the assumptions and methodologies used will prove to be correct or that the projections will match actual results of operations. We do not make any representation with respect to the likelihood of any specific future outcome, and cannot and do not accept liability for losses suffered.

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