SolarAPP+ Performance Review (2023 Data)

Jeff Cook,[1] Sertac Akar,[1] Danny Chang,[1]
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and Kaifeng Xu[1]

1 National Renewable Energy Laboratory
2 Clean Kilowatts LLC

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Technical Report
NREL/TP-6A20-89618
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Executive Summary

The Solar Automated Permit Processing Plus (SolarAPP+) platform is an online portal designed to facilitate and expedite residential rooftop solar photovoltaic (PV) and battery storage permitting processes. SolarAPP+ allows PV contractors to upload system specifications, have that information automatically reviewed for code compliance, and receive instant approval for code-compliant systems, reducing the authority having jurisdiction (AHJ) staff time needed for review. SolarAPP+ also provides inspection checklists to verify installation practices and adherence to approved designs. SolarAPP+ is available to AHJs at no cost.

Consistent with previous performance reviews, in this report we summarize SolarAPP+ adoption trends to date and compare various metrics for PV systems permitted through SolarAPP+ to those for systems permitted through traditional AHJ permitting processes.

As of the end of 2023, 752 AHJs had expressed interest in the platform, with 167 AHJs either fully adopting (97) or piloting (70) the platform. In 2023, 668 installers submitted 18,906 permits through the SolarAPP+ platform, including 4,834 permits for PV+storage systems. SolarAPP+ permits accounted for around 43% of all permits issued in all participating AHJs (Figure ES-1), and more than 80% of all permits in several participating AHJs.

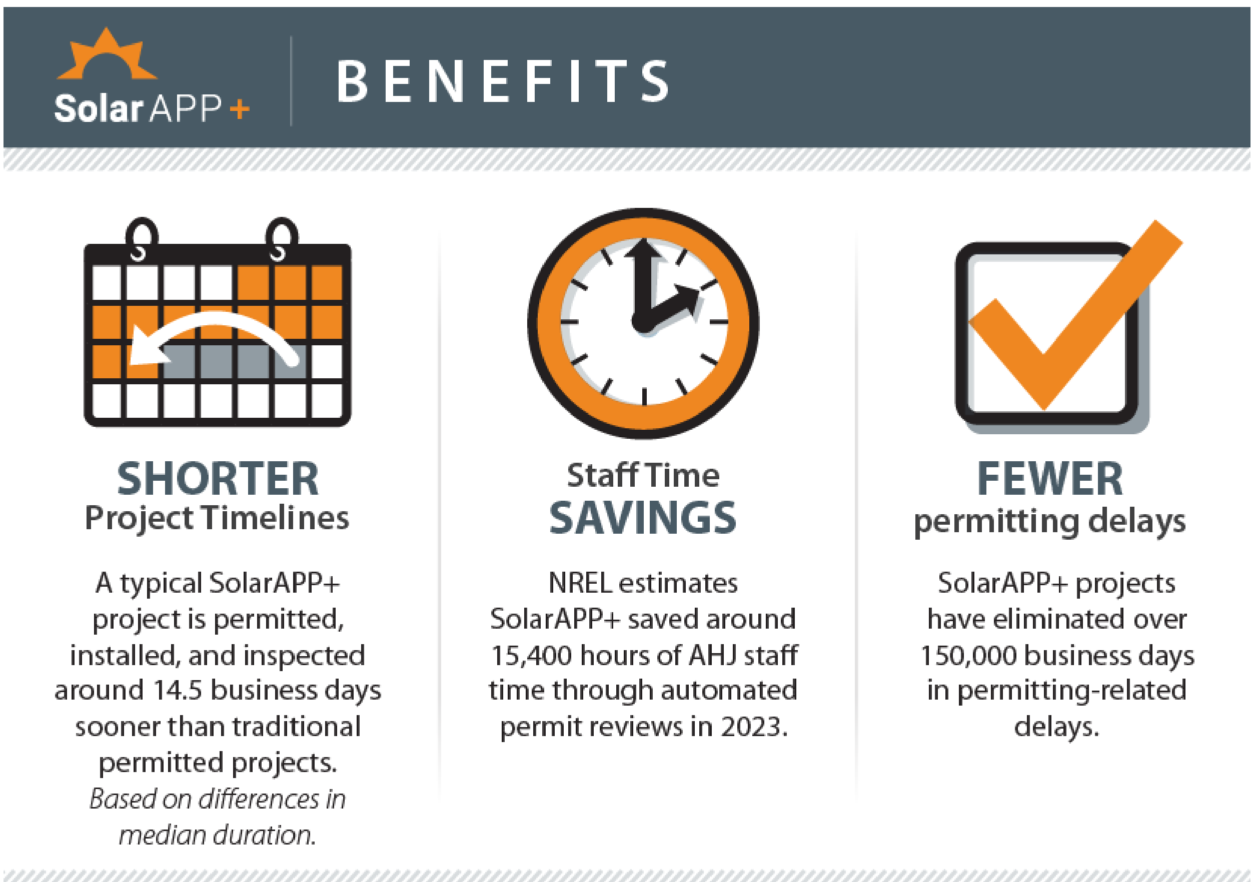

Figure ES-1. Summary of performance review results

Consistent with previous SolarAPP+ performance reviews, we find that permitting timelines are significantly shorter for SolarAPP+ projects as compared to traditionally permitted projects. In 2023, we estimate that:

- A typical SolarAPP+ project is permitted and inspected 14.5 business days sooner than traditional projects (based on median timelines).
- Automatic SolarAPP+ permitting saved around 15,400 hours of AHJ staff time and collectively accelerated PV permitting by around 150,000 business days in 2023.
- SolarAPP+ reduced PV installation costs by around 2%–13%, increased rooftop PV deployment by around 2%–17%, abated around 0.5M-2.0M tCO_2 emissions, and saved around $945,000 in household electricity costs in SolarAPP+ AHJs.

Table of Contents

List of Figures

List of Tables

1 Introduction

The Solar Automated Permit Processing Plus (SolarAPP+) platform is an online portal designed to facilitate and expedite permitting of residential rooftop solar photovoltaic (PV) and battery storage systems. SolarAPP+ was developed by the National Renewable Energy Laboratory (NREL) in collaboration with local governments, code development organizations, and industry stakeholders. SolarAPP+ is available to local permitting authorities at no cost.

This report is part of an ongoing series of reviews of SolarAPP+ performance. Consistent with previous performance reviews, we summarize SolarAPP+ adoption trends to date and compare various metrics for PV systems permitted through SolarAPP+ to those for systems permitted through traditional authority having jurisdiction (AHJ) permitting processes. In this introduction, we briefly explain the impetus for SolarAPP+ development, the functions of the platform, and the results of previous performance reviews.

1.1 The Need for Standardized PV Permitting

Most rooftop PV systems are subject to local permitting requirements implemented by local AHJs. Figure 1 depicts a typical permitting process and how it relates to the interconnection processes implemented by utilities. Rapid and accelerating rooftop PV deployment has strained the capacity of AHJs to efficiently navigate these processes (Cook et al. 2021). Conversely, although states typically set minimum requirements, individual AHJs often implement unique permitting requirements (Stanfield et al. 2012). Local permitting variability has presented a challenge to the expanding rooftop PV market by increasing compliance costs (Dong and Wiser 2013; Burkhardt et al. 2015; Cook et al. 2021) and permitting timelines (O'Shaughnessy et al. 2022). A growing number of AHJs and utilities have responded by reforming and standardizing permitting processes to reduce delays (Stanfield et al. 2012; Fekete et al. 2022). However, PV permitting reforms have, to date, occurred in a piecemeal fashion, and many AHJs lack the resources to implement reforms (Parsons and Josefowitz 2020).

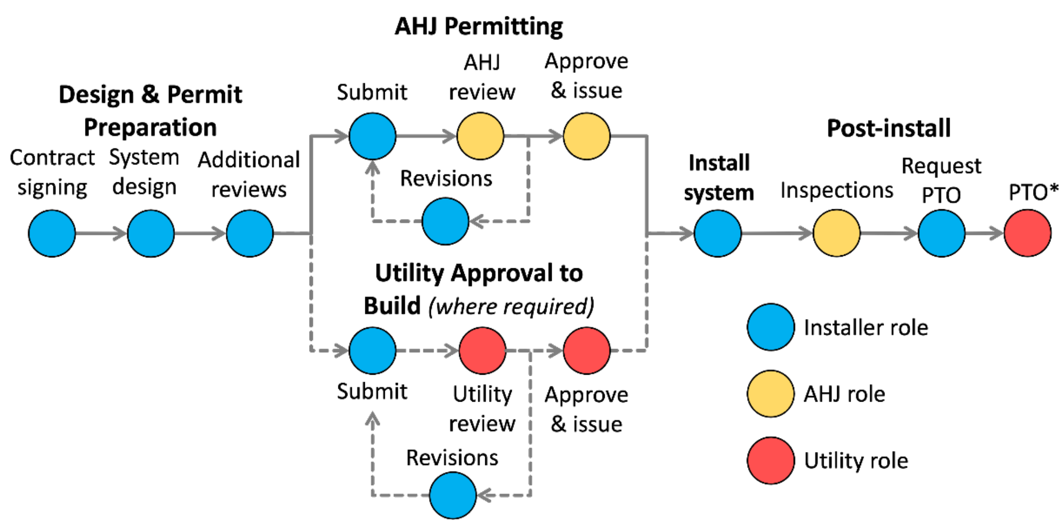

Figure 1. The rooftop PV permitting process

1.2 The SolarAPP+ Platform

SolarAPP+ was developed by NREL in response to the evolving challenges in rooftop PV permitting. NREL developed the platform in collaboration with industry and the building safety community, with funding from the U.S. Department of Energy. SolarAPP+ streamlines AHJ permitting for residential rooftop PV systems that meet certain eligibility requirements,[1] automating the review of eligible systems through the steps illustrated in Figure 2. SolarAPP+ allows PV contractors to upload system specifications, have that information automatically reviewed for code compliance, and obtain instant approval for code-compliant systems. Based on the application inputs, SolarAPP+ also generates checklists and electrical schematics for inspectors to confirm that installed systems match preapproved designs. The SolarAPP+ project formally began in September 2019 with development and testing of the software for alignment with national model codes. NREL piloted the software with five communities in 2021 (Williams et al. 2022). SolarAPP+ was then officially launched in July 2021.

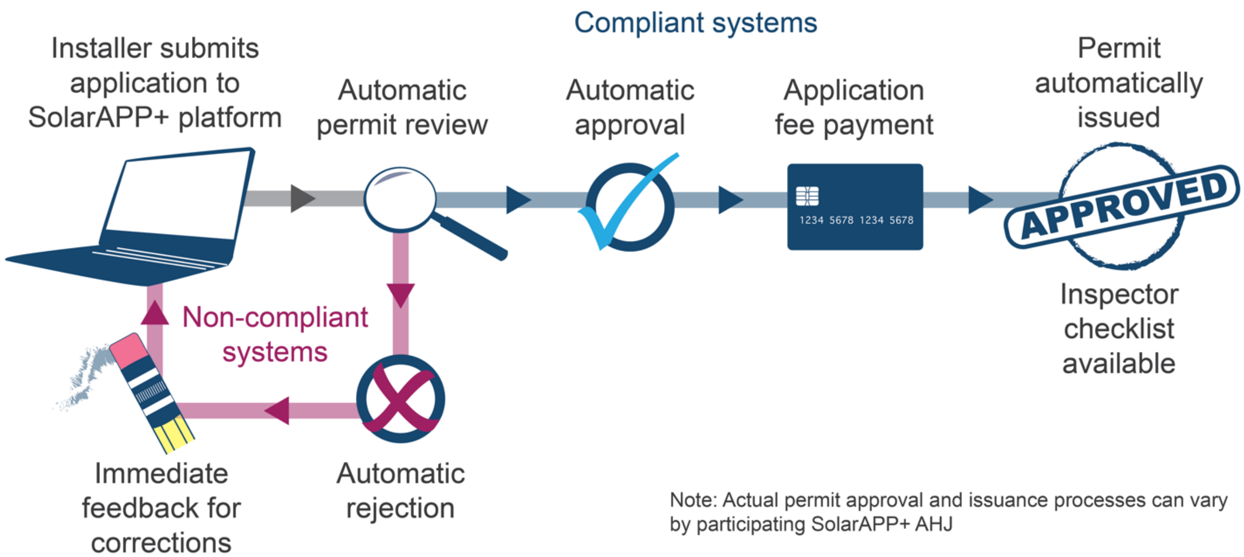

Figure 2. Example SolarAPP+ permit application and approval process

Note: In most AHJs, the fee payment and permit issuance occurs via the AHJ's existing permitting system.

1.3 Past SolarAPP+ Performance Reviews

NREL has published three reviews of SolarAPP+ platform performance to date. Williams et al. (2022) analyzed the performance of five SolarAPP+ pilots, Cook et al. (2022) evaluated platform performance in 10 AHJs that had piloted or implemented SolarAPP+ by the end of 2021, and Cook et al. (2023) evaluated performance in 31 AHJs that had piloted or implemented SolarAPP+ by the end of 2022. The three reviews reach similar conclusions:

- SolarAPP+ saves AHJ staff time otherwise spent on permit and revision reviews.

[1] For a complete list of the eligibility requirements, see https://help.solar-app.org/article/43-what-types-of-systems-are-not-eligible-for-solarapp-review.

- SolarAPP+ instantly issues permits for code-compliant systems, effectively reducing permit review times to zero. By contrast, typical review times through traditional permitting processes are a week or more.

- SolarAPP+ projects had similar inspection durations and passed inspections at similar rates as other projects.

- SolarAPP+ projects complete the full permitting timeline (permit submission to passed inspection) faster than projects using traditional permitting processes.

This report builds on and largely corroborates the results from these previous performance reviews with updated results for projects permitted in 2023.

2 SolarAPP+ Implementation

As of the end of 2023, NREL had contacted over 1,700 AHJs as potential users of the SolarAPP+ platform. Of these, 752 were interested in implementing SolarAPP+.[2] Interested AHJs are geographically distributed throughout the United States and are at various stages in the implementation process (Figure 3). Of the 752 interested AHJs, 127 AHJs were in a technical demonstration stage, 83 AHJs were evaluating and testing SolarAPP+, 66 AHJs were in pilot onboarding, 70 AHJs were in a pilot stage, and 97 AHJs had publicly launched the platform. Interested AHJs have a range of demographic features; 192 of the interested AHJs meet one typical criterion for identifying a community as disadvantaged (median income less than 80% of state median income).

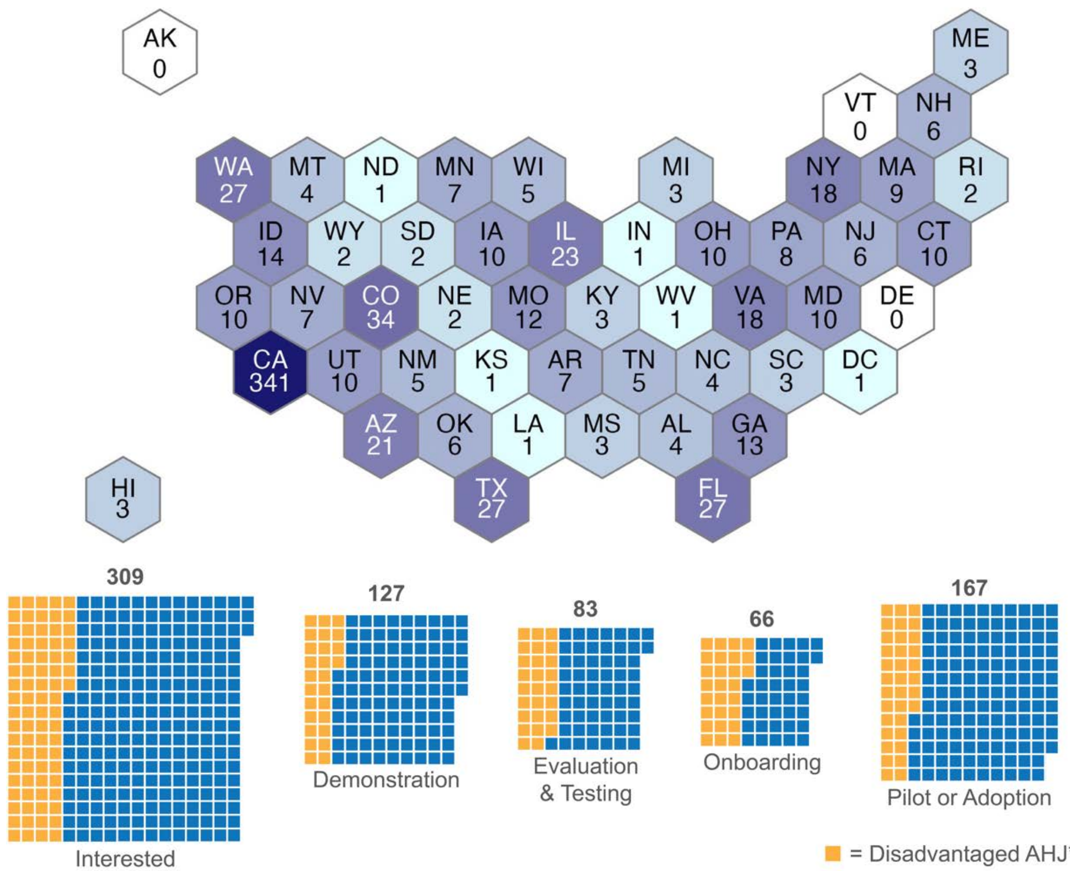

Figure 3. Number of AHJs that have expressed interest in SolarAPP+, by state (top pane) and by adoption stage (bottom pane)

* Refers to AHJs with median income less than 80% of state median income

Figure 4 depicts the platform implementation timelines for the 97 AHJs that had adopted SolarAPP+ by the end of 2023, ordered by the timing of the first interaction. These AHJs are the focus of this study. The median duration from first interaction to pilot was 505 days (or 553 days

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[2] An expression of interest occurs when an AHJ follows up on an initial contact, and it includes AHJs at any level of implementation: demonstration, evaluation, testing, pilot, or adoption.

on average), and the median duration from pilot to public adoption was 69 days (or 114 days on average). About 48% of AHJs moved from pilot to adoption in fewer than 3 months, and 84% of AHJs completed the process in fewer than 6 months (Figure 5). Over 70 AHJs adopted SolarAPP+ in the final months of 2023 (Figure 6), due largely to the implementation of a new policy in California requiring AHJs to adopt automatic permitting processes.

Figure 4. AHJ SolarAPP+ implementation timelines

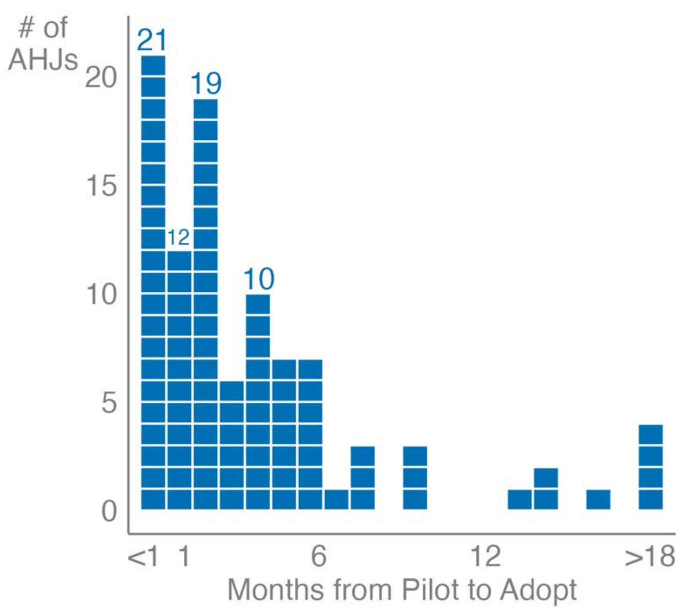

Figure 5. Distribution of AHJ SolarAPP+ implementation timelines from pilot to adoption

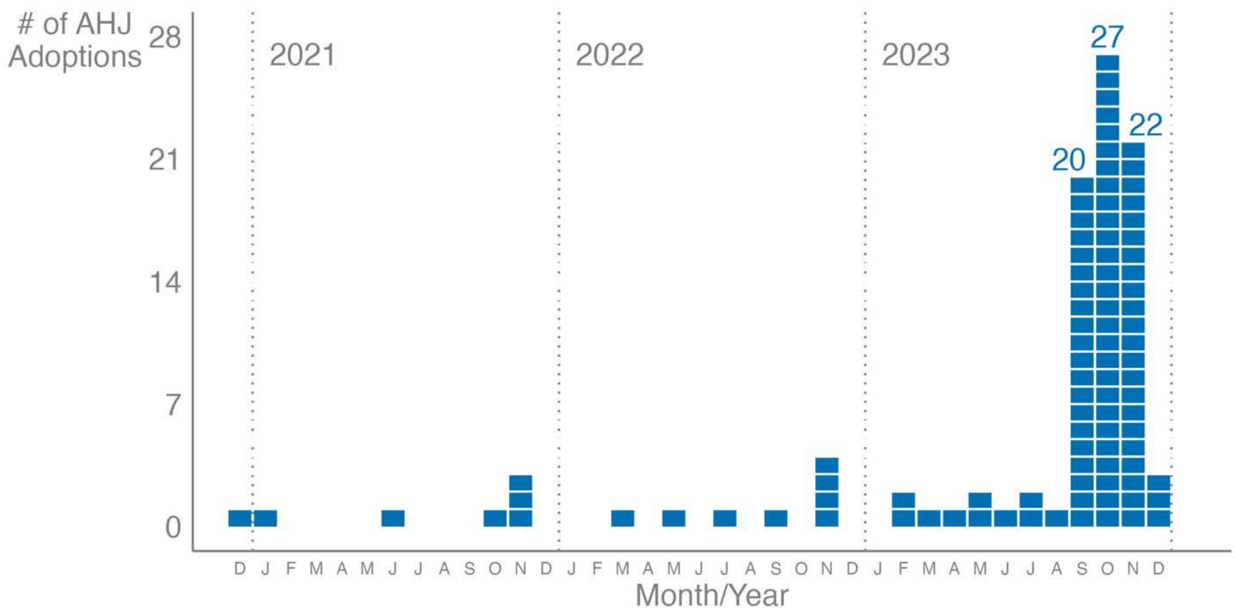

Figure 6. Month of adoption for the 97 AHJs that adopted SolarAPP+ by the end of 2023

NREL documented 215 AHJs that have explored SolarAPP+ but have delayed implementation for various reasons. Figure 7 summarizes the reasons most frequently cited by interested AHJs for delayed implementation. AHJs most commonly cite issues with integrating SolarAPP+ with existing permitting software, issues with payment processing, and conflicts with local codes (e.g., building, electrical, fire, or zoning codes). Note that delayed implementation does not necessarily reflect issues with the SolarAPP+ platform.

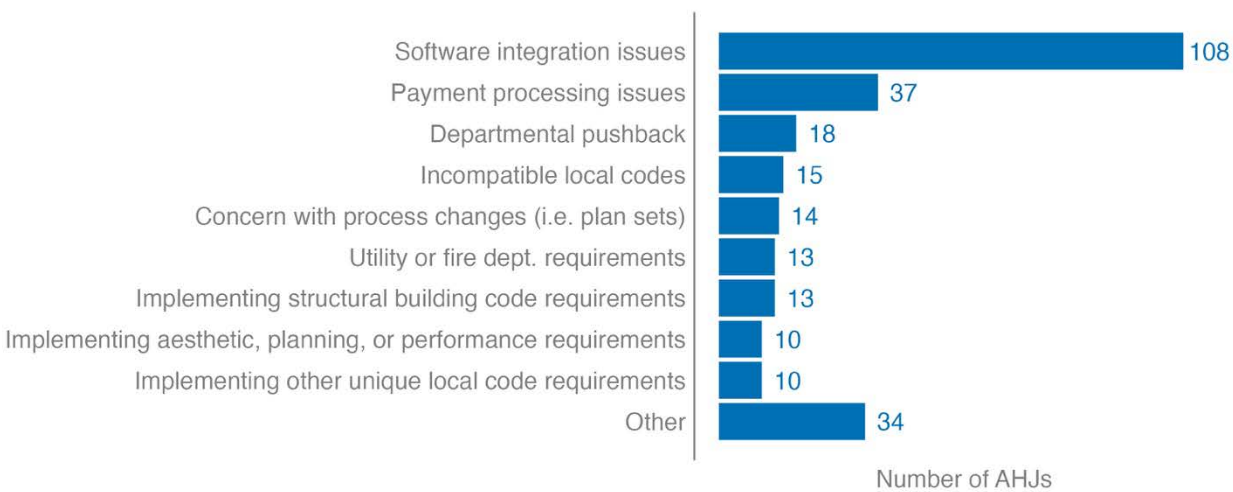

Figure 7. Reasons cited for delays to SolarAPP+ implementation

Note: Some AHJs cite multiple reasons.

Of the more than 1,700 contacted AHJs, 149 AHJs ultimately decided not to adopt SolarAPP+. Figure 8 depicts the reasons provided by these AHJs. Most of these non-adopters are satisfied with their existing permitting systems.

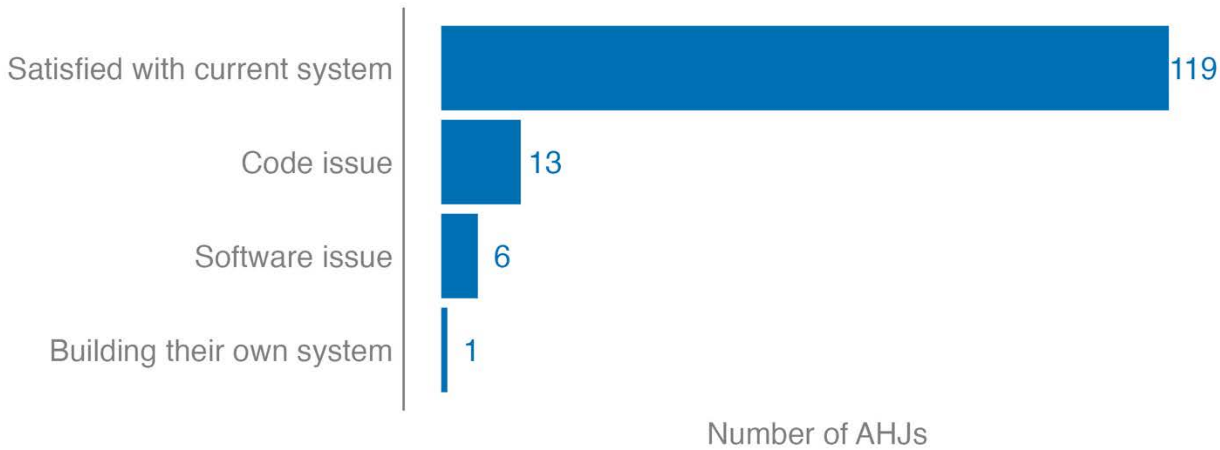

Figure 8. Reasons cited for not adopting SolarAPP+

Note: Some AHJs cite multiple reasons.

3 Performance Review

We review SolarAPP+ performance by comparing metrics for projects processed through SolarAPP+ to those for projects processed through traditional AHJ permitting processes. Performance review data were collected from two sources. First, we pulled data directly from the SolarAPP+ software, including data on projects, installers, AHJ adoption challenges, interested AHJs, and detailed project-level characteristics such as system size, module brand, and information on home electrical upgrades (summary statistics for these project-level characteristics are provided in the appendix). Second, we requested data from 47 AHJs that had adopted SolarAPP+, issued at least 40 SolarAPP+ permits in 2023, and also provided data on permits processed through traditional AHJ permitting processes. Of the 47 AHJs we contacted, 32 were able to provide us with usable data on both SolarAPP+ and traditional permit data. These 32 AHJs provided data, when available, on SolarAPP+ adoption timelines, permit submission dates, permit issuance dates, permit fees, and whether systems included battery storage. Twelve of the AHJs were also able to provide us with the inspection records for all solar permits, including inspection dates, date of final inspection passing, and inspection failure causes. For some analyses, we used the AHJ-provided dates to calculate durations. All durations reported in days are in terms of business days. The degree of data completeness across performance metrics varied by AHJ. The distinct samples used for each analysis are identified in the figure captions.

The term "SolarAPP+ project" refers to any PV or PV+storage system that was entered into SolarAPP+ by a contractor. All SolarAPP+ projects are issued approved system designs/plans, but only some projects are automatically issued a permit via the SolarAPP+ platform, depending on the SolarAPP+ integration pathway chosen by the AHJ.[3] The SolarAPP+ projects that do not receive a permit within SolarAPP+ receive their instant permit from the AHJ after the contractor uploads the SolarAPP+ preapproved system plans in the AHJ's online permitting system. The term "SolarAPP+ permits" refers to both permits automatically issued on the platform and permits issued by the AHJ.

Before proceeding to the results, it is worth noting that our performance review is based on a comparison of outcomes for SolarAPP+ and traditional permits that does not control for potentially confounding factors. Potential differences between the SolarAPP+ and traditional project groups could cause misleading deviations between SolarAPP+ and traditional process durations. For instance, installers that tend to use SolarAPP+ may navigate permitting processes more or less efficiently than installers that use SolarAPP+ less often. Further, the estimated differences between the AHJs in this study are not necessarily representative of the potential impacts of SolarAPP+ in other AHJs. It is possible that the AHJs in this study had more or less efficient traditional permitting processes than an average AHJ prior to implementing SolarAPP+. For these reasons, the reported impacts should be considered approximate impacts of SolarAPP+

[3] SolarAPP+ provides two different implementation pathways for AHJs based on their existing permitting process. AHJs who only accept permits in their traditional process via email, mail, or in person are onboarded using the "standalone" method, where SolarAPP+ also handles their fee collection and issues the final permit. AHJs who use a pre-existing government software system to issue permits are onboarded using the "integrated" method, where SolarAPP+ issues permit documents for upload into their existing software. The contractors then complete their payments in the AHJ's existing software, and that software issues the final permit instantly.

on AHJ permitting process durations. Further research would be required to estimate precise causal impacts of SolarAPP+ on permitting process durations.

3.1 AHJ Permit Volume

In 2023, 668 contractors submitted 18,906 projects and completed 2,879 revisions on these projects (including revisions during inspection) within the SolarAPP+ platform across 150 AHJs (Figure 9). Of those projects, 4,834 were PV+storage projects submitted in 131 AHJs. AHJs with the greatest SolarAPP+ permit volumes were concentrated in Arizona and California (Figure 10).

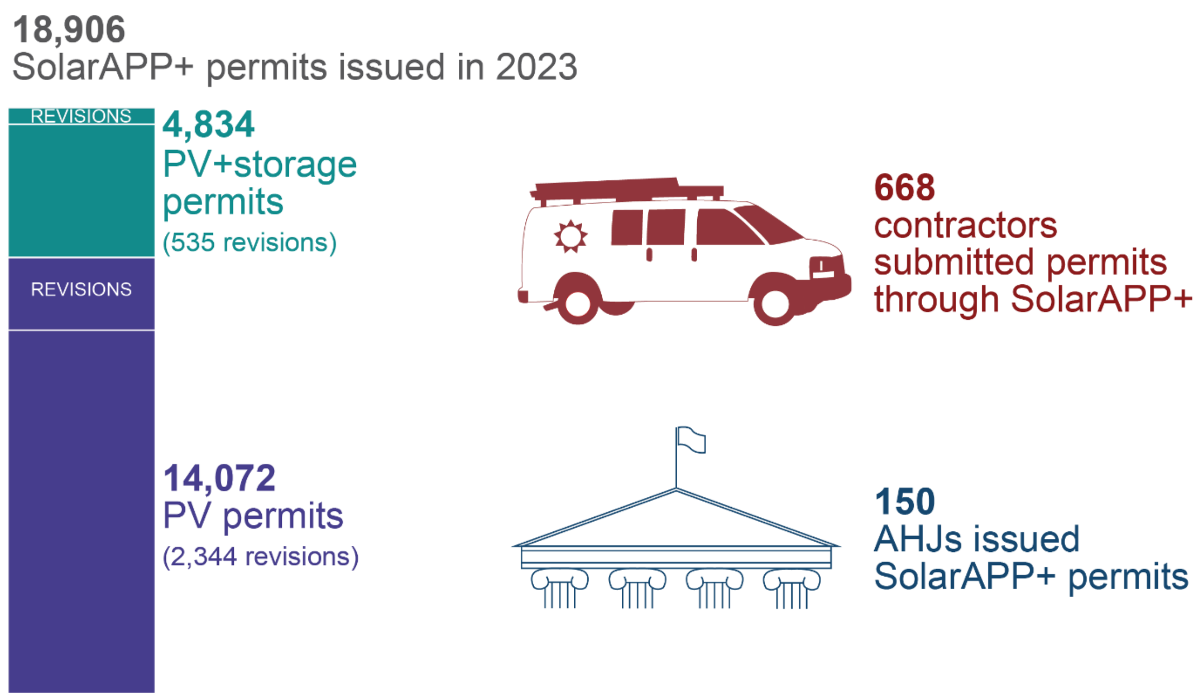

Figure 9. Key statistics on SolarAPP+ permits and revisions in 2023

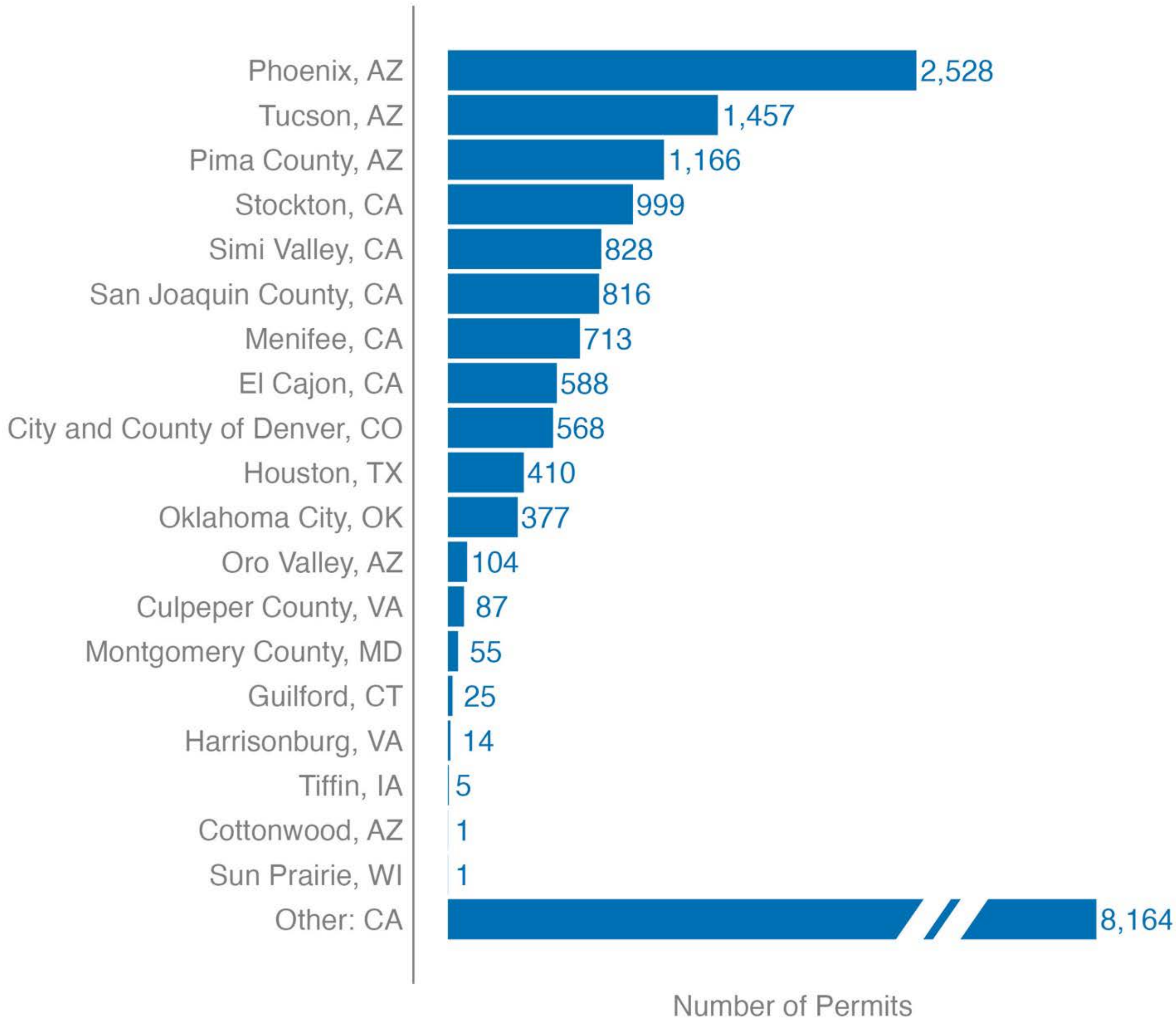

Figure 10. SolarAPP+ permit counts by AHJ

Each AHJ has about 15 installers using SolarAPP+, on average (Figure 11). Participating installers reflect a range of characteristics and installation volumes, confirming that the SolarAPP+ platform is not used exclusively by specific types of installers (Figure 12). The data suggest that a significant share of installers participate in SolarAPP+. For instance, 57 installers submitted SolarAPP+ permits in Tucson, Arizona, in 2023, and data from Barbose et al. (2023) suggest that around 107 installers operated in Tucson in 2022 (the latest year with available data). Although more installers may have been active in Tucson in 2023, the comparison suggests that around half of installers in Tucson used SolarAPP+.

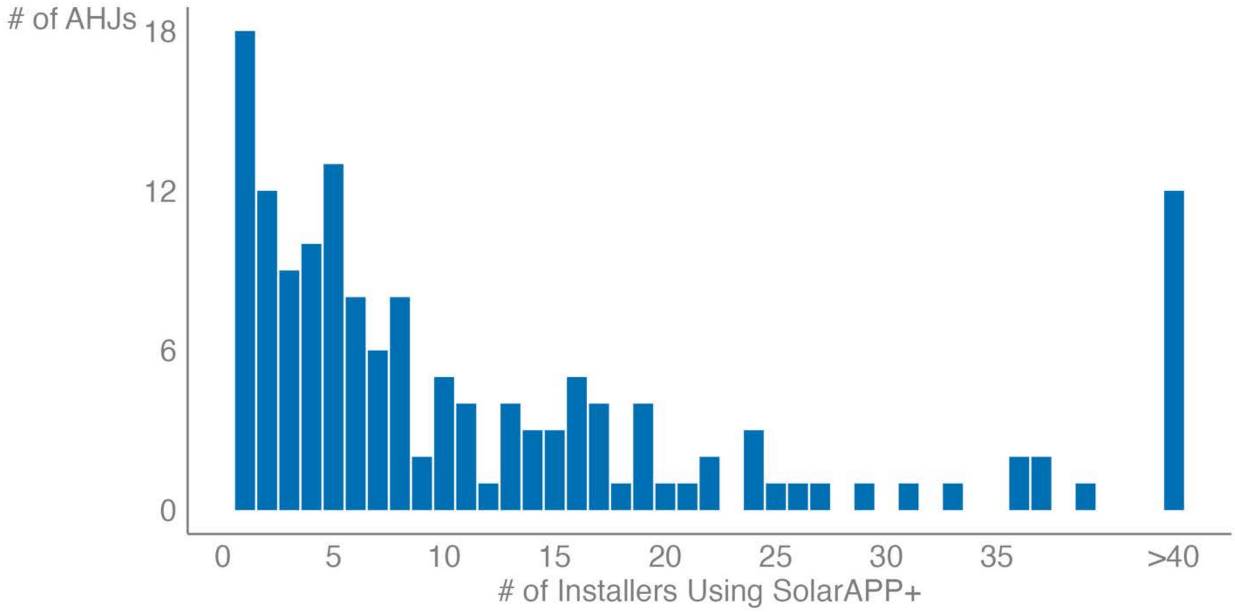

Figure 11. Number of installers using SolarAPP+ by AHJ (2023)

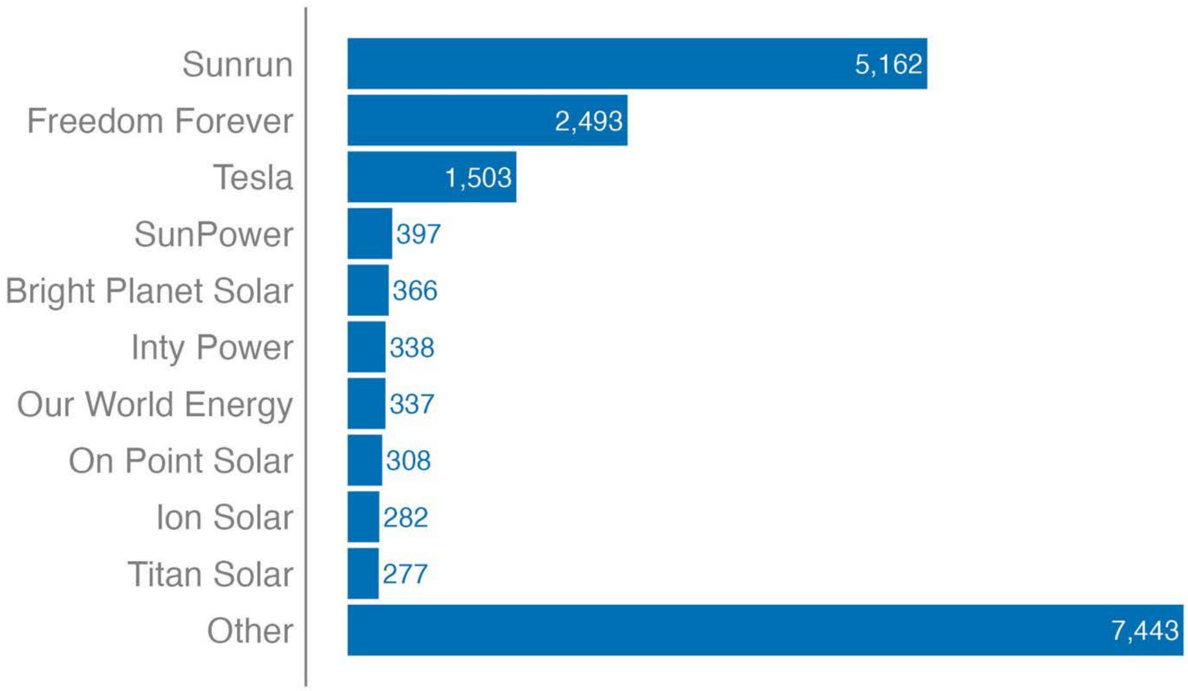

Figure 12. Number of SolarAPP+ projects by participating installer (2023)

After the public launch of SolarAPP+, about 43% of the permits submitted in 2023 in the subsample of 32 AHJs were submitted through the SolarAPP+ platform. The remaining 57% of permits were processed through the AHJs' traditional permitting systems. Figure 13 depicts the distribution of post-launch SolarAPP+ utilization rates by AHJ, showing how utilization rates in most AHJs fall between 20% and 40%, with utilization rates of greater than 80% in several

AHJs. The data suggest that SolarAPP+ utilization rates increase over time. In the 13 AHJs with available data that had publicly launched SolarAPP+ before 2023, monthly utilization rates steadily increased from about 36% in January 2023 to 57% in December 2023 (Figure 14).

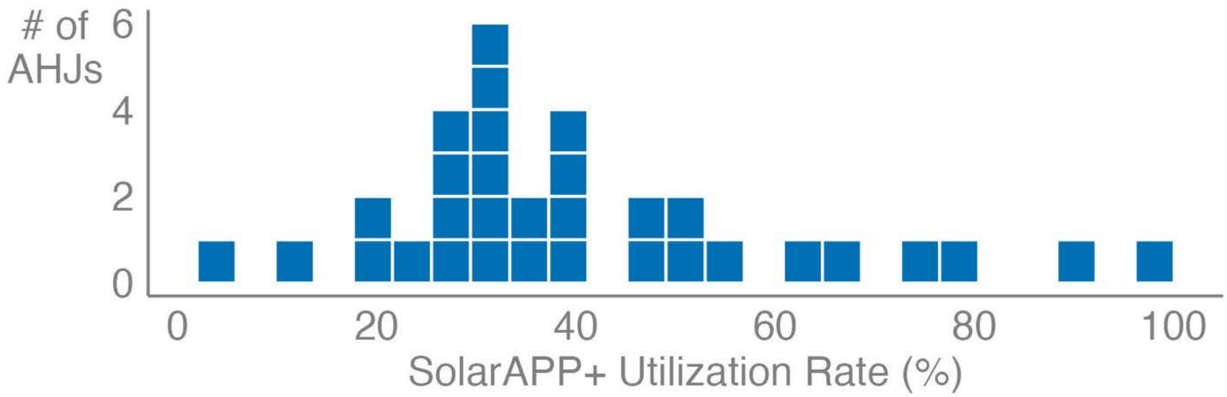

Figure 13. SolarAPP+ utilization rates (2023)

Note: This figure is based on AHJs with at least 30 SolarAPP+ permits submitted in 2023 and available data on traditional permits.

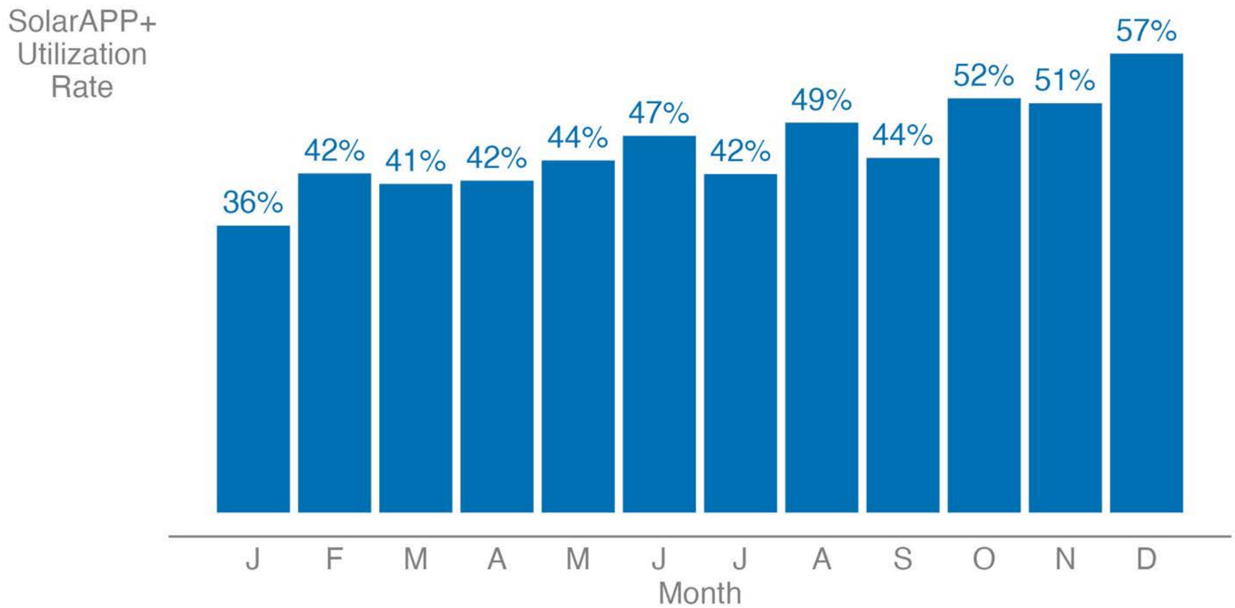

Figure 14. SolarAPP+ utilization rate by month (2023)

Limited to AHJs that publicly launched SolarAPP+ before 2023

3.2 AHJ Permit Review Impacts

Permit review durations refer to the time (in business days) between a permit submission and permit issuance. We compare permit review durations for SolarAPP+ and traditional projects to evaluate the platform's performance during the review stage. In every AHJ, median permit review times for PV-only SolarAPP+ projects were lower than or equal to median review times for traditional permits (Figure 15). The median permit review time for traditional PV-only projects across all AHJs was 7 days.[4] In contrast, SolarAPP+ facilitates instant permits for code-compliant applications, meaning that the median permit review duration for SolarAPP+ projects was zero days. Review times for PV+storage projects are mostly comparable, with a median review time of 9 days for traditional projects and zero days for SolarAPP+ projects. Median durations represent the permitting experiences of most PV customers. However, some customers experience much longer durations. Around 13% of traditional permits took more than 30 business days, and around 4% took longer than 60 days. SolarAPP+ nearly eliminates these extreme durations, with fewer than 1% of SolarAPP+ permits taking longer than 30 days to be issued.

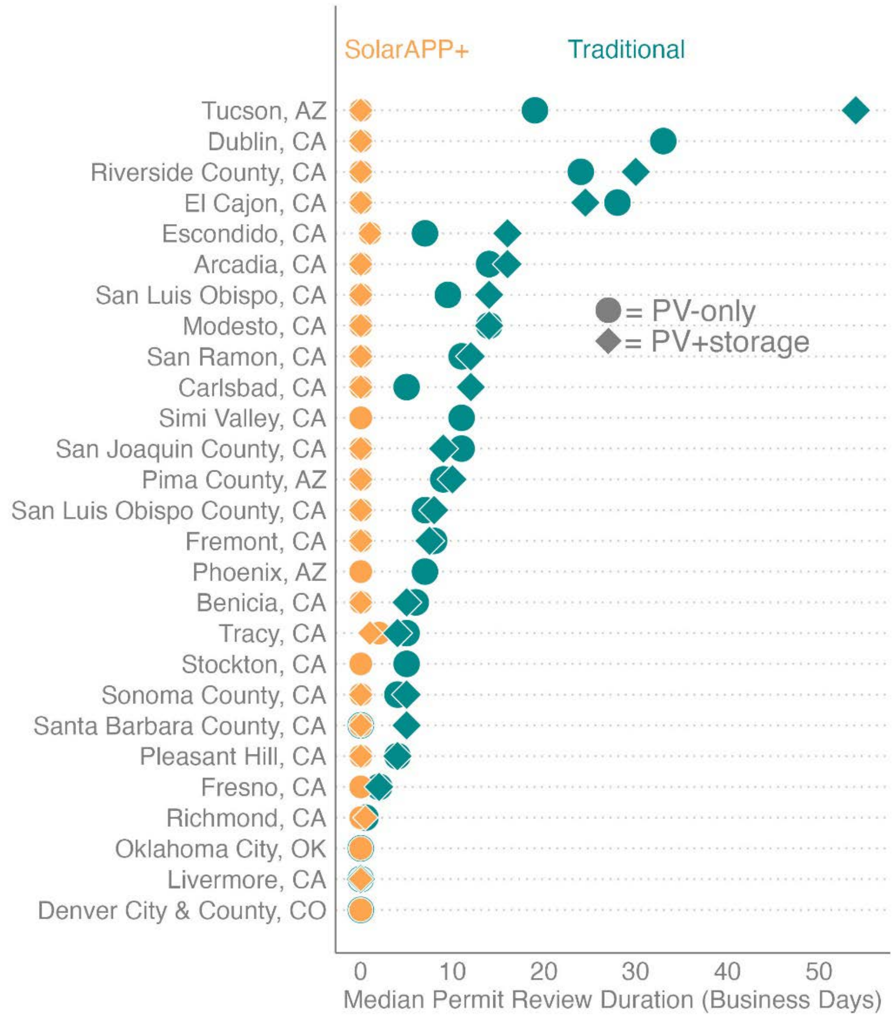

Figure 15. Median permit review times

Note: This figure excludes five AHJs for which duration data were not available for traditional permits.

In addition to reducing permit review durations, the SolarAPP+ platform reduces AHJ staff review time by removing the need for individual permit reviews. The net impact of SolarAPP+ on staff time is influenced by both the time savings from permit reviews and the time required to

[4] Based on feedback from AHJs, these durations reflect timelines for a single permit entry, i.e., they do not include revisions, allowing for an apples-to-apples comparison with SolarAPP+ durations for code-compliant systems.

implement SolarAPP+. According to feedback from AHJs reported in Cook et al. (2022), manual permit reviews require around 25–60 minutes of staff time. Figure 16 depicts the estimated AHJ staff time saved in 2023 by automating permit reviews on the SolarAPP+ platform, assuming reviews take 25–60 minutes. Overall, we estimate that AHJs collectively saved between 9,080 and 21,790 hours of staff time in 2023 by adopting SolarAPP+, including saved time on reviews for permit revisions. This reflects savings for PV-only and PV+storage permits and assuming that every revision must go through AHJ reviews. Estimated staff time savings are the equivalent of about 4–10 full-time employees. Figure 16 depicts the estimated staff time savings in the 10 AHJs with the largest estimated savings in 2023.

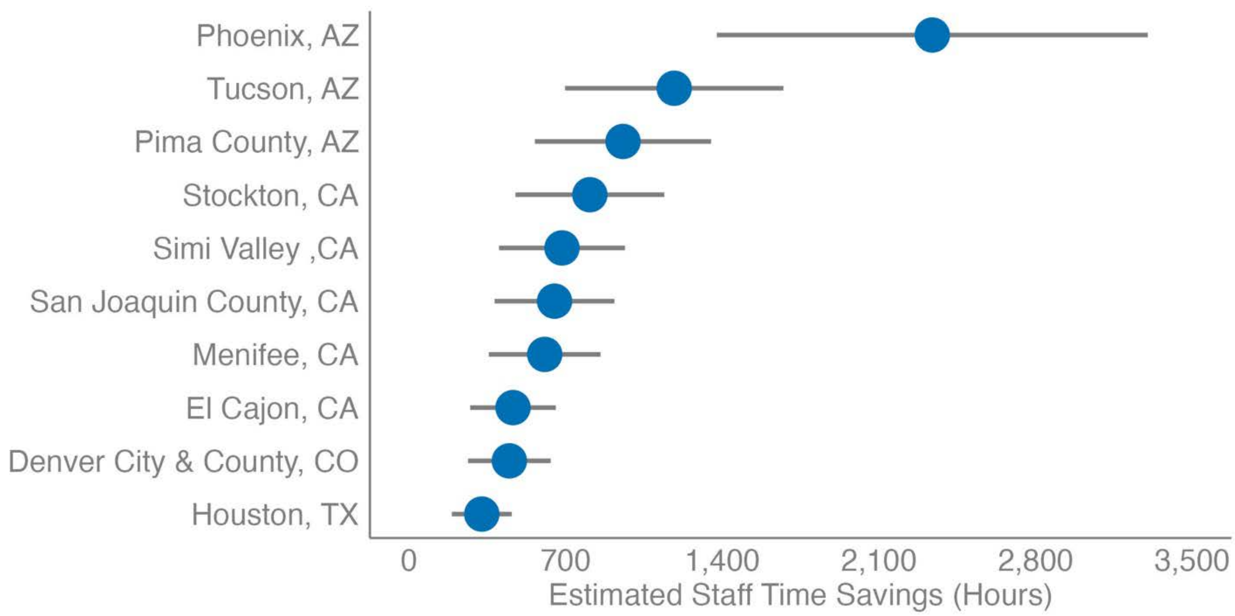

Figure 16. Estimated AHJ staff review time savings (2023) from SolarAPP+ permit processing in the 10 AHJs with the highest estimated savings

Note: The lower and upper bounds of the bars represent staff time savings assuming each review and revision takes between 25 and 60 minutes, respectively, while the points represent the middle of the range (42.5 minutes). These numbers are based on AHJ-provided estimates of permit review time.

3.3 AHJ Inspection Impacts

We define the inspection failure rate as the percentage of projects that failed at least one inspection. Figure 17 depicts inspection failure rates for traditional and SolarAPP+ PV-only projects across 11 AHJs with available data. For PV-only projects, SolarAPP+ inspection failure rates were less than or equal to traditional inspection failure rates in seven of the 11 AHJs in 2023. However, across all 11 AHJs, PV-only inspection failure rates were slightly higher for SolarAPP+ projects than for traditional projects in 2023: about 35% of all SolarAPP+ projects failed an inspection at least once, compared to 29% of traditional projects. That difference is largely driven by Phoenix, the AHJ with the most SolarAPP+ permits and also one of the few AHJs with higher SolarAPP+ inspection failure rates. Excluding Phoenix from the analysis, inspection failure rates were about 23% for SolarAPP+ permits and 26% for traditional permits. As with other analyses, fewer data are available for PV+storage permits, and any analysis of PV+storage data must be treated with caution. With that caveat in mind, the data show that

SolarAPP+ PV+storage inspection failure rates are less than or equal to traditional project rates in the six AHJs with available inspection data for at least 10 records of each type (Figure 18).

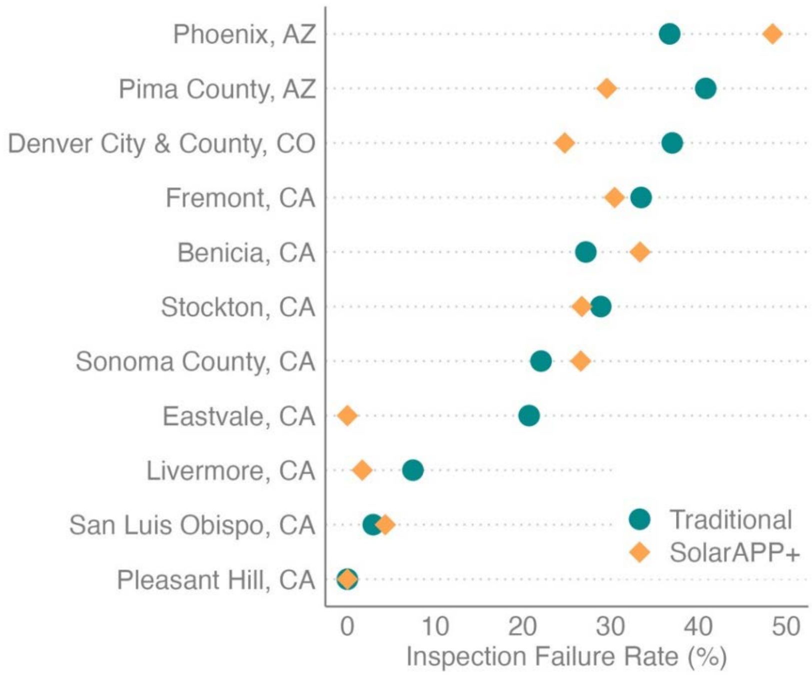

Figure 17. Inspection failure rates for PV-only projects by AHJ (2023)

Note: This figure is limited to AHJs with complete inspection failure data for SolarAPP+ and traditional permits. The figure depicts data from 10,651 inspections (3,455 SolarAPP+, 7,196 traditional).

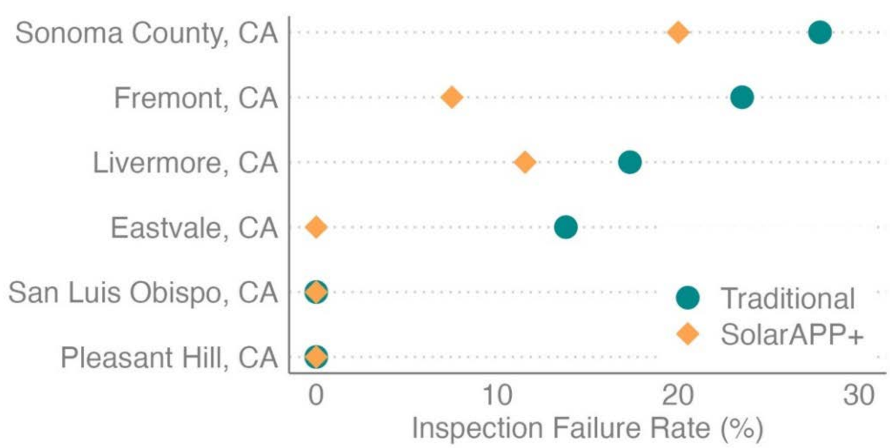

Figure 18. Inspection failure rates for PV+storage projects by AHJ (2023)

Note: This figure is restricted to AHJs with at least 10 inspection records for both SolarAPP+ and traditional permits. The figure depicts data from 682 inspections (156 SolarAPP+, 526 traditional).

While the results are mixed, these results suggest that expedited permitting through SolarAPP+ does not drive any downstream issues with inspections for PV-only or PV+storage projects. Further, the results suggest that—in most AHJs—SolarAPP+ permitting may reduce inspection failure rates. This second result should be treated as a working hypothesis; it is possible that the differences in inspection failure rates reflect preexisting differences between installers that do and do not use SolarAPP+. Further research is required to understand the impacts of SolarAPP + on inspection failure rates.

In addition to tracking the volume of SolarAPP+ inspection failures, we also tracked the reasons for inspection failure (Figure 19). 78% of the identified failures related to a work quality issue, meaning that the system was not installed per the code, either in isolation (71%) or accompanied by other issues (6%). About 13% of failures related to rescheduling, primarily because the homeowner or contractor was not available at the scheduled inspection time. Of the remaining inspection failures, a combined 17% were related to SolarAPP+ (install did not match the SolarAPP+ plan or inspection checklist was not on site). It is possible that more contractor education could result in fewer inspection failures of these types, thereby further improving SolarAPP+ inspection performance.

Figure 19. Known reasons for inspection failures among SolarAPP+ projects

3.4 Solar Adoption Timeline Impacts

In the previous two sections, we explored the impacts of SolarAPP+ at specific stages of the solar adoption timeline. Here, we explore the full timeline impacts of SolarAPP+, from permit submittal to final inspection. Across 27 AHJs with available data for PV-only projects,[5] the median duration from permit submission to final passed inspection was 33 business days for SolarAPP+ permits and 47.5 business days for traditional permits, suggesting that SolarAPP+ reduces permit-to-inspection timelines by around 14.5 days or about 31% (Figure 20). Similarly, across 19 AHJs with available data for PV+storage projects, the median permit-to-inspection duration was 29 days for SolarAPP+ permits and 52 days for traditional permits, suggesting that SolarAPP+ reduces permit-to-inspection timelines by around 44% for PV+storage permits.

[5] These subsamples refer to AHJs for which we have available data for complete durations for both SolarAPP+ and traditional permits.

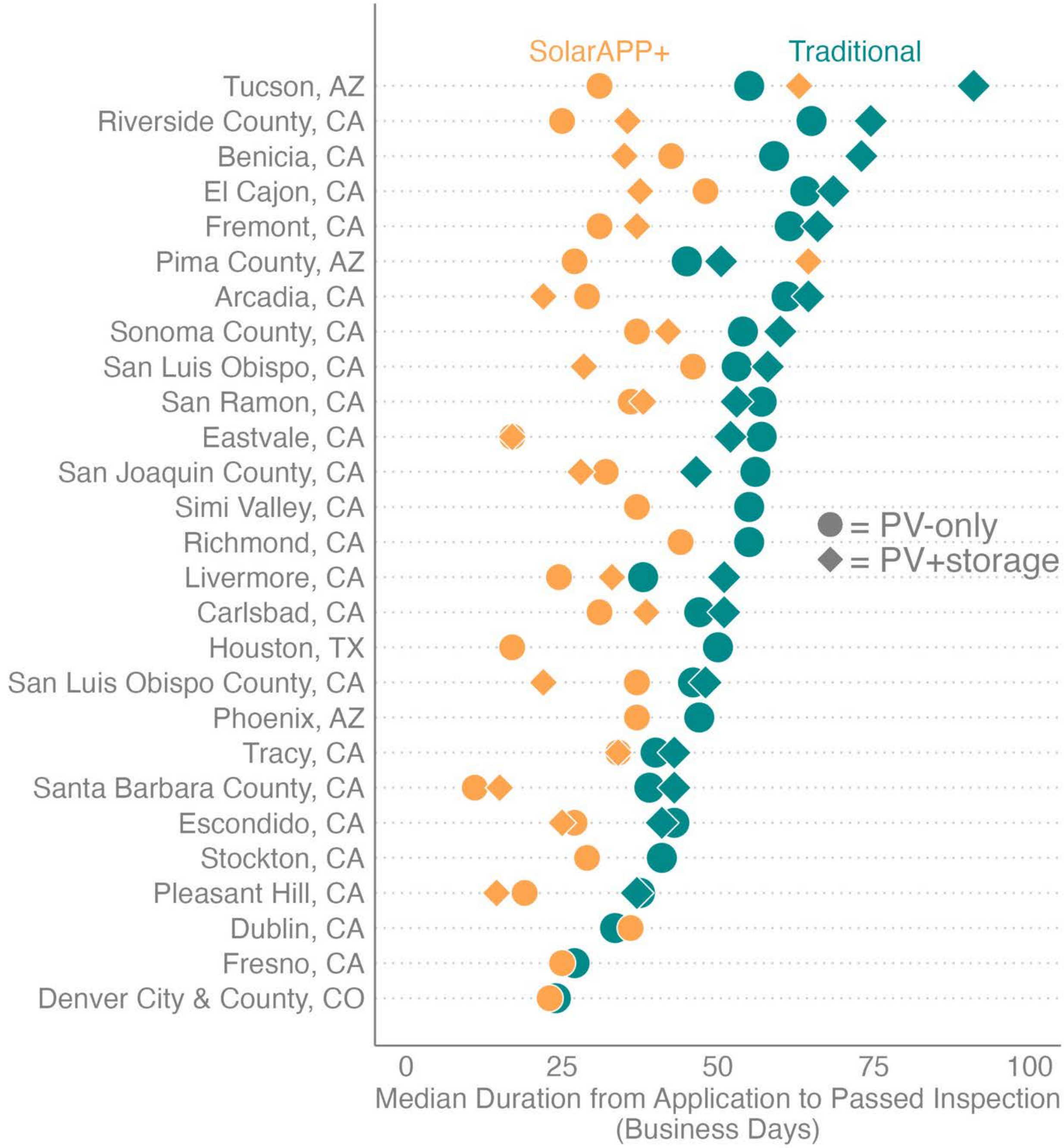

Figure 20. Median project time from permit submission to passed inspection by AHJ (2023)

Note: This figure excludes five AHJs for which duration data were not available for both SolarAPP+ and traditional permits.

Figure 21 depicts the estimated total impact of the SolarAPP+ platform in terms of reduced days for the 27 AHJs with available data. The total impact is a function of the number of permits processed and the estimated permit-to-inspection duration reduction in each AHJ. The figure shows that SolarAPP+ is estimated to have accelerated permitting processes by thousands of days in 2023, with savings of well over 10,000 days in some large AHJs. Across the 27 AHJs, the total estimated acceleration is 154,000 business days. As a reminder, these results are indicative of the total impact of SolarAPP+ on permit-to-inspection durations, but further research would be required to estimate the precise causal impact of SolarAPP+ on total time savings.

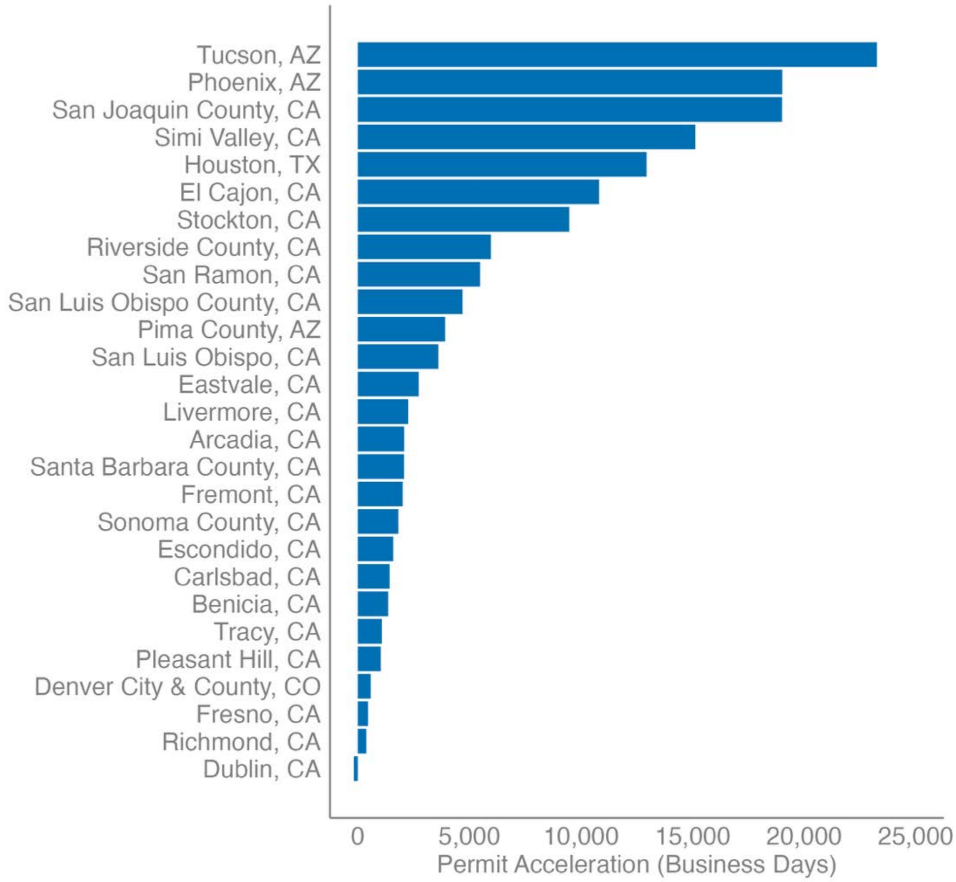

Figure 21. Total estimated acceleration of project timelines (permit submission to passed inspection) across AHJs

4 SolarAPP+ Estimated Impacts

The impact of SolarAPP+ on PV permitting processes may translate to broader impacts on the rooftop PV market. In this section, we explore the potential broader impacts of SolarAPP+ adoption in three dimensions: impacts on PV costs/prices, impacts on PV deployment, and AHJ benefits. We estimate ranges of potential impacts based on lower- and upper-bound assumptions in each of the three dimensions. We estimate the impacts of the 18,906 SolarAPP+ permits issued in 2023.

As in Section 3, we note here that the estimated impacts in this section should be interpreted as indicative of estimates under reasonable assumptions. Again, some estimated impacts may be sensitive to confounding factors that correlate with SolarAPP+ utilization. One possibility is that installers that use SolarAPP+ were already more efficient (i.e., quicker through permitting and inspection) than installers that tend to use traditional permits, in which case some of the estimated impacts of SolarAPP+ are in fact attributable to these preexisting differences. We have no specific reason to suspect that such confounding factors correlate with SolarAPP+ utilization, but the analysis that follows should be interpreted in light of that potential limitation.

4.1 Installation Costs

SolarAPP+ adoption could reduce PV installation costs and prices. We estimate the total impact on costs based on potential savings in permitting fees, permitting costs, cancellation costs, and inspection costs.

4.1.1 Permitting Fees

SolarAPP+ could reduce AHJ budgets for staff time to process PV permits and allow AHJs to reduce PV permitting fees (Plaisted 2022; Cook et al. 2023). Fee savings in AHJs that have already adjusted their fees range from \$6–\$251 per permit (Cook et al. 2023). Plaisted (2022) estimated fee savings of \$215 per permit for PV-only systems and \$390 per permit for PV+storage systems. Here, we assume that SolarAPP+ adoption reduces net permitting fees in the range of \$50–\$250.

4.1.2 Permitting Costs

SolarAPP+ adoption could reduce permitting compliance costs by facilitating the permitting process. Permitting costs can be direct, such as installer time spent preparing permitting applications for specific projects, and indirect, such as installer time spent learning how to navigate different permitting requirements across different AHJs. The Solar Energy Industries Association (SEIA) estimates that direct permitting costs (including inspection) are around \$0.13/W, while full (direct and indirect) permitting costs are about \$1/W (SEIA 2019). Our best proxy for the impacts of SolarAPP+ on these costs is the estimated 31% reduction in permitting timelines associated with SolarAPP+ estimated in Section 3.4. Assuming SolarAPP+ has a similar impact on costs, that equates to a permitting cost reduction of around \$0.04–\$0.31/W, which we use to define our lower- and upper-bound assumptions for SolarAPP+ permitting cost reductions.

Our assumed range is comparable to, if slightly lower than, the estimated range of \$0.20–\$0.57/W in permitting cost savings from SolarAPP+ that was estimated in an independent analysis (Plaisted 2022).

Further, Plaisted (2022) estimated substantially higher direct and indirect permitting cost savings for PV+storage projects of about \$0.4–\$1.1/W. Plaisted's estimate suggests that SolarAPP+ could play a particularly important role in mitigating permitting costs for PV+storage systems, which tend to be higher than for PV-only systems. Further research is required to characterize the role of SolarAPP + more precisely in PV+storage permitting.

4.1.3 Cancellation Costs

Estimates across the literature suggest that around 11%–33% of PV customers cancel their contracts (Liao 2020; Cook et al. 2021; Cruce et al. 2022).[6] Customer cancellations leave installers with costs that must be recouped through higher prices on successful projects. SolarAPP+ could reduce PV costs by reducing permitting delays and thus reducing cancellation rates. Cruce et al. (2022) estimate that these costs amount to about \$0.1/W for a typical system. We assume that SolarAPP+ reduces customer cancellation costs by 2%–5% (see Section 4.2.1), amounting to an additional \$0.002–\$0.005/W reduction in PV installation prices.

4.1.4 Inspection Costs

SolarAPP+-permitted systems are more likely to pass inspections than other systems in most AHJs (see Section 3.3). This impact remains inconsistent across AHJs and uncertain: It is possible that the measured difference reflects preexisting differences between installers that use SolarAPP+ and those that do not. Insofar as SolarAPP+ improves inspection outcomes, installers would save money by avoiding repeated inspections. However, these cost savings are unlikely to be substantial. Assuming that inspection failures require 8 hours of installer or electrician time to address issues and repeat inspections,[7] assuming a wage of \$25.50/hour,[8] each reinspection costs around \$200. For those savings to make a material impact, SolarAPP+ would need to lead to significantly fewer reinspections. Excluding Phoenix, SolarAPP+-permitted systems failed inspections 4 percentage points less frequently than other systems in 2023 (see Section 3.3), which only equates to about \$8 in savings per installed system. Given the uncertainties and potential minor impact of this cost, we exclude this factor from our analysis below.

4.1.5 Total Installation Cost Impacts

To convert \$/W savings estimates to total savings, we multiply the \$/W estimates by 6 kW, the median system size of SolarAPP+-permitted systems (see Appendix A.1). The total assumed per-install cost savings range from \$300–\$2,100. For perspective, those estimates reflect a 2%–13% cost reduction relative to residential PV system cost benchmarks (Ramasamy et al. 2023). We

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[6] The wide range may reflect methodological differences and how cancellations are defined, as discussed in Cruce et al. (2022).
[7] Typical inspections last around 20–30 minutes. Most of the time assumed here is to address the inspection failure issue.
[8] Based on a mixed wage of installers (median wage of \$22/hour: Palmer et al. 2023) and electricians (\$29/hour based on Bureau of Labor Statistics data).

then multiply these system-level savings by the number of SolarAPP+ permits issued in 2023. Table 1 summarizes the three cost savings components. In total, we estimate that SolarAPP+ permitting avoided around \$6M–\$41M in permitting-related costs in 2023. The wide range primarily reflects the uncertainty in the degree to which SolarAPP+ permitting can reduce both direct and indirect permitting costs.

Table 1. Estimated Cost Savings (\$M) From SolarAPP+ Implementation

Cost Savings	Lower Bound	Upper Bound
Permitting fees	0.9	4.7
Permitting costs	4.5	35.2
Cancellation costs	0.2	0.6
Total	**\$5.6M**	**\$40.5M**

4.2 Deployment

We explore potential impacts of SolarAPP+ on deployment due to avoided customer cancellations, reduced costs, and improved customer experiences.

4.2.1 Avoided Cancellations

As noted in Section 4.1.3, around 11%–33% of PV customers cancel their contracts. Cruce et al. (2022) estimate that about 2% of those cancellations occur during permit review. In our lower-bound case, we use that estimate to assume that SolarAPP+ reduces customer cancellations by 2% by expediting permit reviews. That share likely understates the role of permitting in driving customer cancellations, given that installers cite permitting delays as the key driver of cancellations (Cook et al. 2021) and permitting-related delays can begin before a permit is submitted (Plaisted 2022). We therefore assume that SolarAPP+ reduces customer cancellations by 5% in our upper-bound case. Finally, based on the range of estimates from the literature, we assume that around 22% of contracts are canceled. Under these assumptions, SolarAPP+ adoption would increase deployment by 0.4%–1.1% above background levels by avoiding cancellations.

4.2.2 Deployment Impacts From Reduced Prices

In Section 4.1, we estimated that SolarAPP+ reduces PV costs by \$300–\$2,100 per install. In competitive markets, most of those cost reductions will be passed through to customers as lower prices. Assuming that 90% of cost reductions are passed through to customers, a \$300–\$2,100 cost reduction equates to roughly a 2%–17% price reduction relative to post-incentive prices for typical systems.[9] Gillingham and Tsvetanov (2019) estimate that rooftop PV demand declines by about 65% for each doubling in price, meaning that a 2%–17% price reduction from SolarAPP+ equates to roughly a 2%–11% increase in demand.[10]

[9] Assuming a median-sized 6-kW system at the NREL benchmark price of \$2.68/W that receives at least a 30% incentive from the federal investment tax credit.
[10] The Gillingham and Tsvetanov estimate may be conservative. Ros and Shetty Sai (2023) estimate rooftop PV price elasticities on the order of 100%–300%.

Plaisted (2022) argues that SolarAPP+-related price reductions would have a particularly substantial impact on PV deployment among low- and moderate-income (LMI) households. The rationale is that LMI customers are more price sensitive, such that a given change in price would have a larger impact on LMI deployment than on deployment among more affluent households. This is a plausible hypothesis, but the precise impact of price reductions on LMI deployment requires further research. LMI households face numerous barriers to adoption unrelated to price, such as lower homeownership rates. Further, many LMI adopters lease rather than purchase PV systems, such that the net impact of cost reductions on LMI PV prices could be muted. The specific impacts of SolarAPP+ on LMI deployment is a potential area for further research.

4.2.3 Improved Customer Experiences

Some households base their rooftop PV adoption decisions on the previous experiences of other adopters (Wolske et al. 2020). In many cases, households actively consult with previous adopters (Sigrin et al. 2017), and paid referrals (i.e., installers paying previous adopters to refer other customers) are common (Mond 2017). Insofar as SolarAPP+ facilitates PV permitting and improves customer experiences, customers of installers who use SolarAPP+ may be more likely to recommend adoption to their peers. This potential impact is highly uncertain and requires further research. We therefore exclude the impact from our lower-bound case. In our upper-bound case, we assume that improved customer experiences result in 0.05 additional referrals per SolarAPP+ adopter, roughly a 10% increase over background referral rates (Mond 2017).

4.2.4 Total Impacts

Table 2 summarizes the three deployment impact components. The total estimated impacts are a 2%–17% increase in deployment, equating to an additional 380–3,260 additional installs. That is, we estimate that the existence of the SolarAPP+ platform *increased* rooftop PV deployment by around 2%–17% in 2023 relative to what would have otherwise been deployed in the same year. For comparison, Plaisted (2022) estimates a 7%–25% increase in deployment for middle-income customers, and a 19%–100% increase for low-income customers.

Table 2. Assumed Deployment Impacts From SolarAPP+ Implementation

Deployment Impact	Base Case	Advanced Case
Reduced cancellations	80	210
Reduced prices	300	2,100
Improved customer experience	0	950
Total	**380**	**3,260**

4.3 AHJ Benefits

SolarAPP+ could benefit AHJs in at least three ways: permitting cost savings, electricity bill savings for AHJ residents, and progress toward sustainability goals.

4.3.1 Permitting Cost Savings

By automating PV permitting, SolarAPP+ frees up AHJ staff time for other AHJ services. Available data suggest that AHJs save around 25–60 minutes of staff time per permit, on average, equating to around 7,900–18,900 hours saved for SolarAPP+ AHJs in 2023. Based on an average wage of $21.9/hour for administrative staff (BLS 2023), the value of the saved time in 2023 is about $173,000–$414,000.

4.3.2 Electricity Bill Savings

While household electricity bill savings may not directly benefit an AHJ, bill reductions from automatic permitting are a type of AHJ service. These bill savings accrue from the accelerated timelines associated with SolarAPP+. In Section 3.4, we estimate that SolarAPP+ systems are permitted and installed 14.5 days faster than other systems, at the median. To estimate a rough heuristic of the bill savings accruing from that acceleration, consider that a typical household uses around 30 kWh per day and pays a rate of around $0.2/kWh.[11] Under those simplifying assumptions, a typical household spends about $87 for 14.5 days of electricity use. In the summer months, PV systems could offset nearly that full amount, although rate reforms in states such as California mean that PV systems cannot fully offset those charges. To be conservative, we assume that a typical customer saves $50 from the accelerated PV timeline. Applying that heuristic, SolarAPP+ PV adopters saved around $945,000 in 2023 due to the accelerated timelines from SolarAPP+ permitting.

4.3.3 Progress Toward Sustainability Goals

Many AHJs have set sustainability goals, such as achieving target rates of decarbonization by specified dates (Watts et al. 2017). SolarAPP+ adoption could help AHJs achieve their sustainability goals more quickly in at least three ways:

- As discussed in Section 4.2, we estimate that SolarAPP+ increased rooftop PV deployment by about 340–3,150 systems in 2023. That incremental deployment could contribute directly to the clean energy deployment goals of those AHJs. The additional deployment would also accelerate decarbonization. Likewise, accelerated permitting means that PV systems come online faster and begin to abate emissions sooner. Assuming that the 18,906 SolarAPP+-permitted systems came online 14.5 days faster than they otherwise would have, that equates to adding 274,000 days of emissions abatement. Rooftop PV decarbonization benefits are estimated to be on the order of 500 kg CO_2/year avoided per installed system (Zheng et al. 2021),[12] varying with the underlying emissions intensities of the grid in different AHJs. Using that estimate, the total emissions reduction in 2023 from added and accelerated deployment due to SolarAPP+ was around 0.5M–2.0M tCO_2 in 2023. For context, that is roughly the equivalent of offsetting the emissions from the electricity use of 110,000–380,000 homes (EPA n.d.).
- Permitting and inspection cost savings from SolarAPP+ would free up AHJ resources, some of which could be dedicated to clean energy programs.

[11] The U.S. average is about $0.16/kWh; we adjust this slightly higher to account for higher rates in California ($0.27/kWh on average) (EIA 2023).

[12] Zheng et al. (2021) estimate emissions benefits of 110–570 kg CO_2/year for a 4-kW system. Adjusting that for the median SolarAPP+ system (6 kW) and taking the middle of the range yields an estimate of 510 kgCO_2/year.

- SolarAPP+ adoption could help AHJs achieve recognition of their clean energy programs. To provide one tangible example, SolarAPP+ (or similar instant permitting) has been recognized as a key component for SolSmart designation, a program that recognizes AHJs with outstanding achievement in PV permitting. In 2024, two SolarAPP+ adopters (Fremont, California, and Sun Prairie, Wisconsin) were awarded some of the program's first platinum designations.

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Appendix. SolarAPP+ Project Design Characteristics

The SolarAPP+ platform provides a new data source for rooftop PV system characteristics. In this appendix, we describe SolarAPP+ solar and battery system characteristics and discuss how SolarAPP+ projects compare to the broader rooftop PV and battery storage markets. All numbers and figures in this section reflect cumulative data, i.e., including projects permitted before 2023.

A.1 System Size

The median system size for SolarAPP+ PV-only projects is about 6 kW, ranging from 0.2–29 kW (Figure 22).[13] The system sizes are comparable to sizes in the broader rooftop PV market, as indicated by the 7-kW median for systems installed in 2022 estimated by Barbose et al. (2023). Projects in the PV+storage pilot tend to be similarly sized, with a median PV system size of 6 kW. Further, most batteries in the PV+storage pilot have similar rated storage capacities, reflecting the standardized rated output of the limited number of battery products used in the pilot. Out of 40 PV+storage projects with available data, 35 projects had 13.5 kWh of storage capacity.

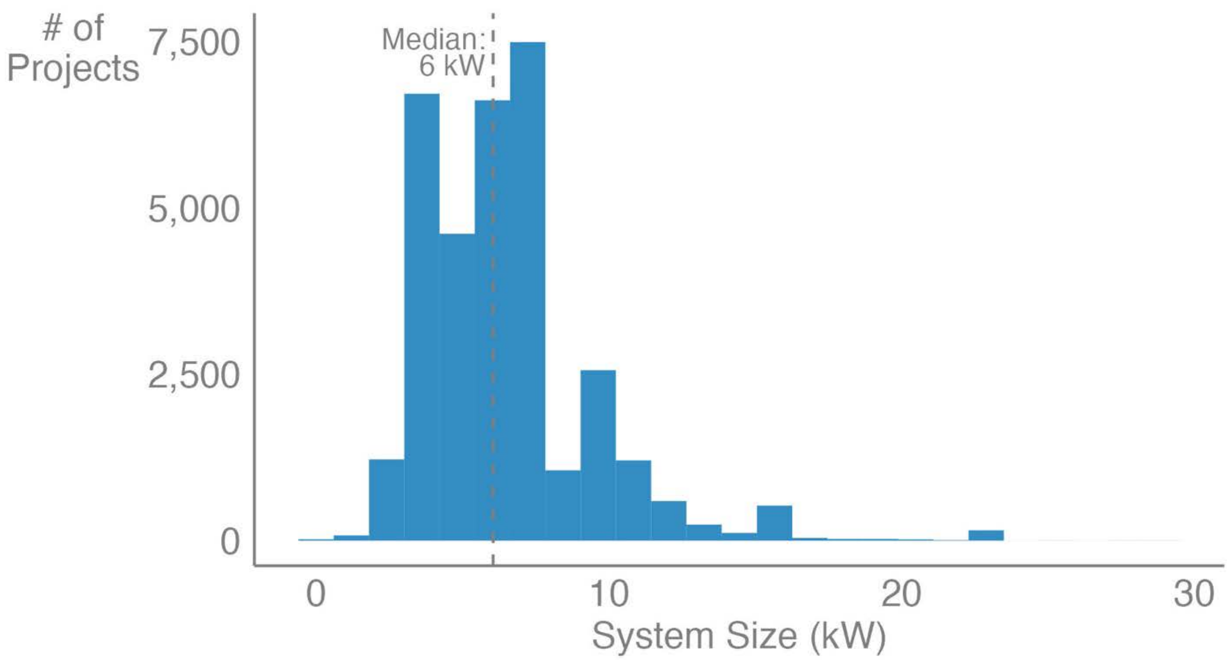

Figure 22. SolarAPP+ PV system size (kW) distribution for PV-only projects (N = 33,359)

A.2 Solar Modules and Inverters

Figure 23 depicts the distribution of module brands used in SolarAPP+ PV-only projects. Module brands largely reflect installer preferences and contractual agreements with module manufacturers. Data from EnergySage (2024) show that Hanwha Q CELLS, Silfab, and

[13] As noted, the statistics in this section are based on cumulative data. However, the median system size restricted to permits submitted in 2023 is also about 6 kW, which is why we use that system size as the basis for our assumptions in Section 4.

Renewable Energy Corporation (REC) modules are similarly popular among other installers off the SolarAPP+ platform. In the PV+storage pilot, JA Solar, Hanwha Q CELLS, and Tesla account for about 77% of PV modules.

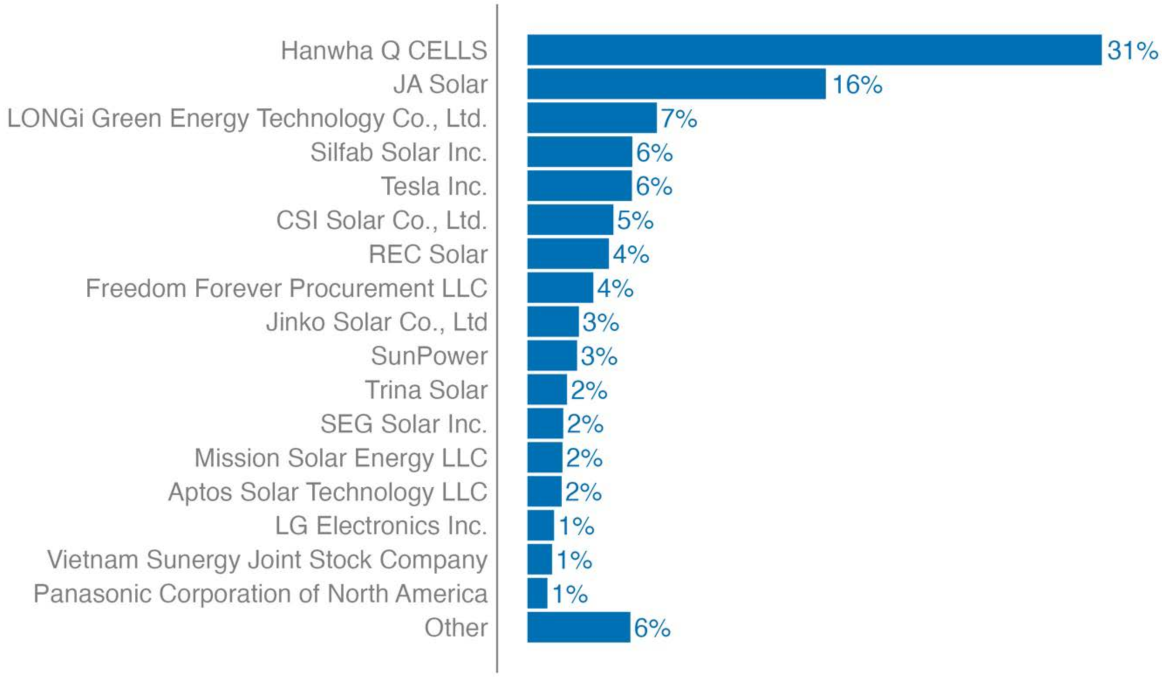

Figure 23. Module brand shares in SolarAPP+ PV-only projects (N = 33,363)

About 82% of SolarAPP+ PV-only systems include module-level power electronics, specifically DC optimizers (46%) and microinverters (36%) (Figure 24). That share is slightly less than the estimated residential marketwide share of 93% (Barbose et al. 2023). Module-level power electronics are less commonly reported in the PV+storage pilot, though the reasons for this remain unclear.

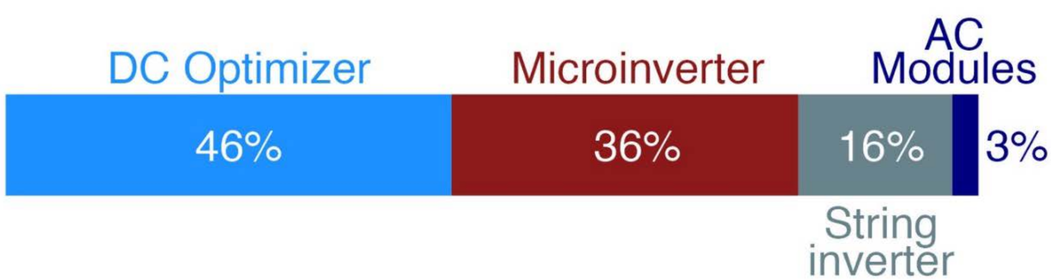

Figure 24. Inverter characteristics of SolarAPP+ PV-only systems (N = 33,363)

Note that percentages don't sum perfectly to 100 due to rounding.

Figure 25 depicts the distribution of inverter brands used in SolarAPP+ projects. Around 80% of SolarAPP+ projects use SolarEdge or Enphase brand inverters, similar to the share of those brands in the broader solar market as estimated by EnergySage (2024).

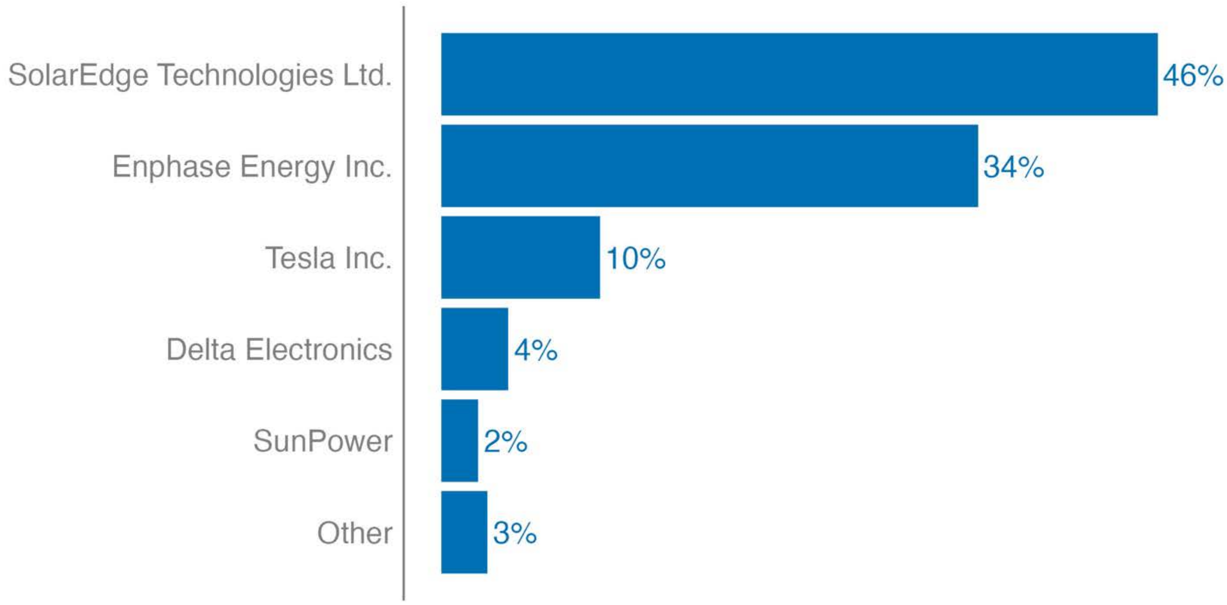

Figure 25. Inverter brand shares in SolarAPP+ PV-only projects (N = 33,363)

A.3 Home Electrical Upgrades and Interconnection Methods

Residential PV system installations can require upgrades to home electrical systems in certain cases. About 18% of SolarAPP+ PV-only permits and 10% of PV+storage permits were associated with a main panel upgrade (Figure 26). Further, about 12% of PV-only permits and 7% of PV+storage permits were associated with derating (reducing) the power limits of the home's main breaker, required in cases where the PV system could cause the home to exceed amperage limits set by the local utility. All PV systems require setting an amperage limit above which the system is automatically disconnected from the grid. SolarAPP+ service disconnect limits ranged from 100 or fewer amps (17% of systems) to 125 amps (5%), 150 amps (3%), 175 amps (8%), or 200 amps (67%). Finally, most SolarAPP+ PV-only systems are connected to the grid using the 120% rule, meaning that the installed system amperage cannot exceed the home meter's safety limit by more than 20%. In contrast, the most common interconnection rule in the PV+storage pilot is the sum-of-breakers rule, which requires that the sum of the home's load and electrical supply (i.e., from PV and batteries) does not exceed the rated capacity of the busbar connecting the home to the distribution grid.

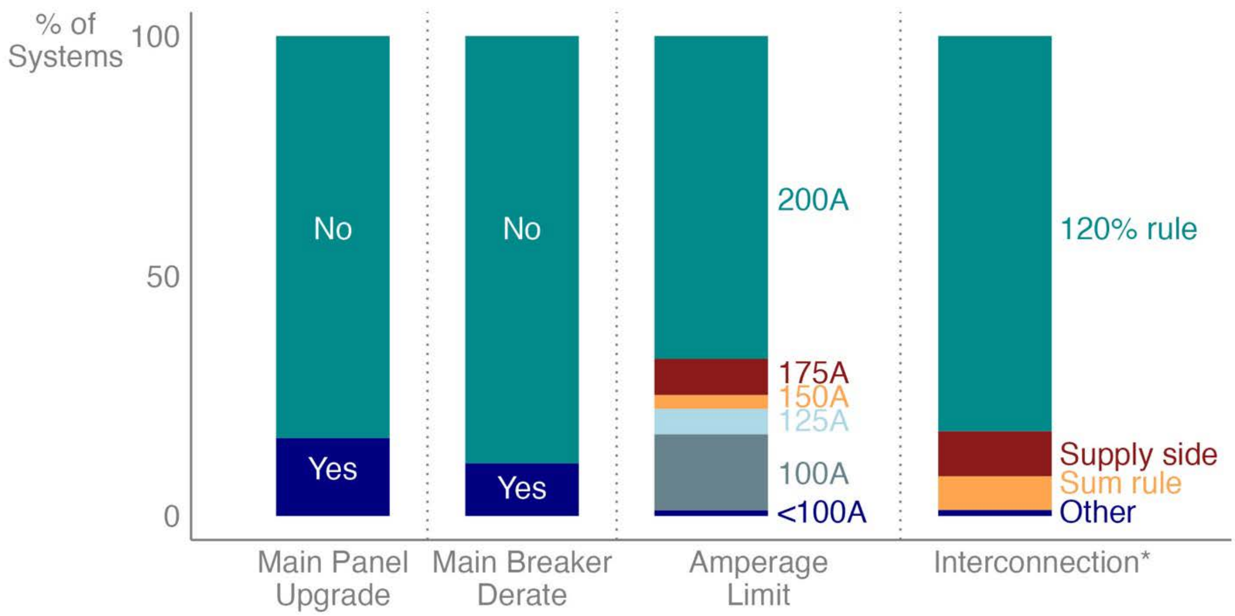

Figure 26. Electrical upgrade features of SolarAPP+ systems

Sample sizes: Panel upgrade N = 25,890; breaker derate N = 19,922; amperage limit and interconnection N = 14,335. *Sum rule = sum of breaker rule; supply-side = supply-side connection; "Other" includes 120% rule on center-fed panels, power control system, and 100% rule

A.4 Battery Characteristics

The following four figures depict data on battery system characteristics. Note that each figure is based on a subsample of data with available information. In some cases, missing data may skew the distributions. For instance, Figure 27 depicts the distribution of battery manufacturers for 569 systems with available data. This distribution is substantially different from other reported distributions (e.g., EnergySage 2024), either because of data reporting issues or because installers that use SolarAPP+ prefer different manufacturers.

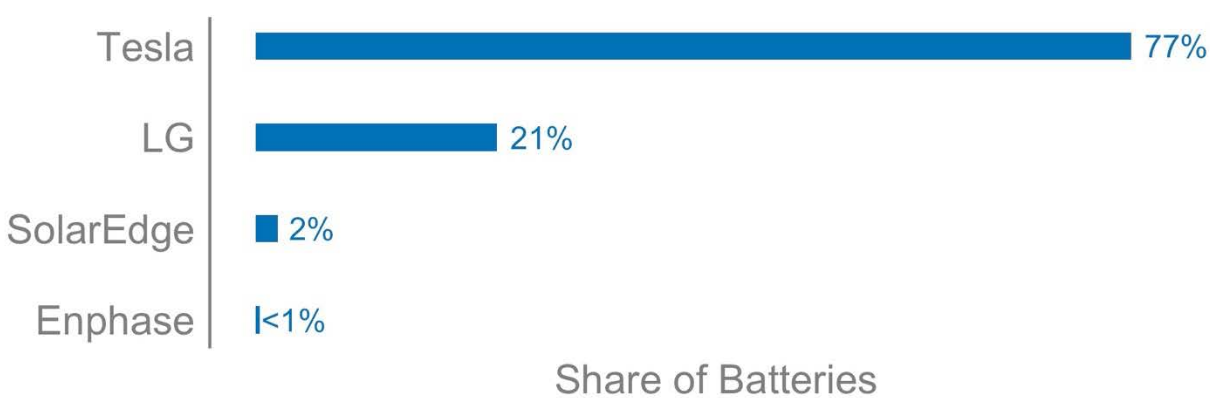

Figure 27. Distribution of battery manufacturers (N = 569)

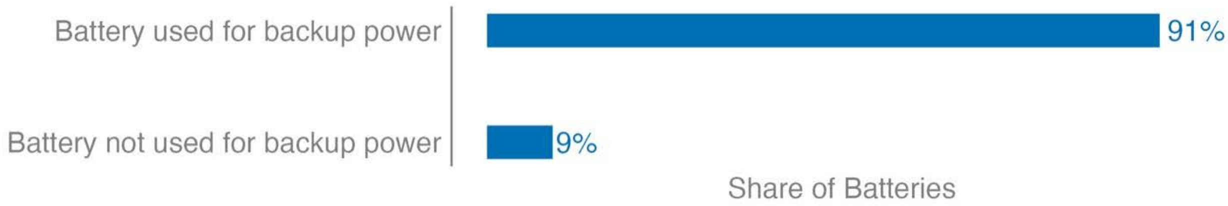

Figure 28. Distribution of batteries used for backup power (N = 945)

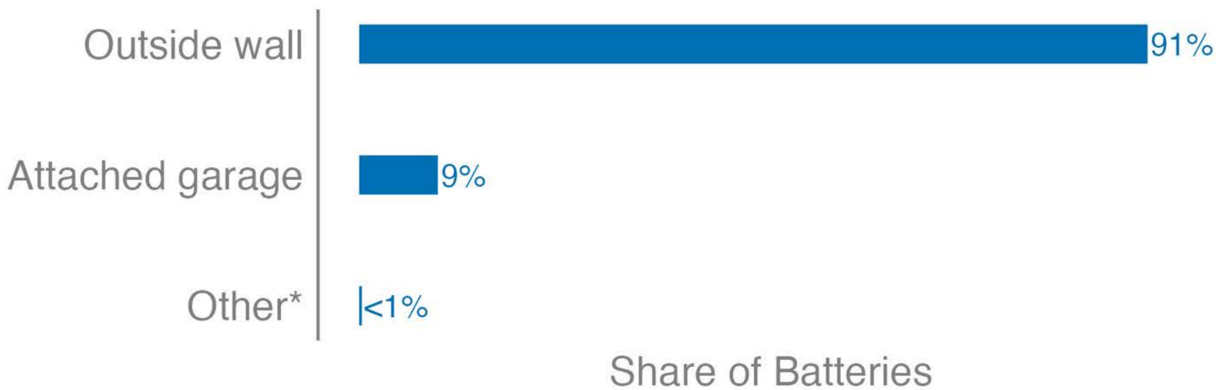

Figure 29. Distribution of battery storage mount locations (N = 5,548)

* Includes accessory structures, basements, detached garages, storage units, and utility spaces

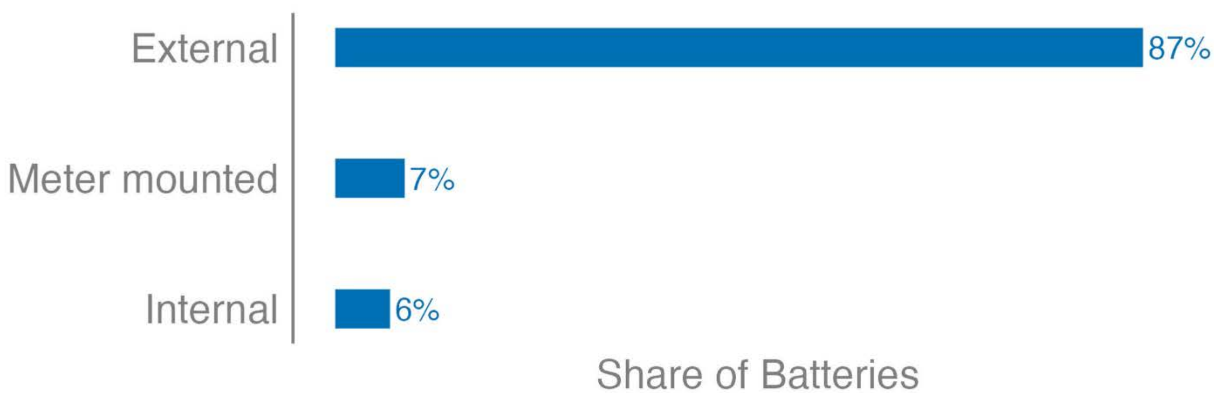

Figure 30. Distribution of battery storage initiation device locations (N = 1,140)