Solar Photovoltaics Technology Brief

Key Challenges and Recommendations for Solar PV on ZNE New Construction Multifamily Housing

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This technology brief is intended for multifamily building owners, architects, engineers, and green building consultants working to design all-electric zero net energy (ZNE) multifamily buildings from the ground up. This paper draws from the findings of the EPIC research project (EPC 15-097) optimizing domestic hot water in four multifamily affordable all-electric new construction projects in California. The research focused on the evaluation of domestic hot water heat pump systems in four multifamily affordable all-electric new construction projects in California. Final Report: Getting to All-Electric Multifamily ZNE Construction Publication Number: CEC-500-202X-XXX.

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Introduction

A key component when evaluating pathways to zero net energy (ZNE) in all-electric new construction multifamily is the renewable energy that offsets the building's energy usage to support net zero energy annually.

Each of the four demonstration projects monitored in the EPC 15-097 ZNE research study has a solar photovoltaic (PV) system to offset the energy consumed by the building. Three of the four properties, which targeted whole property ZNE, have solar PV systems interconnected with the virtual net energy metering (VNEM) tariff in which all the energy produced by the PV system is sent back to the electric grid and allocated virtually as energy credits to offset the usage on account holder energy bills. This is essentially a billing accounting exercise allocating credits and subtracting from kWh during that billing period. The fourth demonstration property, which targeted 100% offset of common area loads due to limited roof area, has a solar PV system interconnected with net energy metering (NEM). The PV system is tied directly into the owner-paid house electric meter and energy produced by the system directly offsets that meter's load with additional energy needs pulled from the grid and any excess energy produced sent back to the grid. This PV system offsets energy used by the central domestic hot water system, central laundry rooms, common area and exterior lighting, community room, computer and learning center rooms, management and service offices, and elevators. Based on the PV system size and estimated production, and the original modeled house meter load, the load should be fully offset with about 20% overproduction.

This technical brief will discuss the challenges and opportunities of solar PV identified through the research project and concludes with recommendations and findings.

Key Findings & Challenges

Monitoring the solar PV systems at the four demonstration sites shed light on many challenges with solar PV on multifamily buildings. The following section examines the key findings from the research study, and uncovers challenges that should be addressed by stakeholders and the industry at large. The discussion below covers design, data collection, installation and physical issues, and interconnection and billing Issues.

Design

PV system design and sizing for new construction multifamily is based on energy models and therefore is dependent on those models to reasonably reflect performance inclusive of actual equipment, typical weather, and usage patterns.   There are three challenges that arise from this in the all-electric new construction multifamily space: 1. there is not an existing load to size to for new construction and therefore the model is the *only* source of energy load information; 2. the modeling tools for certain all-electric systems, mainly large, central heat pump combined or water heating only systems are still being developed and do not yet accurately reflect system performance and consumption; and 3. modeling tools do not always account for all building end uses and can therefore underestimate the true building load. These three challenges were encountered by all four demonstration projects.

Data Collection

Collecting and tracking PV production and system equipment data is the best way to monitor system performance to ensure that the system is operating well. Three issues with data collection were identified: production, performance and completeness of data. Collecting energy production data is straightforward with a dedicated third-party solar monitoring system, as compared to utilizing utility data, which is the alternative.

In the absence of a third-party PV monitoring system, utility data can be used to collect and track solar production information. However, depending on what type of PV system is installed (i.e. how the system is interconnected and on what tariff), identifying performance issues can be challenging , and even determining total production can become difficult when reviewing utility data. For NEM PV systems, the total gross energy production of the system cannot be determined from the utility data for that meter; not even the utility is able to see this, because the building consumes some of the energy produced directly and so it never hits the electric grid. In the case of the demonstration project that installed a NEM PV system, energy production was collected through a third-party monitoring system, and the utility data helped quantify how much PV-produced energy was consumed directly onsite versus sent back to the grid. Many modern-day solar PV inverters have built-in monitoring systems, which solves this problem with equipment selection (integrated monitoring systems still require manual setup and enablement). However, a challenge still persists in accessing the utility consumption data and completing the analysis.

Energy production data can only show so much in terms of system performance, even when the production data is clear and complete. Even when the utility information is available, such as with a VNEM PV system where a utility-installed dedicated production meter exists, the production data alone does not always make individual equipment failures or issues visible, nor does it contain any barometer for expected performance. Alternatively, a third-party monitoring system dashboard might be able to highlight expected performance, which helps one to understand degraded production from soiling, for example. If a whole PV array goes down that is tied to one production meter, it is very clear that there is an equipment failure; however, if one inverter is down in a larger array or multiple arrays connected to the same production meter, this failure may not be visible in the utility production data. A dedicated monitoring system that provides production data per inverter can provide good insight into inverter or array-level system health, in addition to providing insight by showing data on a more granular timescale.

And lastly, another data collection challenge that can arise when relying on utility meter data is ensuring complete and accurate information. In the case of VNEM PV systems where energy production data can be collected via the utility production meter, it is critical that all production meters are accounted for when reviewing total energy production to evaluate system performance and understand how much energy is actually being produced. Multifamily PV systems can be quite large with multiple arrays and potentially multiple production meters. Knowing the design of the system is critical; however, the person monitoring the data may not have access to the design or may not be able to interpret the design to know if all data is being collected. For example, one of the demonstration sites with a VNEM PV system located in Atascadero did not have a third-party monitoring system installed, so the energy production data from the utility was relied upon. Access to the utility data for each building meter was provided, including the account associated with the PV production meter. When evaluating the system performance, it became clear that there might be data missing as the system production was far lower than was anticipated. The team eventually identified that production information was missing based on deep analysis of PV energy production data, aggregated tenant data and whole building consumption data. After extensive coordination with the owner entity, a second PV production meter was discovered whose data had not been included in the initial analysis. Because the PV modeling and estimated production could not be accessed, it is still unclear whether the PV system at this demonstration site is performing as expected. This analysis and discovery was not intuitive, and further highlighted challenges in PV system monitoring and performance verification in the absence of third-party monitoring equipment.

Installation and Physical Issues

Physical issues that impact PV system performance and production can occur both during installation of the system and during the operational life of the system, impacting the ability to achieve ZNE.

At the demonstration sites of this study and properties that have gone through the Low Income Weatherization Program for Multifamily (LIWP-MF), which offers energy efficiency and solar PV incentives statewide, some of the following physical issues have been observed:

- Electrical arcing at the panel and solar array disconnect,
- Inverters turned down to 0% output and thus precluding production while also adding load on the production meter and incurring high charges (observed at the demonstration site at Cloverdale and identified to the building owner and utility by the research team),
- PV panels damaged by errant golf balls as a result of being located next to a golf course,
- The channel A and channel C—consumption and production, respectively—wires being swapped at the meter so as to measure production as consumption and incur load charges on production (also observed at the demonstration site at Cloverdale and identified through troubleshooting by the research team and utility).

Particularly with large VNEM PV systems, there are complexities with the system design, the process by which it gets connected to the utility grid, and the surrounding environment that allow ample room for error. Without care or surveillance, these errors or physical mishaps can have a profound impact on the system's lifetime performance.

Environmental issues, like soiling and tree growth, are external to the installation and more related to the geographic location of the system, but can greatly impact solar production. PV systems in rural areas—surrounded by agricultural land in the Central Valley, for example—have a greater propensity towards dirty panels and degraded production. Properties that have leveraged LIWP-MF to install solar PV systems have shown up to, and in some cases beyond, 20% production reduction as compared to estimated production, with soiling being the main culprit. Similarly, and particular to California as the climate changes, wildfire smoke also has the same effect as dust or soil coating PV panels; in 2017 during the Tubbs Fire in Napa, the demonstration site at Calistoga saw degraded production during the smokiest days there. Similarly, several days after the start of the Creek Fire located east of Fresno in the Sierra Nevada Mountains in September 2020, the PV system in Sunnyvale only produced 30 kWh that day as compared to over 500 kWh two days prior. Both were sunny days with similar weather conditions, yet when the wildfire smoke blocked out the sun in the Bay Area, the PV system was only able to produced 6% of the energy it had produced two days before.

Shading from trees also inhibits PV system production. Inaccurate shading analysis during the design period and tree growth throughout the lifetime of the PV system—20 years allows ample time for growth without tree trimming—can have dramatic impacts on system production that otherwise would not show up in system modeling. The property at Calistoga is surrounded by forested area on its southern and western sides, and with no other physical issues identified through PV monitoring, it is hypothesized that this shading contributed to the PV system's annual production year-over-year during the monitoring period to be an average of 20% below the modeled production.

This list is not exhaustive, but indicates the wide range of installation or other physical issues that can affect a PV system and result in decreased production that cannot be recouped. This lost production has financial implications for both owners and tenants.

Interconnection and Billing Issues

Beyond data and physical and installation-related challenges, a whole set of interconnection and billing-related challenges exist. The interconnection process and associated compliance requirements are nuanced, complicated and unique. The process is also often inconsistent, both across utilities and within the same utility. As a result, errors occur during the process that can cause significant delays to turning on the PV system, missing out on production when the system is fully built and has the potential to be operational. Once interconnected, the owner or tenant may not see the energy or cost offset benefit on their bill as setting up solar billing can take a long time or be missed entirely. One utility quoted it to be reasonable for billing setup to take up to six months after interconnection approval.

In other instances, as was the case with the Cloverdale demonstration site, the utility failed to set up solar billing. The PV system was interconnected for 8 months before the utility set up solar billing, and it was not done until the research team identified an issue through analysis of monitoring data and worked with the utility to resolve the issue. This issue is a problem particularly for VNEM systems; because all energy produced by a VNEM system is sent back to the grid to be allocated as bill credits, VNEM systems rely exclusively on solar billing to deliver the benefits.

In most cases, the utility will retroactively allocate solar credits for a VNEM system and back-bill to the date of interconnection approval for credits missed as a result of billing setup delays. From the utility's perspective, this might be a sufficient delivery of value; however, in affordable multifamily housing, it is problematic and presents economic challenges. Low-income families often have immediate costs that are greatly impacted by higher utility cost burden, even if reconciled later on. Similarly, building owners can be strapped by higher operational cost, particularly shortly after the upfront investment of building the PV system; the delay in cost savings can be debilitating.

Lastly, while VNEM PV systems enable multifamily buildings to achieve ZNE, the very way that the tariff enables ZNE also presents a design and field operating challenge. The allocation of solar PV credits to multiple meters relies solely on building energy modeling for new construction, which will not necessarily correspond to meter configurations. Within the limitations resulting from full reliance on energy models to understand consumption per meter, clear communication and coordination between the building and solar PV design teams is needed to ensure proper credit allocation. The allocation of PV credits to each of the buildings' meters is what determines financial benefits of real ZNE. The challenge arises because, utility-dependent, the PV credit allocation cannot be changed for a certain amount of time once submitted to the utility for permission to operate (PTO), and once it can be changed, it can only be updated thereafter with a certain frequency. In the case of one utility, the VNEM allocation sheet cannot be updated for 5 years after approval, which is a quarter of a typical system's life. Thereafter, the allocation can be changed once a year. If the VNEM allocation does not align with energy usage from the beginning—i.e. certain meters receive too many credits while other meters do not receive enough credits—ZNE may not be achieved on a cost or utility-reported net energy basis simply because of the misallocation of credits. This was the case at several of the demonstration sites, where some of the building account meters received too many credits and resulted in ZNE with additional credits over the course of a year, while other meters had considerable net annual consumption and would have benefitted from more credits. Appropriate credit allocation can be inhibited and limited by reliance on modeling and inability to make real world data-informed adjustments.

Solutions & Recommendations

Despite there being many challenges associated with solar PV on low-income multifamily housing, solutions exist to alleviate or even overcome them. These recommendations are based on experiences at the demonstration sites and other properties that received solar PV systems through LIWP-MF. The set of recommendations are directed toward building owners, operators, consultants, and code development teams. They are organized in three distinct categories: design and install, operations and maintenance, and interconnection processes. These recommendations present actionable steps as well as shed light on higher level changes that could be implemented, that are useful for building owners and the building design community to be aware.

Design and Install

Energy code and tools can continue to support and promote energy efficiency and load shifting in buildings to alleviate stress on the electric grid and reduce overall energy consumption. Improving tools, creating more successful designs and installs will assist property owners in maximizing investment in PV systems.

Because PV design for new construction rely so heavily on building energy models, it is necessary to have more comprehensive and accurate modeling tools to lead to better estimating and designing of zero net energy buildings, both on the consumption and production ends. Both the public and private sectors have developed solar PV modeling tools to support PV design and sizing. These tools are already quite robust and effective, but are not as comprehensive to include the diversity of building loads that exist (i.e elevators). Having broadly available tools would be ideal, but in lieu of that, calculations can be developed and applied by individual consultants or design teams (See EPC 15-097 Technology Brief on ZNE Modeling). An area that should be investigated further is how climate change and change in weather trends in the coming decades will impact solar access and PV production output. Solar PV modeling tools rely on accurate projections of solar radiation and weather in order to estimate how much solar-generated electricity will be produced over the life of the PV system; in the case of third-party owned, PPA style systems, this is especially important as the production is even more directly tied to system financing. Current and evolving climate and weather trends must be incorporated in PV production modeling tools in order to better estimate the expected system output. With our rapidly changing climate, weather patterns become harder to predict and also change with greater speed over time, so identifying methodologies to capture this variance in PV production modeling is critical for estimating production over a 20-year system lifetime.

From the code perspective, more robust and code-required third-party, such as HERS, verification of PV systems would deliver great benefits to solar deployed on multifamily housing. With often larger and more complicated systems, third-party verification upon system PTO would allow installation issues to be identified and production modeling to be trued up. This would allow for issues to be identified and addressed upfront, rather than found later on in PV monitoring data, or worse, lack of production. In addition to on-site physical verification, there is opportunity for verification of billing and utility account configuration (see Interconnection Processes section below). Both levels of verification are needed to ensure system performance and benefits are realized.

Interconnection Processes

Many issues can arise, both physical and billing related, from the interaction with the utility and through interconnection and beyond. Currently, the responsibility for ensuring that solar systems are interconnected in a timely manner and reviewing bills to ensure that credits appear largely falls on the building owner. However, standardizing interconnection requirements across utilities and the process of activating solar PV systems could make the process much more streamlined and easy to navigate.

Standardizing interconnection and associated requirements across utilities is one way to streamline the process of activating solar PV systems and make it more navigable. This would primarily benefit solar contractors, but would have a trickle-down effect to building owners as well. Streamlining the post-interconnection process on the utility end could also alleviate many of the issues, particularly related to billing, that arise after system PTO. Particularly for VNEM systems billing that relies solely on the utility to receive solar PV credits, the post-PTO billing process needs to be more streamlined, standardized, and rapid. VNEM solar billing and credit reception is essentially an accounting exercise, and more automation should be implemented to ensure this PV credit application is set up correctly, very quickly, and is confirmed by the utility. In addition to automating the billing setup process for more rapid and accurate application, pursuing a process that builds in a stop gap to ensure that solar billing is setup and does *not* get missed could also be effective. To that end, increased utility surveillance of VNEM systems may also help alleviate billing issues, or missed billing setup, and bolster electric grid management with increased awareness of total electric supply to benefit all stakeholders.

Lastly, policy resulting in solar tariffs and the rules guiding those tariffs can be structured to support the most optimal energy outcome, and also ease the path to ZNE. Ensuring that VNEM allocations, for example, can be adjusted after a year's worth of building energy data would allow for a better chance at ZNE for multifamily buildings with VNEM solar PV systems. Tenants and building owners would greatly benefit from an energy usage and utility cost perspective. The challenges and pain-points addressed should be considered in the CPUC's review and implementation of NEM 3.0. And perhaps most notably, ensuring that a VNEM tariff option is offered by a utility and available for the multifamily buildings in its service territory is critical to the ability to achieve ZNE in multifamily housing.

Operations and Maintenance

Building owners and operators—including property management and maintenance staff—have the ability to obtain direct information about the PV system, both remotely and with boots on the ground. It is almost never obvious that something is wrong at a glance, though.

In order to have visibility into the solar PV system's operation and output, a third-party PV monitoring system with alarm and/or notification functionality should be installed to provide information on system components and system production. Individuals can actively interact with monitoring systems, receive alerts and review dashboards with summary level information to monitor and track system performance. Not only is there visibility into system performance, there is also engagement by alert. Ideally, someone will be actively reviewing the monitoring system on a regular basis. Along with alerts, a dashboard can be created to give a high-level snapshot of performance. Many of the anecdotal challenges addressed above were resolved through PV data monitoring. For example, the solar PV production data in tandem with the utility bills at Cloverdale showed that there was some issue leading to 50% or less than expected production. This led to further digging with the owner and utility to uncover the misconfiguration with the inverters. Even without a dashboard or system component information, the production data alone can shed light on problems, and active attention to the monitoring system is integral for the effectiveness of the tool.

In addition to having and actively using a solar PV monitoring system, the property maintenance staff or service contractor should create and follow a scheduled maintenance plan. Alternatively, the building owner can pursue a service contract instead. The scheduled maintenance plan should include and reference the warranty terms, with which the building owner and operator should familiarize themselves. This allows the building owner or operator to leverage the contract put in place to ensure they are protected against faulty components, or those with premature failure. The same is true of a performance guarantee, and active engagement with a third-party monitoring system will help verify that the full value of the PV system is realized, or present opportunity to identify underproduction and lost value.

Regular maintenance should include: thoroughly cleaning the panels, trimming any trees that have grown to shade the panels, and doing a thorough check of the equipment through the PV monitoring system and comparing monitored production with estimated production. Frequency of maintenance activities should be based on geographic impacts. For example, a property located next to agricultural land in the Central Valley will require panel cleaning much more frequently as compared to a property in a suburban area. Cleaning may also be event- based. A property exposed to heavy wildfire smoke part of the year may need one or several panel cleanings directly after the time of sustained smoke, but require little other cleaning otherwise.

And lastly, building owners and operators can stay engaged on solar policy and requirements, and advocate for more favorable conditions to navigating the solar installation and operation processes. From an owner advocacy standpoint, the most important area for support is in ensuring that policy is in place to make solar PV available to multifamily housing properties and their tenants, which in turn can ensure that those tenants and buildings can benefit from the financial and environmental benefits solar PV provides. Ensuring that an effective VNEM tariff is available is paramount.

Conclusion

Solar PV systems interconnected on multifamily housing, particularly VNEM systems, face a number of challenges that can greatly impact their performance in the short term, or the lifetime of the system. Some solutions are more complicated and longer term efforts such as addressing tariffs and interconnection processes; however, other solutions exist immediately that can be low effort and high return, like actively utilizing a third-party PV production and equipment monitoring system. The main takeaway from a design perspective is to realistically take into account some of the anticipated challenges to system performance, like those related to the surrounding environment, and design accordingly, paired with monitoring, and try to account for comprehensive loads in building to best estimate consumption and inform sizing. The main takeaway on operational solar PV performance is that any number of challenges can be met at any given system, but actively reviewed solar PV monitoring allows for a low-cost, low-effort way to ensure that those challenges are realized and are eventually met with solutions. Overall, large NEM and VNEM solar PV systems can provide clean and affordable energy to multifamily housing residents, and addressing the challenges to delivering this energy benefit is of the utmost importance to protect residents and undertake California's clean energy goals.

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