Residential and Small Commercial Solar Photovoltaic and Storage Permitting, Inspection, and Interconnection Timelines: A Retrospective Review (2017–2023)

Jesse Cruce, Dalila Lara, Noah Frey, Emily Dalecki, and Jeff Cook

National Renewable Energy Laboratory

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List of Acronyms

AHJ	authority having jurisdiction
ATB	approval to build (from utility)
IX	interconnection
NREL	National Renewable Energy Laboratory
PI&I	permitting, inspection, and interconnection
PTO	permission to operate (from utility)
PV	(solar) photovoltaic
SETO	Solar Energy Technologies Office
SolarAPP+	Solar Automated Permit Processing Plus
SolarTRACE	Solar Time-Based Residential Analytics and Cycle Time Estimator

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Executive Summary

This report is part of the ongoing Solar Time-Based Residential Analytics and Cycle Time Estimator (SolarTRACE) project, led by the National Renewable Energy Laboratory (NREL). The SolarTRACE project uses project-level data provided by installer-partners to assess timelines for residential and small commercial solar photovoltaic (PV) projects—and now storage projects—of up to 20 kW that were installed in the United States between 2017 and 2023. This report provides an update to our previous 2022 report, which analyzed projects installed between 2017 and 2021 (Cruce et al., 2022b).

Residential and small commercial solar PV and storage projects in the United States require anywhere from several weeks to several months between contract signing and system operation (Cruce et al., 2022b). As part of the installation and interconnection process, most projects require review and approval by the local electrical utility and the authority having jurisdiction (AHJ). These reviews typically include permits, one or more inspections, and the utility interconnection agreement and permission to operate (PTO), collectively called the PI&I process. The PI&I process helps ensure that installed systems meet building, electrical, and fire codes and safety standards. However, PI&I processes, complexity, and timelines vary widely across the tens of thousands of AHJs and 3,000 utilities in the United States (Stanfield et al., 2012). For example, a typical (median or average) solar permit might take 1–2 weeks for review and approval by the AHJ, but timelines can range from as short as same-day approval to as long as 6 weeks or more (Cruce et al., 2022b; O'Shaughnessy et al., 2022). Other non-PI&I interactions between the solar installer and customer—including contracting, site surveys and system design, scheduling and completing the installation, and roof repairs or electrical upgrades as needed—may also contribute to project timelines.

The SolarTRACE project continues to track timeline changes for residential projects in the United States. The dataset now covers 22% of residential solar and 33% of residential storage installations in the United States between 2017 and 2023. This report updates our previous analysis from 2022 and includes:

- Updated 2017–2023 timelines for rooftop solar PV projects up to 20 kW, which, after decreasing 2017–2019, have now increased again and averaged **4.5–6 months from contract signing to PTO in 2023**

- The first-ever reporting of timelines for residential and small commercial PV-plus-storage projects up to 20 kW, which are longer than those for residential solar and averaged **8–9 months from contract signing to PTO in 2023.**

As shown in Figure ES-1, overall project timelines (contract signing to PTO) for residential and small commercial PV were a month longer in 2023 than in 2019. This trend reverses the timeline improvements found in our previous report (Cruce et al., 2022b) and shows that, after declining 2017–2019, overall PV-only project timelines in our data increased again starting in 2021. Recent timeline increases were primarily due to longer design (contract signing to permit submission) and installation (permit approval to installation complete) phase times than in earlier years. These timeline increases affected most projects in the data, with increases of 3–4 weeks at the first quartile, interquartile range, median, mean, and standard deviation between 2019–2020

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and 2023 (the third quartile and the 90th percentile increased by about 5 weeks). This trend is true for most but not all installers in the data and for most AHJs. Finally, residential and small commercial storage projects both had longer timelines than solar-only projects and saw further timeline increases during this same period. The median and average differences between PV and PV-plus-storage projects increased from about 4 weeks in 2019 to 13 weeks (3 months) in 2023, again due to longer design and installation phase timelines.

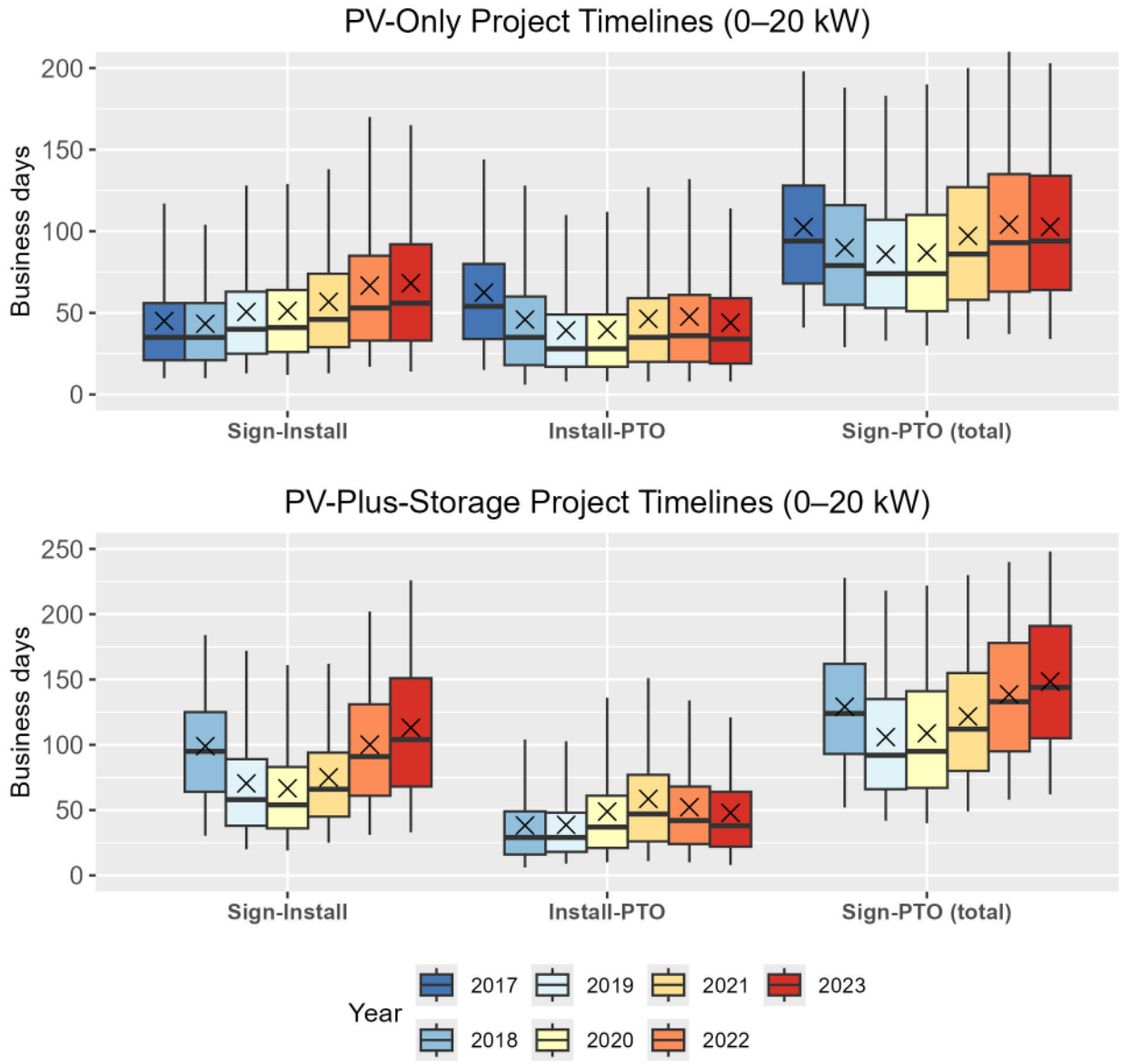

Figure ES-1. Rooftop PV and PV-plus-storage timelines for 0–20-kW projects, including pre-installation (contract signing to installation) and post-installation (installation complete to PTO) phases and total project time (contract signing to PTO)

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles. All values are in business days. Note that 5 business days typically constitute a week, whereas a month varies from 20–23 business days.

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1 Introduction

This report is part of the ongoing Solar Time-Based Residential Analytics and Cycle Time Estimator (SolarTRACE) project, led by the National Renewable Energy Laboratory (NREL). The SolarTRACE project uses project-level data provided by installer-partners to assess timelines for residential and small commercial solar photovoltaic (PV) projects—and now storage projects—of up to 20 kW that were installed in the United States between 2017 and 2023. This report provides an update to our previous 2022 report, which analyzed projects installed between 2017 and 2021 (Cruce et al., 2022b).

Residential and small commercial solar PV and storage projects in the United States require anywhere from several weeks to several months between contract signing and system operation (Cruce et al., 2022b). As part of the installation and interconnection process, most projects require review and approval by the local electrical utility and the authority having jurisdiction (AHJ). These reviews typically include permits, one or more inspections, and the utility interconnection agreement and permission to operate (PTO), collectively called the PI&I process. The PI&I process helps ensure that installed systems meet building, electrical, and fire codes and safety standards, along with any additional requirements set forth by states, local AHJs, and/or utilities. However, PI&I processes, complexity, and timelines vary widely across the tens of thousands of AHJs[1] and 3,000 utilities in the United States (Stanfield et al., 2012). For example, a typical (median or average) solar permit might take 1–2 weeks for review and approval by the AHJ, but timelines can range from as short as same-day approval to as long as 6 weeks or more (Cruce et al., 2022b; O'Shaughnessy et al., 2022).

Using best practices and streamlined PI&I processes—such as the Solar Automated Permit Processing Plus (SolarAPP+™) online-instant permitting platform—can decrease project timelines and costs, benefiting customers, installers, AHJs, and utilities (Cook et al., 2024; O'Shaughnessy et al., 2022). The number of AHJs offering online-instant permitting platforms has accelerated over the last 5 years, alongside a widespread switch to online/electronic permitting options in general (Cruce et al., 2022b). Similarly, many utilities have worked to streamline their interconnection processes, and some do not require an interconnection approvals prior to system installation (Ardani and Margolis, 2015; Fekete et al., 2022). At the same time, the U.S. residential solar market has also faced other changes and challenges, including a significant increase in project volume across many markets (followed by a contraction in some markets), a rapidly increasing market share of residential storage projects, supply chain disruptions, staffing shortages, cost increases, new state net rate structures, and the closure of many solar companies, including several large-volume installers (Agopian, 2024; Cruce et al., 2022b; Davis et al., 2024; Feldman et al., 2024; Kennedy, 2023; SEIA, 2024). Whether these and other challenges have offset ongoing improvements to solar adoption processes remains an open question.

[1] Estimates for the number of AHJs that could be involved in residential rooftop solar permitting vary, from 10,000–20,000 (shovels.ai, 2024), to 18,000 (Taylor, 2019), to over 43,000 (Hirsch, 2020). For reference, there are about 39,350 incorporated villages, towns, cities, municipalities, boroughs, townships, counties, and consolidated city-counties listed in the U.S. Census, not including Tribes or state building authorities (U.S. Census Bureau, 2024).

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The SolarTRACE project continues to track timeline changes for residential and small commercial projects in the United States. The dataset now covers 22% of residential solar and 33% of residential storage installations in the United States between 2017 and 2023. This report updates our previous analysis from 2022 and includes:

- Updated 2017–2023 project timelines for rooftop solar PV up to 20 kW
- First-ever reporting of timelines for residential and small commercial PV-plus-storage projects up to 20 kW.

This report is structured as follows. Section 2 provides an overview of the solar adoption process and previous research on PI&I and total project timelines. Section 3 details the SolarTRACE project, data collection, market coverage, and analysis for this paper. Section 4 presents the timeline results for residential and small commercial rooftop PV projects and PV-plus-storage projects. Timeline results are reported for the overall dataset and for the top 10 states by market volume for both PV and PV-plus-storage projects.

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2 Background

The rooftop solar adoption process typically consists of multiple interactions between the customer, installer, AHJ, and/or utility (Sinitskaya et al., 2019). These include PI&I processes, which are typically coordinated by the installer with the AHJ and utility, and include permit and interconnection (IX) paperwork development, submission, and inspections. Other non-PI&I interactions between the solar installer and customer include marketing and customer acquisition, contracting, site surveys and system design, scheduling and completing the installation, and roof repairs or electrical upgrades as needed. Collectively, these PI&I and non-PI&I processes and interactions across all stakeholders constitute the solar adoption process. Each process may contribute to project timelines, costs, and customer experiences, positively or negatively.

As shown in Figure 1, the timelines tracked in our data and reported here typically start at contract signing with the customer. Working with the customer, the installer then conducts any necessary site surveys, finalizes the system design, and completes and submits the necessary PI&I paperwork and applications to the AHJ and utility (*the design phase*). The AHJ and utility then review these applications, request revisions as required, and issue the necessary permits and approval to build (ATB) (*the review phase*). In many cases, these reviews occur concurrently, though they may also happen sequentially (e.g., utility approval required prior to issuing an AHJ permit). Alternatively, some utilities do not require an interconnection application/ATB prior to system installation (Fekete et al., 2022), and an increasing number of AHJs offer online-instant approval of systems that meet specific design criteria (Cook et al., 2024).

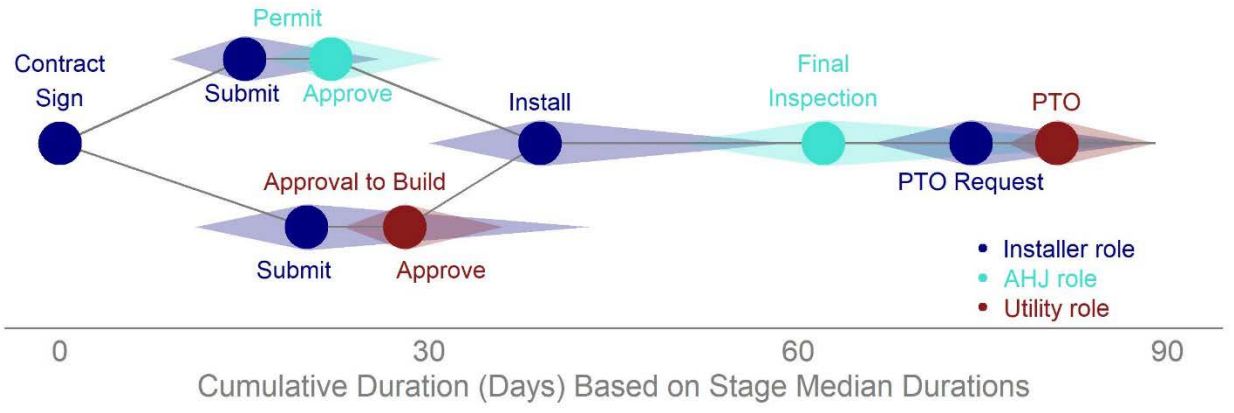

Figure 1. Major steps and example timelines of the residential and small commercial PV adoption process, as tracked by SolarTRACE

Figure design adapted from O'Shaughnessy et al. (2022). Points represent medians, and areas are the interquartile range (25th to 75th percentile).

After all pre-installation permits and approvals are obtained, the installer works with the customer to schedule and complete the system installation (*the install phase*). Although the installation itself may only take a day or two of on-site labor to complete, installers often need to schedule it days or even weeks ahead of time based on customer, crew, and equipment availability. Most AHJs and some utilities then require one or more inspections of the system before final approval (*the inspection phase*). Some AHJs require both rough-in inspections during installation and final inspections when installation is complete. Afterward, the AHJ or

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installer submits the final inspection results to the utility, and the installer submits the final interconnection/PTO request to the utility (*the post-inspection phase*). The utility then reviews and grants/approves PTO (*the final IX/PTO phase*) (Cruce et al., 2022b).

2.1 Project Timelines for Rooftop Solar

Residential PV project timelines have been widely reported over the last 5 years, including from previous iterations of the SolarTRACE dataset (Cruce et al., 2022b; Fekete et al., 2022; O'Shaughnessy et al., 2022); installer surveys (Cook et al., 2021; Taylor, 2019); SolarAPP+ utilization data from AHJs (Cook et al., 2024, 2023, 2022; Williams et al., 2022); BuildZoom permit data (O'Shaughnessy et al., 2020); and other installer-provided interconnection data (Ardani et al., 2015). Some key trends emerge across this body of literature.

First, there is a wide range of project timelines for residential PV projects across the United States, including for individual PI&I (and non-PI&I) phases and for overall project time (from contract signing to PTO). For example, AHJ permit review and approval times can range from same-day (i.e., over the counter or via an online-instant platform) to 6 weeks or more (Cook et al., 2024; Cruce et al., 2022b). Furthermore, AHJ permit review times can differ significantly even within the same AHJ; O'Shaughnessy et al. (2020) identified at least one AHJ where installer-specific AHJ permit review times ranged from same-day to nearly 2 weeks.

The same trend holds true for total project timelines as well. According to installers surveyed in 2019, a typical project took 10 weeks from contract signing to PTO, although reported timelines ranged from 6–13 weeks at the 25th and 75th percentiles, and larger installers typically reported longer timelines than smaller installers (Cook et al., 2021). In the previous study using the SolarTRACE dataset, we found somewhat longer timelines through 2021, ranging from 10–22 weeks at the quartiles (14–16 weeks at the median and mean). We also found that some projects took as long as 40 weeks or more (Cruce et al., 2022b). O'Shaughnessy et al. (2020) found a similar range when measuring from permit submission through passed inspection: 7 weeks at the median but ranging from 4–14 weeks at the quartiles.

These results suggest that timelines span a wide range across AHJs, installers, and customers in the U.S. residential and small commercial solar market. Furthermore, not only do total project and by-phase timelines vary significantly between projects, but overall average timelines are also skewed by projects that are slower and much slower than typical. In our previous study, we found that average timelines were typically 1–2 weeks longer than medians for all project phases as well as for total/overall timelines. Furthermore, at least 5% of projects took 4x–10x longer than the median for any given phase, and at least 5% of projects took 2.5x–3x longer than the median for their total timelines (see the appendix tables of Cruce et al., 2022b). Although we lacked data to assess potential causes, these findings suggest that customers who experience slower-than-typical timelines are not uncommon.

2.2 Residential Solar PI&I

PI&I processes, requirements, and complexity can affect project timelines, and other studies have focused specifically on PI&I-related challenges and costs (Burkhardt et al., 2015; Dong and Wiser, 2013), project cancellations (Cruce et al., 2022a; Liao, 2020; Moezzi et al., 2017), and interactions between the customer, installer, AHJ, and utility (Sinitskaya et al., 2019).

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Many states set minimum PI&I requirements. For permitting, states often select a particular year for building, electrical, and fire codes. Enforcement of these codes is delegated to AHJs, and many AHJs set additional and/or more stringent local requirements (Stanfield et al., 2012). For interconnection, state regulators may mandate specific PI&I process requirements for their regulated utilities and may impose penalties on utilities that do not meet these requirements. For example, many states have established a maximum timeline for residential interconnection application review and response. Other utilities have set review timeline targets or other PI&I process improvements on their own (Ardani et al., 2015; Fekete et al., 2022).

Installers must navigate these differing PI&I requirements and processes across the tens of thousands of AHJs and 3,000 utilities in the country. These AHJs and utilities differ in their levels of PI&I process streamlining or complexity and in their application review and approval timelines. Complex or burdensome PI&I processes can increase project timelines (O'Shaughnessy et al., 2022, 2020), soft costs (Burkhardt et al., 2015; Cruce et al., 2022a; Dong and Wiser, 2013), and project cancellation rates (Cook et al., 2021). For example, surveyed installers reported that permitting and interconnection challenges are primary drivers of project delays and customer cancellations (Cook et al., 2021). Streamlining PI&I processes and using best practices could significantly reduce project timelines and costs (O'Shaughnessy et al., 2022). For example, online-instant permitting platforms automatically review residential systems for code compliance and issue approvals with little or no AHJ staff review time required, saving an average of 14.5 days (31%) across permitting, installation, and inspection timelines (Cook et al., 2024). The number of AHJs now offering SolarAPP+, Symbium, or other automatic, online-instant permitting review platforms has accelerated over the last 5 years, along with a widespread switch to online/electronic permitting options in general (Cruce et al., 2022b).

2.3 Recent Changes in the Residential Solar Market

Other changes in the residential solar market may provide additional insights into year-over-year changes in project timelines. For example, the benefits of PI&I process improvements can be offset by large, rapid increases in permitting volume or other challenges—such as the COVID-19 pandemic and associated supply chain disruptions. Between 2010 and 2020, annual residential PV installations increased by a factor of 10 and, despite a slight slowdown during the first few months of the COVID-19 pandemic, doubled again through the end of 2023 (Davis et al., 2024, 2022; SEIA, 2020). The residential PV-plus-storage market has also expanded dramatically and now accounts for 25% of residential solar installations (Davis et al., 2024). When surveyed in late 2021, many AHJs reported struggling with both this record-high permitting volume and ongoing staffing challenges (Cruce et al., 2022b). The approval of California's new net rate structure for residential solar customers at the end of 2022 led to a rush of projects qualifying under the previous policy prior to the new policy's April 15, 2023 effective date, which may have temporarily delayed interconnection reviews and approvals (Feldman et al., 2024). Other utilities have also experienced recent challenges and delays with interconnection (Kennedy, 2023). Although these challenges are often temporary as AHJs and utilities learn to adapt, hire additional staff, and/or further streamline their PI&I (Ardani and Margolis, 2015; Cruce et al., 2022b), they may offset ongoing improvements to the solar adoption process.

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3 Datasets and Methods

This report uses an updated version of the SolarTRACE project-level timeline dataset, which was originally described in previous publications (Cruce et al., 2022a, 2022b).[2] The dataset was aggregated from time-stamped data provided by installer-partners covering projects they installed from 2017–2023.

3.1 Project-Level Timeline Dataset

Since 2019, NREL has partnered with solar installers/developers who provide project-level and PI&I process data for their residential and small commercial solar projects in the United States. Since then, 16 unique installers have contributed project-level data, representing a range of small (<100 installations per year), mid-scale (100–1,000 per year), large (>1,000 per year), and very large (>10,000 per year) companies.[3] The installer-provided data includes dates for key milestones of the residential solar adoption process (see Figure 1), namely contract signing, permitting, utility ATB/interconnection application, installation, inspections, and final request for PTO. Installers also provided project identifying information necessary for analysis, including project size (in kilowatts), type (PV only, PV plus storage), AHJ responsible for permitting, utility, and whether it was a retrofit project or was part of a new construction build. The installer-provided data was then aggregated into the project-level timeline dataset.[4]

The project-level timeline dataset currently encompasses approximately 900,000 PV and PV-plus-storage projects of up to 20 kW installed from 2017–2023. Of these projects, approximately 875,000 were both retrofits (i.e., not part of new construction) and included at least one set of dates from which timelines could be calculated (e.g., permit submission and permit approval dates). Project counts by year, system size, and system type are shown in Table 1, along with market shares based on annual installation counts from Wood Mackenzie (Davis et al., 2024). Note that our analysis this year differs from our previous report (Cruce et al., 2022b): We now include all 875,000 projects with at least one set of timeline dates in our analysis, rather than only using the smaller subset of projects that include *every date* for all key milestones tracked. This decision gives us greater market coverage than our previous analysis, thus potentially better representing the range and variability in project timelines across installers and jurisdictions.[5] For comparison, about half of projects (~400,000) include every key milestone date.

As seen in Table 1, our dataset covers 22% of the U.S. residential PV market from 2017–2023 and 33% of the residential storage market. The best coverage is between 2018 and 2022, with coverage peaking in 2021 at 29% of the solar market and 49% of the storage market. However, the challenges faced by the solar industry in the last 2 years also affected the data collected for

[2] See www.nrel.gov/solar/market-research-analysis/permitting-inspection-interconnection-timelines.html for more details and a full list of publications.
[3] As categorized by Cook et al. (2021).
[4] The project-level data are not publicly available due to confidentiality requirements. However, timeline results and PI&I data are available for download from data.nrel.gov/submissions/160 and the SolarTRACE data viewer website.
[5] As discussed earlier, O'Shaughnessy et al. (2020) found timeline differences between installers even within the same jurisdiction. Thus, the smaller data subset consisting only of projects and installers that include all tracked dates may not be as representative of all project timelines in those jurisdictions.

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projects installed in 2023, hence the lower market coverage for that year.

Table 1. SolarTRACE Residential PV and PV-Plus-Storage Retrofit Projects That Included at Least One Set of Dates for Timeline Analysis, by Year

	PV-Only				PV-Plus-Storage			
Year	0–10 kW	10–20 kW	Total	% of Market	0–10 kW	10–20 kW	Total	% of Market
2017	45,176	689	45,865	15%	590	79	669	22%
2018	82,808	4,806	87,614	28%	3,908	633	4,541	31%
2019	74,084	13,048	87,132	23%	6,515	1,880	8,395	38%
2020	77,922	18,447	96,369	23%	9,634	3,220	12,854	40%
2021	118,562	30,493	149,055	29%	19,268	7,745	27,013	49%
2022	163,587	39,012	202,599	28%	23,150	9,974	33,124	36%
2023	79,110	21,310	100,420	12%	12,835	6,337	19,172	19%
Total	**641,249**	**127,805**	**769,054**	**22%**	**75,900**	**29,868**	**105,768**	**33%**

SolarTRACE retrofit PV and PV-plus-storage projects cover 38 states, 9,164 AHJs (1,665 with at least 50 installations), and 940 utilities (218 with at least 50 installations). As shown in Figure 2, a significant number of projects come from the key residential solar markets in the United States. California accounts for about 45% of our project-level timeline dataset, compared with 40% of the total U.S. residential market (Davis et al., 2024).[6] Across other key solar states, our data covers on average a quarter of each state's 2017–2023 PV-only market, as shown in Figure 3. This includes 28% market coverage across the top 10 states by installation volume, at least 10% market coverage for six of the next seven states, and a total average of 24% coverage across the top 17 states. For residential storage, available data from 2022–2023 suggests approximately 36% coverage across the top 10 storage states, though with mixed coverage beyond that.

[6] For context, California was an early adopter of residential solar and has historically been the largest single solar market in the United States—California accounts for 41% of all residential solar ever installed (through 2023), along with 35%–53% of residential solar installations every year from 2010–2023. The next 10 states collectively account for the same volume as California, and the remaining 39 states make up the remaining ~20% of the solar market.

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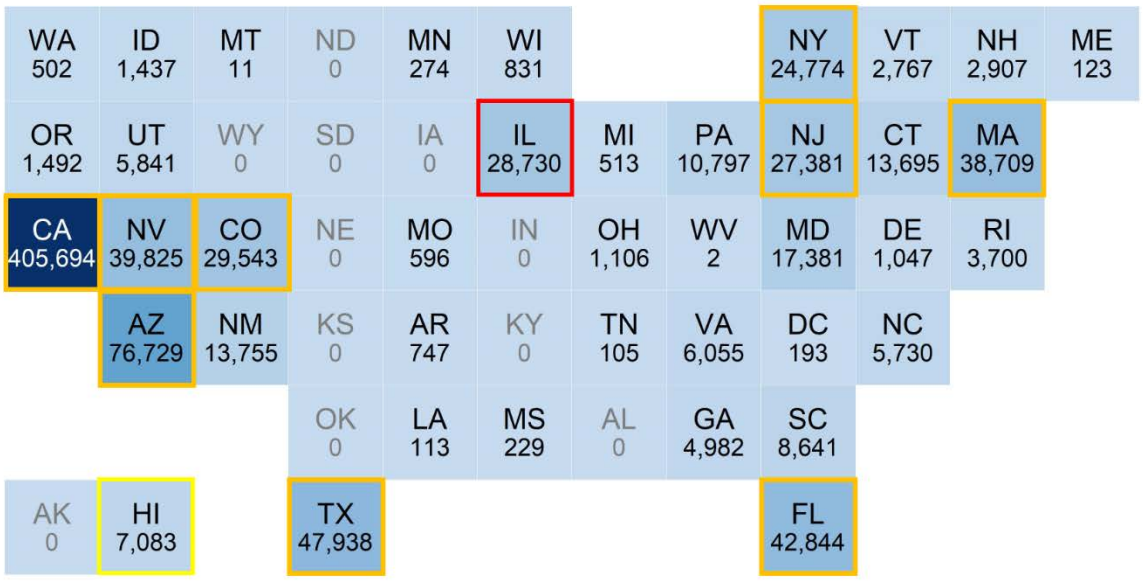

Figure 2. SolarTRACE PV and PV-plus-storage retrofit installations by state, 2017–2023

All projects shown were included in nationwide/overall dataset results. Highlighted states were also evaluated in a state-by-state timeline comparison and represent the top 10 states by installation volume for residential PV (red), PV plus storage (yellow), or both (orange).

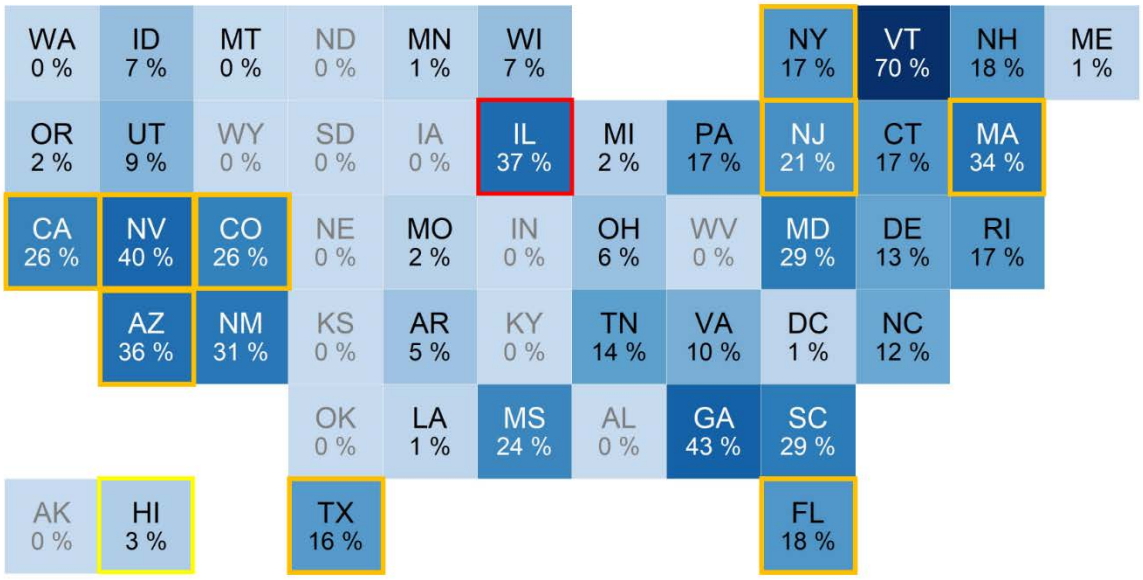

Figure 3. SolarTRACE PV-only market share coverage by state, 2017–2023

Insufficient state-by-state data were available to report PV-plus-storage market coverage over this time period.

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We analyzed project timelines by first assessing annual timelines and year-over-year changes across all retrofit PV or PV-plus-storage projects nationwide in the project-level dataset. Then, we compared state-by-state timelines for the top 10 states by installation volume (shown in Figure 2 and Figure 3).

We calculated timelines for each PI&I and non-PI&I phase shown in Figure 1, along with pre-installation and post-installation phase totals and total project timelines (contract signing to PTO). Timelines for each phase were bucketed into their corresponding year via two methods: The design and review phases were categorized by the date of permit submission, and the installation phase and all post-installation phases were categorized by the date of installation. Overall project timelines, including pre-installation and post-installation phase totals, were also based on the installation date.

Finally, note that not all installer-partners provided data for all years in the dataset. Of our 16 installer-partners, five provided data covering 2019–2023, and a sixth provided data covering 2020–2023. Together, these six installers represent about 410,000 projects, referred to as the "six installer subset." Although we do not focus our analysis or directly report results on installer-by-installer differences in the data, we do discuss where year-over-year changes in timeline results may be affected by the changing number of installers who provided data in that year (for example, installers with notably faster-than-average timelines in earlier years who were not able to provide data in 2023).

3.2 Study Limitations

As with our previous work using SolarTRACE data, this study is limited by its data sources and applicability of results. Our data covers a quarter of residential PV-only projects and a third of storage projects in the United States in 2019–2023, but does not include every state, AHJ, or utility that installed solar, nor does it cover all projects across jurisdictions that are included. Because of the limited number of installer-partners, our results are weighted by the higher installation volumes from our larger installers; previous studies have found timeline differences between installers even within the same AHJ (O'Shaughnessy et al., 2020), so timelines reported here, in our public data, and on our data viewer website might not be fully representative of timelines seen by all projects in a given jurisdiction. Our choice to use the larger overall project-level dataset, rather than the smaller subset of projects reporting all key milestone dates, means that a differing number of installers and projects may be included in the timeline calculations for each phase. Thus, because timelines for each PI&I or non-PI&I phase—and pre- and post-installation and overall totals—are calculated individually, results for individual phases cannot be added together directly to estimate composite timelines.

Finally, because California represents a large proportion of both the U.S. solar market and our data (45% of projects), our national/overall dataset trends are also heavily weighted by trends in California. Similarly, national and state-level results may also be weighted by trends in jurisdictions with the largest installation volumes, both in California and in other states.

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4 Results

We first report results for residential and small commercial solar PV timelines (up to 20 kW), including for the overall project-level dataset and for the top 10 states by market volume. We then report results for residential storage projects in the same categories.

4.1 PV-Only Timelines (up to 20 kW)

Here, we report timeline summary statistics for PV-only projects up to 20 kW. Timeline results are first presented for the overall dataset of all installed projects, then by state for the top 10 markets by 2017–2023 volume. Year-over-year timelines from 2017–2023 are reported for each category.

Note that our previous study (Cruce et al., 2022b) only reported residential PV-only timelines for systems up to 10 kW. However, we now have sufficient data on systems sized 10–20 kW—representing large residential and/or small commercial projects—to include in our analysis. We initially separated the smaller (<10 kW) and larger (10–20 kW) systems into separate data subsets for our timeline analysis. However, we found that total and most phase timelines for these subsets have become increasingly similar since 2020: Medians for total project timelines (contract signing to PTO) were within 6% in 2020 and ±1% since 2021; differences at the quartiles averaged ±5% since 2020; and means differed by an average of 4%. We also found that the subset of smaller projects had somewhat more distribution in the range of overall timelines than the larger projects, both in terms of standard deviation (77 versus 65 days) and interquartile range (75 versus 69 days). However, given that these timeline differences are relatively small—and that year-over-year timeline changes are comparable—we have elected to combine both subsets back into a single dataset consisting of all PV-only projects up to 20 kW for reporting and analysis. Timelines for each subset (<10 kW, 10–20 kW) are reported in the SolarTRACE public data file.[7]

4.1.1 Overall PV-Only Dataset Timelines

PV-only project phase and total timelines for each year are shown in Figure 4 and Figure 5. Additional summary statistics are listed in Table A-1 in the Appendix, and Figure 14 shows the project phase timelines inclusive of the 5th and 95th percentiles. Note that all values are in business days, and that 5 business days typically constitute a week, while a month varies from 20–23 business days.

[7] See data.nrel.gov/submissions/160 for the SolarTRACE public data file.

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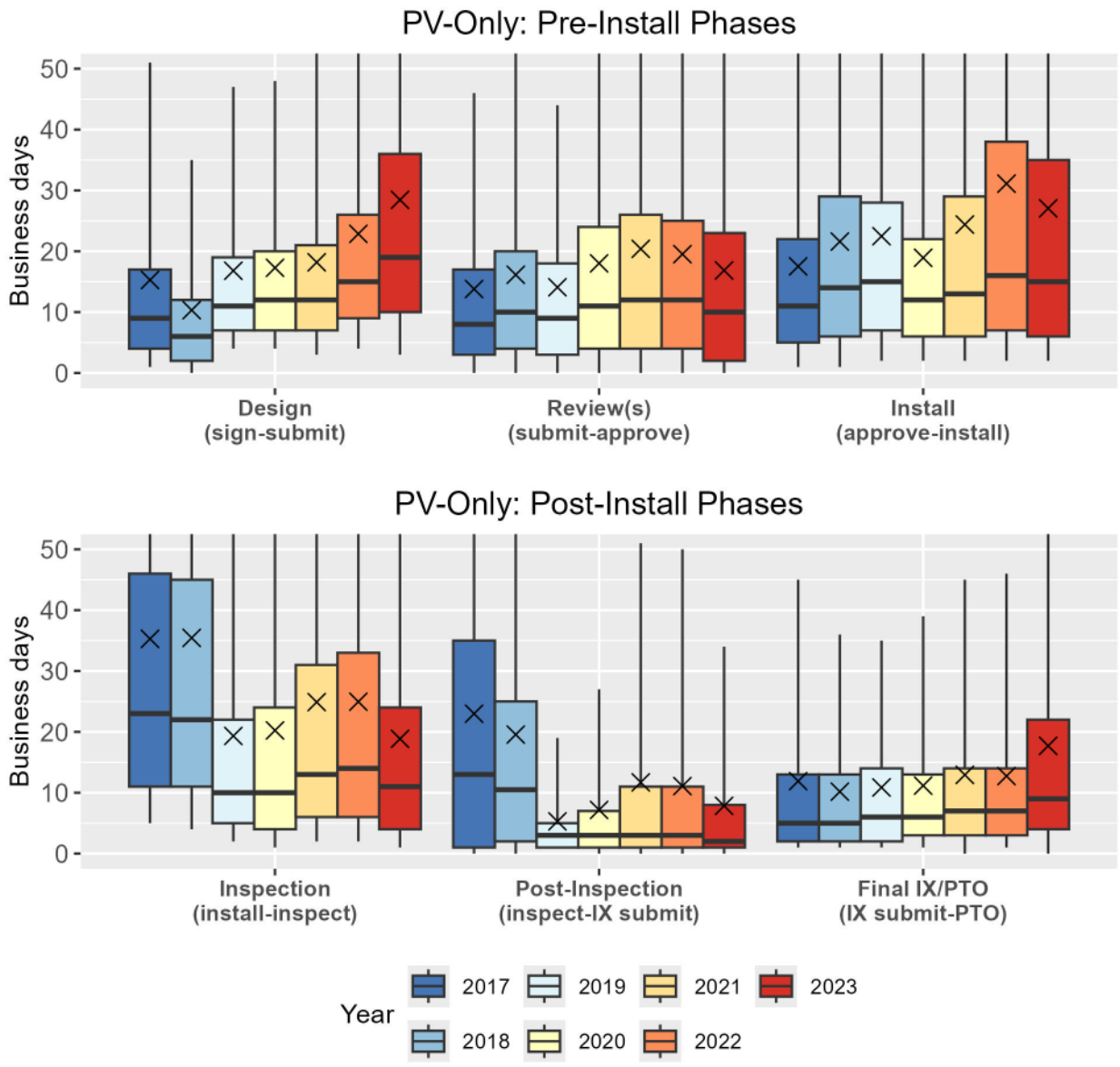

Figure 4. PV-only project timelines for each pre-installation and post-installation phase in the SolarTRACE data

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles. The review phase includes both the AHJ permit and the utility pre-installation interconnection/ATB, where required.

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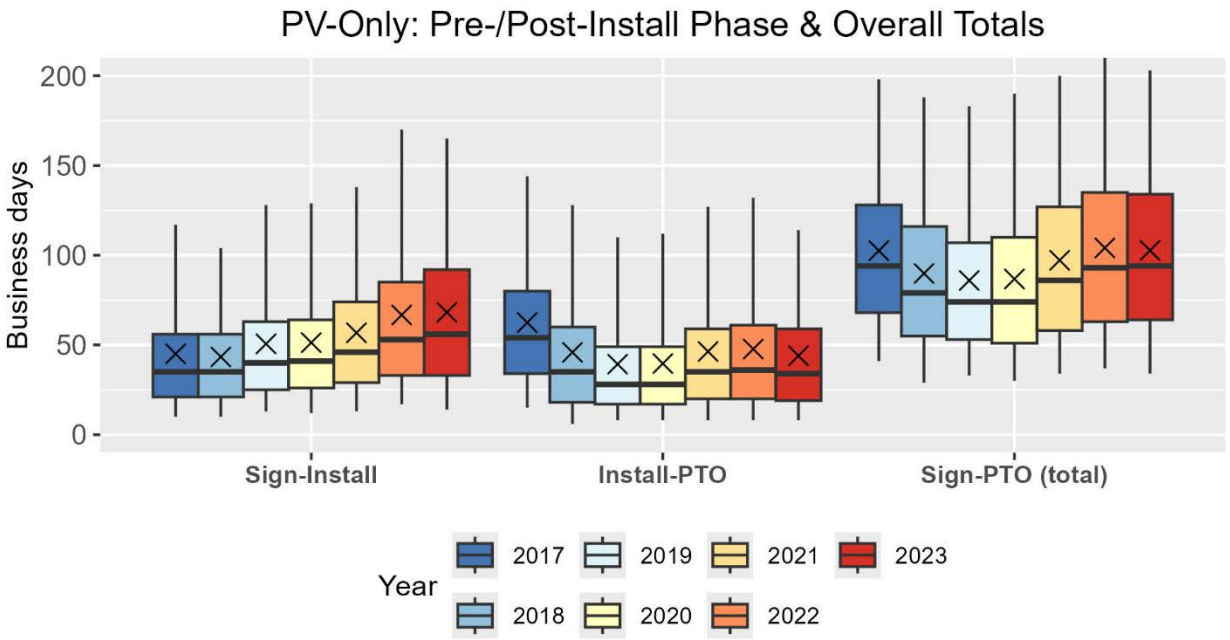

Figure 5. PV-only timelines for overall pre-installation (sign–to–install) and post-installation (install–to–PTO) phases and total project time (sign–to–PTO)

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles.

As shown in the figures, in 2022 and 2023, a median or average PV-only project in the United States required approximately 100–115 business days between contract signing and PTO (20–23 weeks, or about 4.5–6 months). However, there is significant range across project timelines in the data: A quarter of projects required 3 months or less (first quartile), while 10% of projects required more than 9 months and 5% of projects took a year or more. These slower- and much-slower-than-typical projects skew the average of both total and by-phase timelines upward, resulting in mean timelines that are usually 5–15 days slower than the median.

The results show that after declining from 2017–2019, overall PV-only project timelines in our data increased again starting in 2021 (Figure 5). A PV-only project in 2022/2023 took nearly a month longer to complete than in 2019/2020 (20 business days longer at the average and median)—a 20%–30% increase. This increase is also found at the quartiles (14 and 26 days longer at the first and third quartile, respectively) and the 90th percentile, and both the interquartile range and standard deviation increased by approximately 25 days.

As we identified in our previous report (Cruce et al., 2022b) and as seen in Figure 4, much of the improvement in overall timelines from 2017–2019 came from faster post-installation timelines, especially for the inspection and post-inspection (inspect-to-IX submit) phases. Although these timelines also saw a small uptick during the COVID-19 pandemic (2021–2022), they have since declined again. Note that the recent uptick in final interconnection/PTO timelines is primarily due to a significant increase in 2023 timelines in California, which accounts for 45% of the dataset (see the next section for state-by-state timelines).

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The recent longer project timelines in our data are primarily due to increased pre-installation phase times. Pre-installation timelines have increased steadily since 2020, driven by increases in both design (sign–submit) and installation (approve–install) times. For the design phase, project timelines at the median and above nearly doubled between 2020 and 2023: from 2.5 to 4 weeks at the median, from 3.5 to 7 weeks at the mean and 75th percentile, and from 7 to 13 weeks at the 90th percentile.[8] Installation phase timelines also increased by 1–3 weeks at the median and mean in 2021/2022, though 2023 timelines have improved slightly. Notably, the longest 10% of projects (above the 90th percentile) saw substantial increases in installation timelines, doubling from 2–3 months to 4–6 months or longer. Altogether, total pre-installation phase timelines (sign–install) increased for all statistical values, with larger increases for longer projects, i.e., an increase of 1.5 weeks at the 25th percentile, 3.5 weeks at the median, 5 weeks at the mean, 6.5 weeks at the 75th percentile, and 9 weeks at the 90th percentile.

We also evaluated whether these increased timelines were present across all installer-partners and whether the overall results were affected by the loss of 2023 data from previously faster-than-average partners. In the six installer subset, five of the six installers saw timelines increase from their respective lows in either 2019 or 2020. For two of these installers, timelines increased through 2022 before decreasing again in 2023, while other installers saw continued increases through 2023. However, timeline increases for each installer and across the entire subset were generally similar to the overall dataset, suggesting that the year-over-year trends in the overall timeline data are not primarily caused by the changing availability of partner data for each year.[9]

Finally, although not a significant driver of overall timeline changes, we found a larger increase in AHJ permitting timelines during the COVID-19 pandemic than in our earlier report. Previously, we found that permit review times increased by about 1–2 days between 2019 and 2020/2021 (Cruce et al., 2022b) at the median and mean. However, our new analysis found a somewhat larger increase across our larger dataset, of about 3–6 days at the median and mean.

[8] However, the 25th percentile only increased slightly between 2020 and 2023, from 7 to 10 business days.
[9] Namely, (1) overall contract–PTO timelines for these installers' timelines typically increased 20%–30% between 2019/2020 and each installer's respective peak in 2022 or 2023 (though one installer saw a nearly 60% increase); and (2) most installers saw larger pre-installation timeline increases, and smaller (or no) changes in post-installation timelines.

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4.1.2 PV-Only State-Level Timelines

Project timelines at the state level provide insights into (1) differences between regional markets and (2) variability within a particular market. For example, permit and interconnection review times are known to vary widely across AHJs and utilities, which in turn constitute their respective states and regional markets. PI&I requirements, processes, and timelines are also often set or regulated at the state level, such as via public utility commissions and state laws. However, while stricter state-level requirements or targets alone do not necessarily correlate with faster timelines (Fekete et al., 2022), states can also encourage or require the use of best practices (e.g., California Senate Bill 379). Thus, the question is: How do PI&I and total project timelines differ both across and within states?

Permit review timelines for the top 10 residential solar states are shown in Figure 6.[10] As seen in the figure, most states shown here saw permitting timeline increases during the COVID-19 pandemic, and most states saw subsequent permitting timeline improvements in 2023. However, review times still show significant variability, ranging from same-day at the low end[11] to 15 business days (3 weeks) at the 75th percentile and 30 days (6 weeks) or more at the 90th percentile (average timelines were between 10 and 15 days).

[10] Additional state-level timelines are available on the SolarTRACE web viewer and public data file.
[11] Large-volume AHJs in the states shown here that offered online-instant approval by the end of 2022 included Phoenix, Pima County, and Tucson, Arizona; Denver, Colorado; Tampa, Florida; Clark County, Las Vegas, and North Las Vegas, Nevada; Fort Worth and Houston, Texas; and at least 60 AHJs in California.

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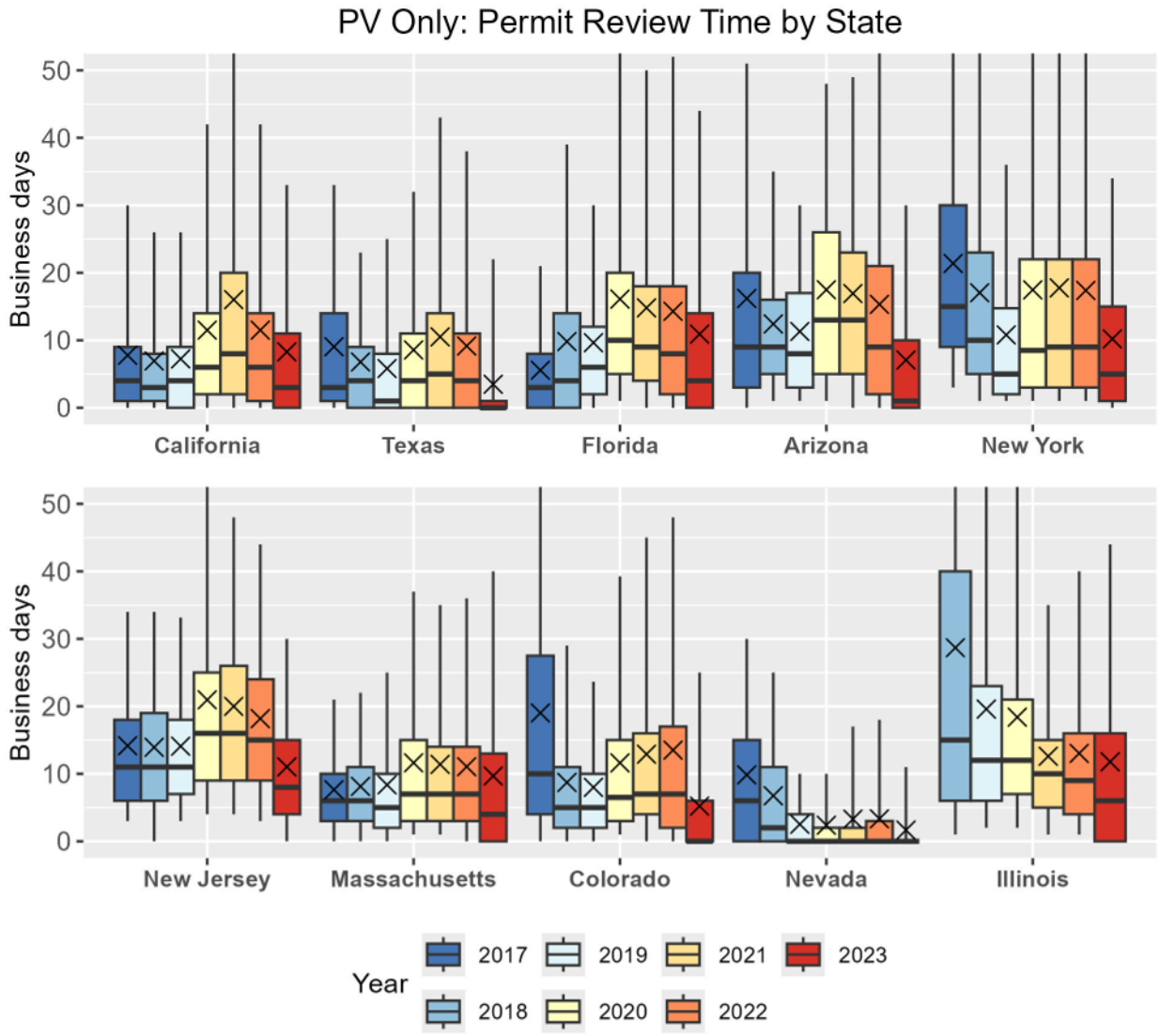

Figure 6. PV-only permit review times (submit–to–approve) for the top 10 residential solar states. States are shown in order by 2017–2023 market volume.

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles.

As shown in Figure 7, interconnection/ATB review timelines also show similar variability trends between states. For example, states with large utilities without pre-installation ATBs for residential solar show much faster timelines than states that require pre-installation approvals—especially California (six utilities),[12] Nevada (NV Energy North and South), and Florida (Duke Energy). In contrast, projects in Colorado saw significant interconnection timeline increases (in both magnitude and range) in 2022 and 2023, correlating with recent delays in processing by Xcel Energy, the largest utility in the state (Weis, 2023).

[12] Namely, the City of Alameda, City of Riverside, Los Angeles Department of Water and Power, Pacific Gas and Electric, San Diego Gas and Electric, and Southern California Edison.

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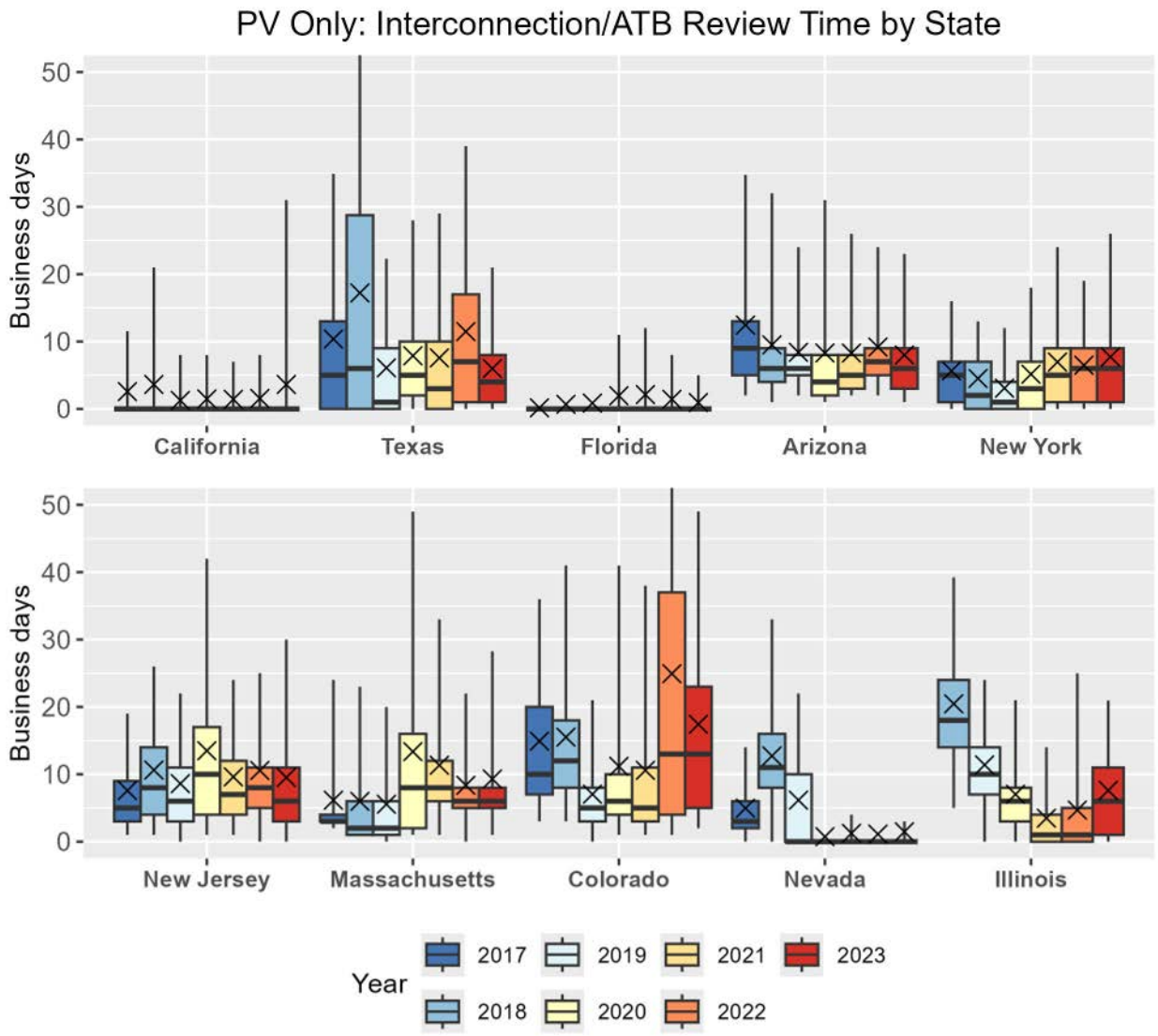

Figure 7. PV-only pre-installation interconnection/ATB review times (submit–to–approve) for the top 10 residential solar states. States are shown in order by 2017–2023 market volume.

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles.

Total project timelines by state are shown in Figure 8. Although there are differences in overall timelines and year-over-year trends, there are also some key similarities. First, most states (except Massachusetts) saw some level of timeline improvement through 2019 or 2020 compared to previous years. Second, most states also saw timeline increases at some point during the COVID-19 pandemic, though the exact timing of these increases—and whether timelines later improved again or not—varied between states.

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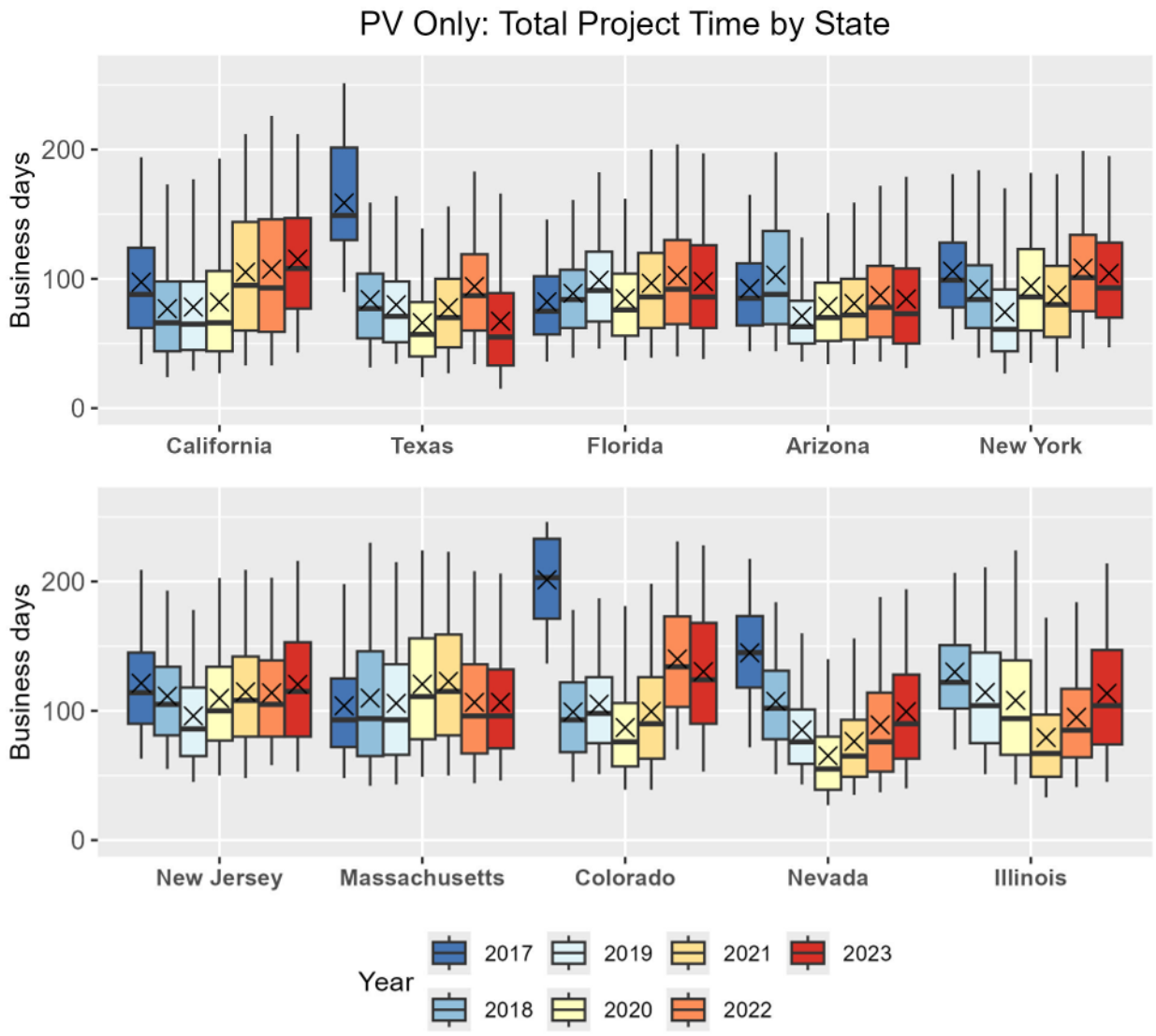

Figure 8. Total PV-only project time (contract signing to PTO) for the top 10 residential solar states. States are shown in order by 2017–2023 market volume.

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles.

Next, for projects across these 10 states, the typical first and third quartiles for total project times in 2023 ranged from about 50–75 business days and 100–150 business days, respectively. Projects in Texas were notably faster, with a median of 55 days and a first quartile of 34 days. In contrast, projects in Colorado were notably longer, with a median of 126 days and a third quartile of 174 days. Other states with somewhat longer timelines included New Jersey (median 117 days) and California (median 113 days), whereas Arizona had somewhat shorter timelines (median 70 days).

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4.2 PV-Plus-Storage Timelines (up to 20 kW)

Timeline summary statistics are reported here for PV-plus-storage projects up to 20 kW (based on the solar PV capacity). We evaluated timelines for the overall dataset and for the top 10 states, delineated by year from 2018–2023.

4.2.1 Overall PV-Plus-Storage Dataset Timelines

PV-plus-storage project phase and total timelines for each year are shown in Figure 9 and Figure 10. Additional summary statistics are listed in Table A-2 in the Appendix.

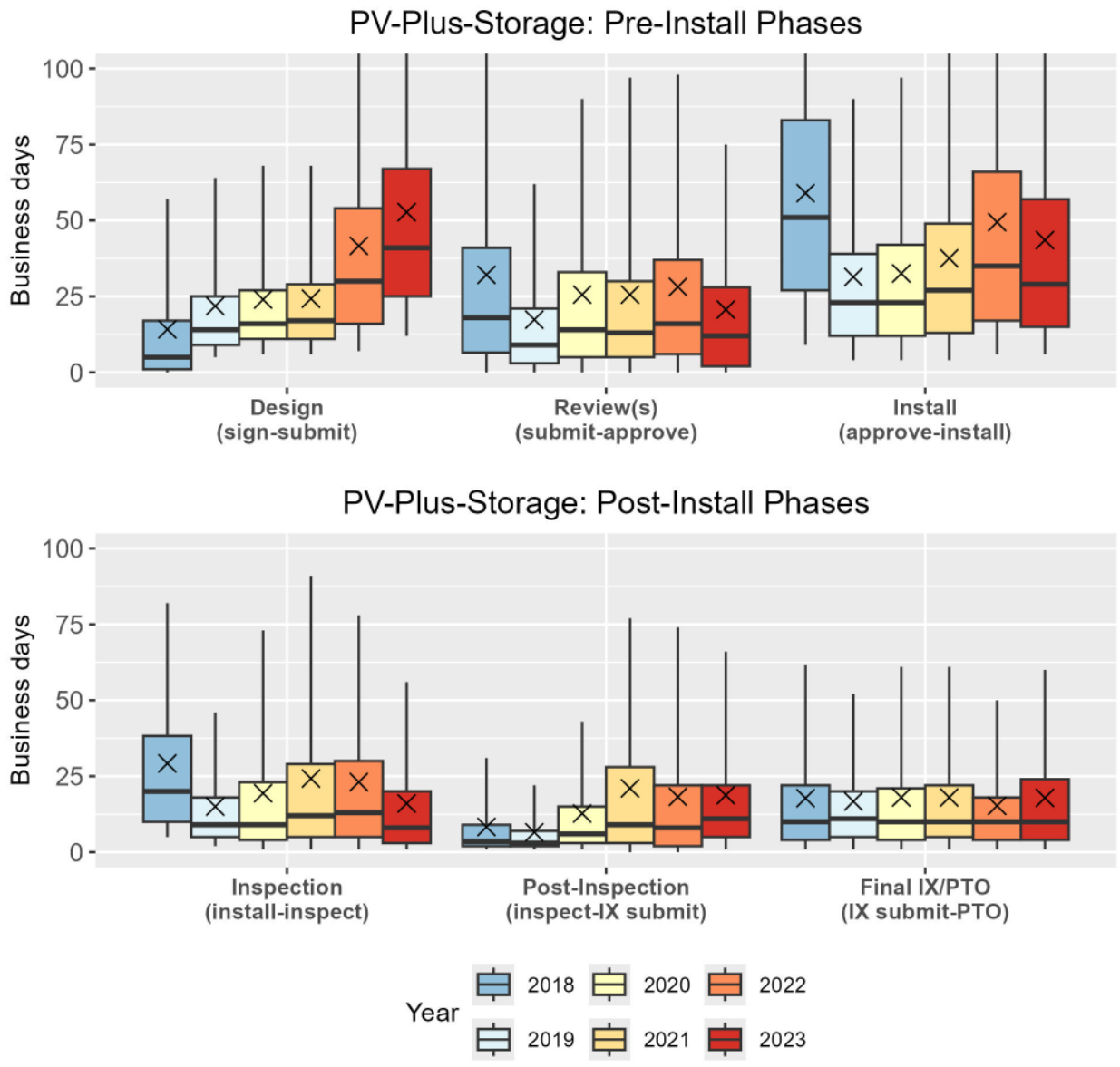

Figure 9. PV-plus-storage project timelines for each pre-installation and post-installation phase in the SolarTRACE data

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles. The review phase includes both the AHJ permit and the utility pre-installation interconnection/ATB, where required.

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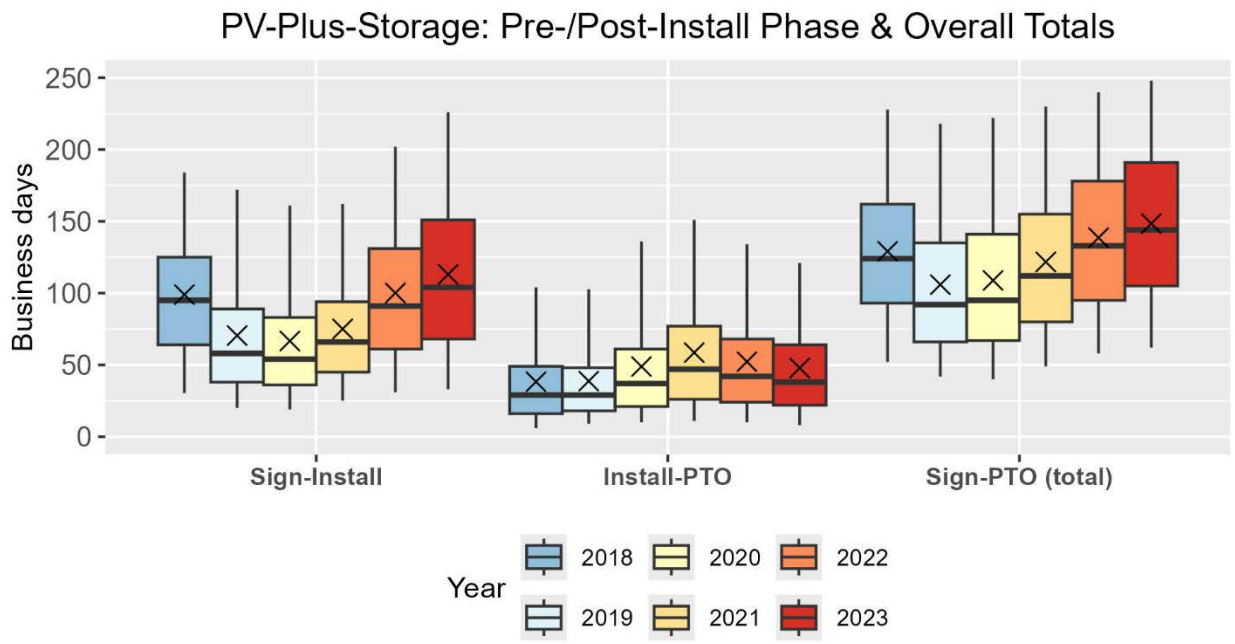

Figure 10. PV-plus-storage timelines for overall pre-installation (sign–to–install) and post-installation (install–to–PTO) phases and total project time (sign–to–PTO)

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles.

Our results suggest that total PV-plus-storage timelines (contract signing to PTO) initially improved as the residential storage market developed—even as total annual installations increased by a factor of 10 from 2017–2020 (Davis et al., 2024). In 2019/2020, a typical residential PV-plus-storage project required approximately 100 (median) to 120 (mean) business days from contract signing to PTO (20–24 weeks, or 4.5–6 months)—that is, only about 25 business days (5 weeks) longer than PV-only projects at the time. However, as with PV-only projects, PV-plus-storage timelines also increased dramatically starting in 2021. By 2023, PV-plus-storage timelines were 50%–60% longer than in 2019/2020: The median and mean both increased by 60 business days, the 75th percentile by 70 days, and the 90th percentile by over 80 days. As a result, in 2023, a typical residential storage project required around 8–9 months from contract to PTO—or 3 months (13 weeks) longer than for a typical residential PV-only project.

As with PV-only projects, most of the recent increase in PV-plus-storage timelines is from the pre-installation phase, which doubled from a median of 55 days to 110 days and a mean of 70 days to 130 days between 2020 and 2023. Design phase (sign–submit) timelines accounted for the majority of this increase (adding 25–30 days, or 5–6 weeks), but installation phase (approve–install) times also increased (adding another 1.5–4 weeks). In contrast, post-installation phase timelines have returned to 2020 levels after a moderate increase in 2021–2022.

In comparing review phase timelines, there are a few trends to note. First, total review phase timelines have been somewhat longer for PV-plus-storage projects than for PV-only projects, by about 2–9 days at the median and mean over the last several years. For AHJ permit reviews, the difference is smaller: only up to 2 days at the median and 3–4 days at the mean through 2022, with a larger difference of 5 days at the median in 2023 (PV-only permitting times declined more

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in 2023 than did PV-plus-storage times). The larger difference is between utility pre-installation interconnection/ATB timelines, where PV-only timelines appear to be much faster than PV-plus-storage timelines. However, this effect is primarily due to the large number of projects in California, where several of the largest utilities do not require ATB prior to PV-only system installation—resulting in a "same-day" review timeline for these projects. When California was excluded from the data, a typical PV-only project across other states took about 1–2 weeks for utility review, whereas a PV-plus-storage project took 2–4 weeks.

4.2.2 PV-Plus-Storage State-Level Timelines

PV-plus-storage permit[13] and pre-installation interconnection/ATB review timelines for the top 10 residential storage states[14] are shown in Figure 11 and Figure 12, respectively. Total project timelines are shown in Figure 13.

As shown in Figure 11, most states show significant range in their permit review times for residential storage, typically with at least a 2–4-week (10–20-business-day) difference between the first and third quartiles (25th and 75th percentiles) across most years in the data. Many states saw review times increase during the COVID-19 pandemic. For example, New York and New Jersey both saw review timeline increases in 2020, which remained high through 2022 before decreasing again in 2023. Meanwhile, timelines in Massachusetts have not yet returned to prepandemic levels. Hawaii also saw a large increase in 2021, followed by a significant decrease through 2023. In contrast, Texas consistently had notably shorter review times than other states and saw very little impact during COVID-19.

[13] Note that PV-plus-storage projects became eligible for online-instant approval in SolarAPP+ starting in early 2023.

[14] Note that we chose to show Colorado here instead of other higher-volume states (Utah, Georgia, North Carolina) because it had significantly better coverage in the SolarTRACE data, including year-by-year timelines back to 2018.

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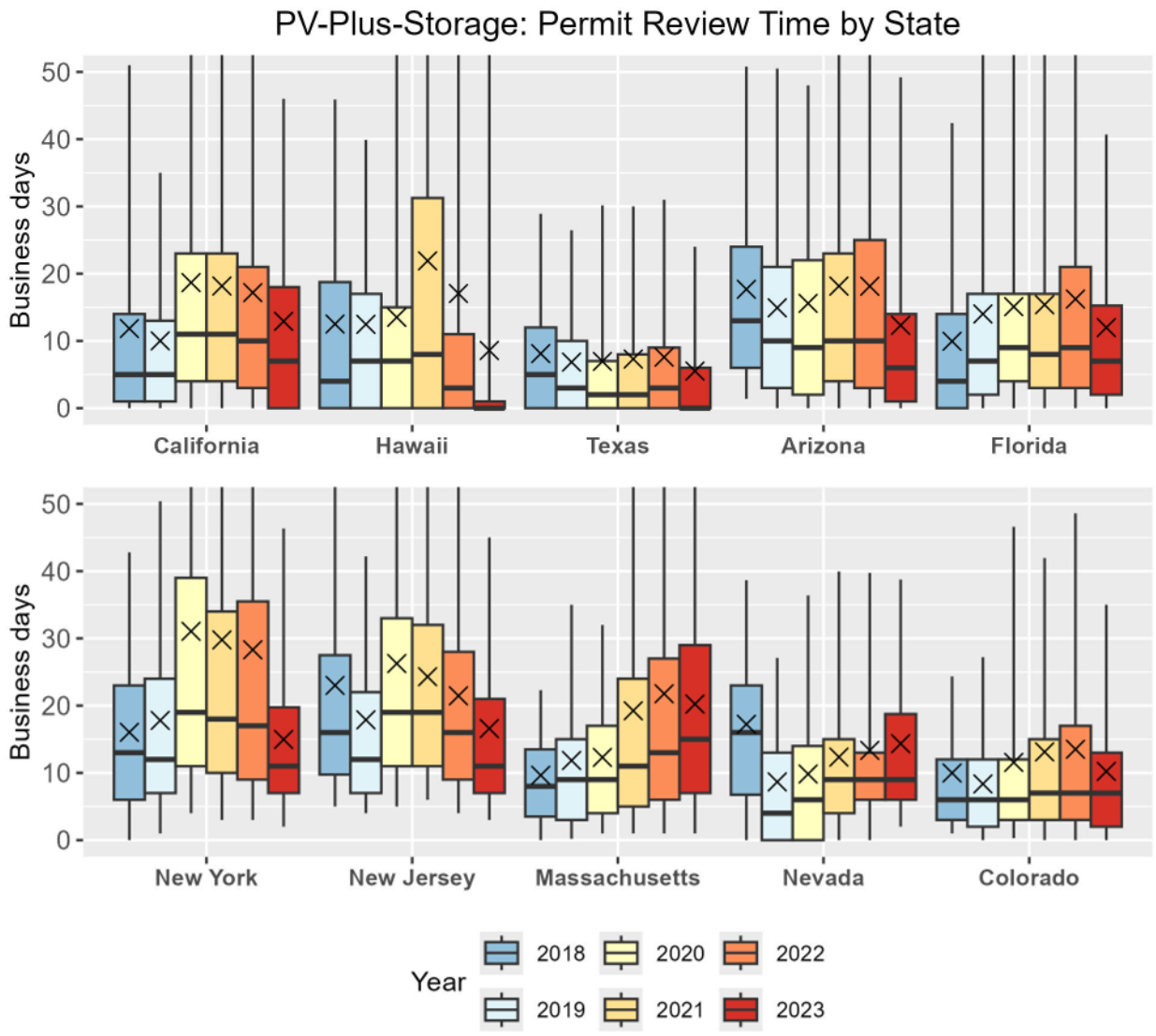

Figure 11. PV-plus-storage permit review times (submit–to–approve) for the top 10 residential storage states. States are shown in order by 2018–2023 market volume.

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles.

Compared with permitting, interconnection timelines for residential storage showed even greater variability year over year and between states, as shown in Figure 12. First, interconnection review times in Texas were much longer than permit reviews, while the opposite was true for New York. Several states experienced significant timeline increases during COVID-19, especially Florida but also Colorado and Massachusetts. After improving in 2021, timelines in Colorado increased even more in 2022 and 2023, while timelines in Florida decreased to prepandemic levels again. Interestingly, the data suggests that some residential storage projects in Hawaii, Florida, and now Neveda have been able to receive same-day or quick-turnaround interconnection approvals, though we do not yet have PI&I data for residential storage to explain these findings.

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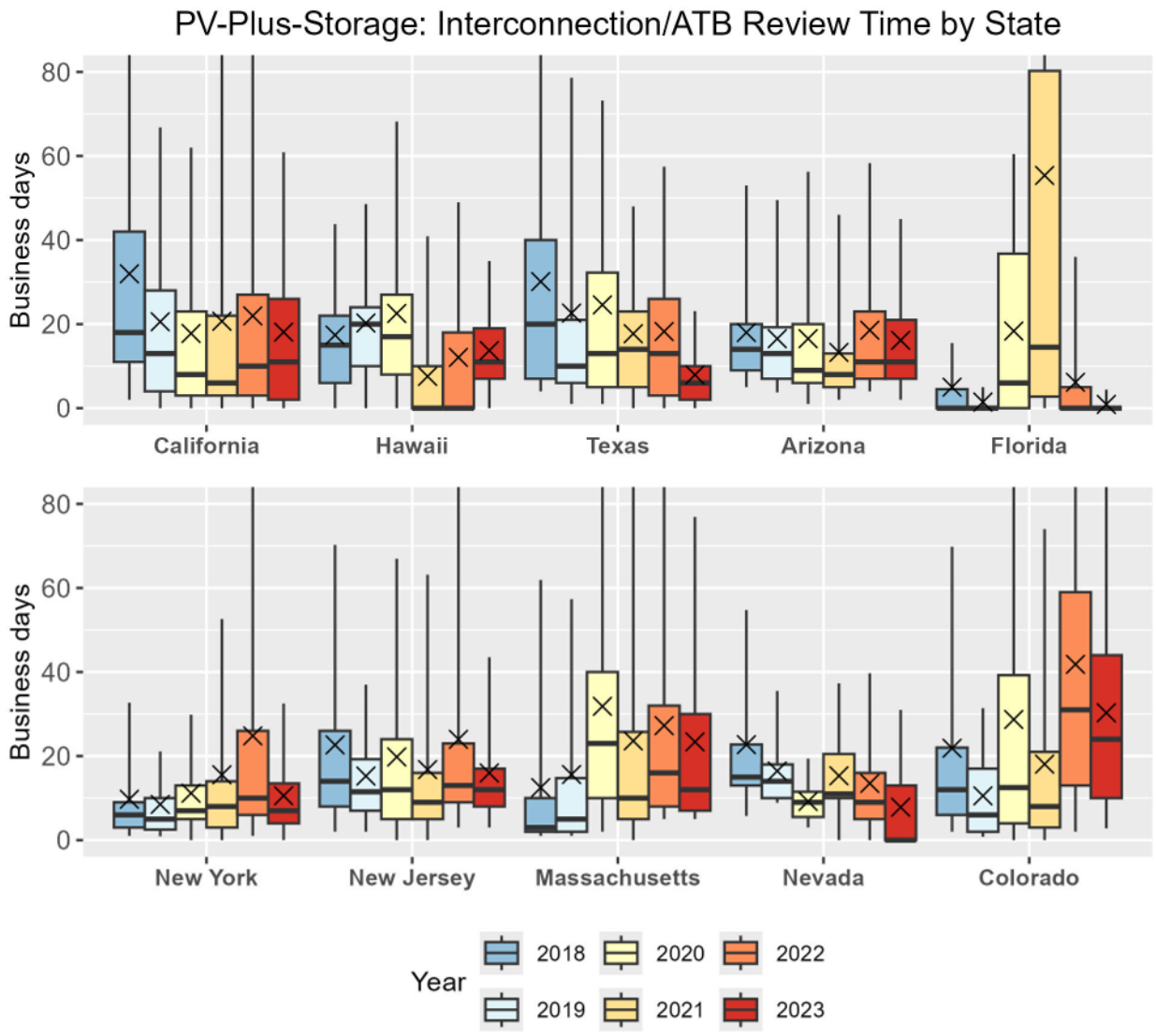

Figure 12. PV-plus-storage pre-installation interconnection/ATB review times (submit–to–approve) for the top 10 residential storage states. States are shown in order by 2018–2023 market volume.

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles.

As shown in Figure 13, overall timelines for PV-plus-storage projects showed different year-over-year trends than PV-only projects for the states shown. As discussed earlier, overall timelines for PV-only projects in some states improved in 2023 (or at least stayed the same), even as timelines across the entire dataset continued to increase. In contrast, all 10 states evaluated here saw timeline increases for residential storage in 2023 compared to 2022, and many states have seen timelines increase by 50% or more since 2019–2020.[15]

[15] Most of these states also experienced a doubling, tripling, or even quadrupling of residential storage applications between 2019 and 2022 (Davis et al., 2024), which may have contributed to timeline changes.

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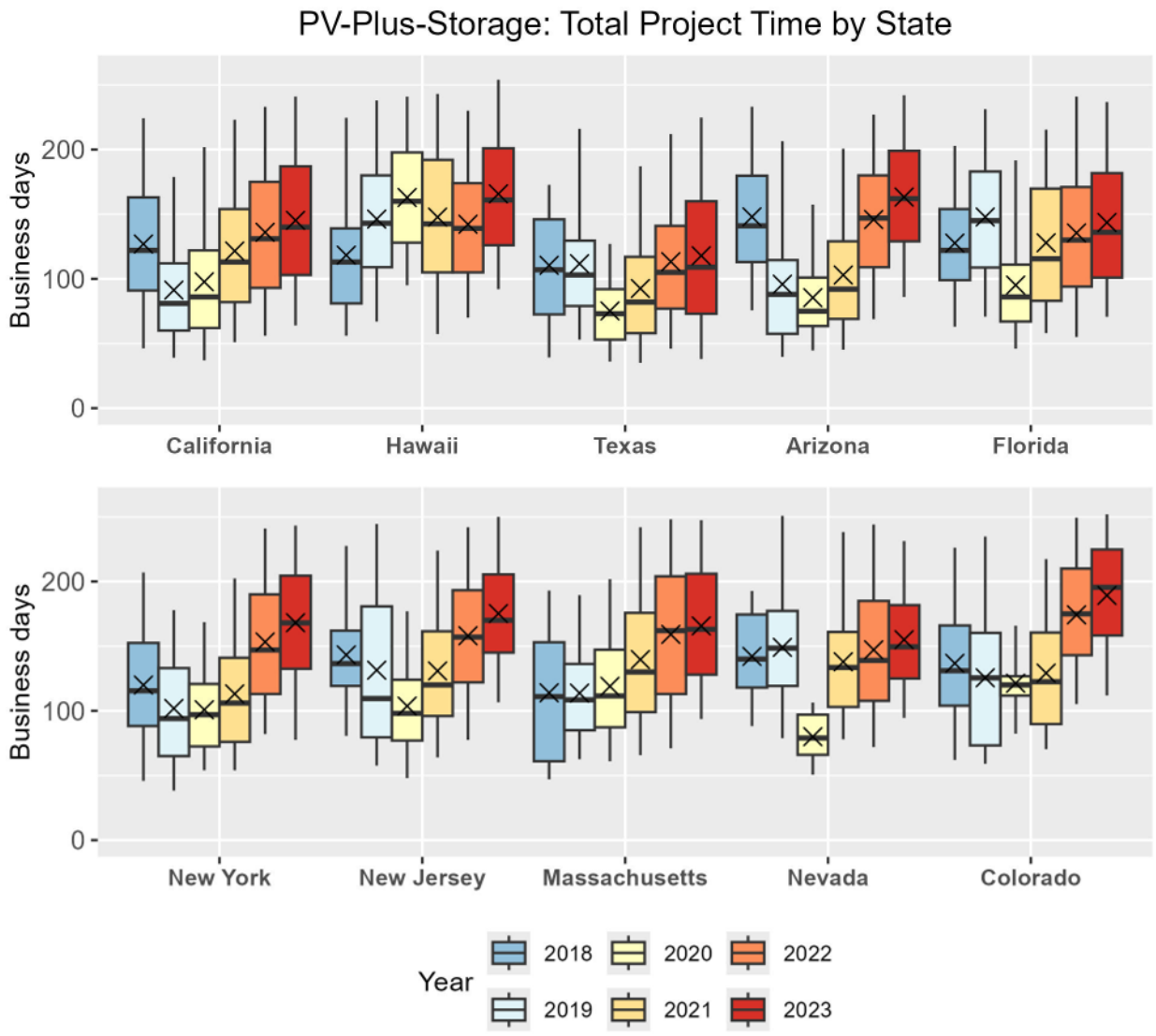

Figure 13. Total PV-plus-storage project time (contract signing to PTO) for the top 10 residential storage states. States are shown in order by 2018–2023 market volume.

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles.

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5 Conclusions

This study provides an update to previous work that uses the SolarTRACE dataset to evaluate residential solar timelines (Cruce et al., 2022b, 2022a; Fekete et al., 2022; O'Shaughnessy et al., 2022). Our project-level dataset now encompasses 22% of residential solar and 33% of residential storage installations in the United States from 2017–2023. Key takeaways from this study include the following.

- After declining from 2017–2019, overall project timelines for residential solar have increased by nearly a month since 2019. A typical solar project in the United States now requires 4.5–6 months between contract signing and PTO. However, there is also significant variability in timelines: There is a range of 3.5 months between the first (3 months) and third (6.5 months) quartiles, while 10% of projects require more than 9 months to complete.

- Recent timeline increases are primarily attributable to longer design (contract signing to permit submission) and installation (post-permit) timelines, which collectively increased by 1.5–9 weeks at these statistical values (including median, mean, quartiles, and 90th percentile).

- Overall project timelines for residential PV-plus-storage projects are longer than for residential solar, and the median/average difference has increased from about 5 weeks in 2019 to almost 13 weeks (3 months) in 2023. A residential storage project now requires 8–9 months from contract signing to PTO.

Our results suggest that continued work to improve and streamline PI&I processes is valuable, but that non-PI&I phases are also increasingly important contributors to project timelines. It remains unclear what the exact cause(s) of recent increases in project timelines are, or whether a combination of factors is at play—new data collected over the next year or two, following the recent contraction of the residential solar market, might provide greater insights in the future.

Our analysis presents several avenues for future work. Such work may include:

1. Continuing to track PI&I processes, changes, and differences between AHJs/utilities, including the use of best practices and online-instant permitting, requirements specific to residential storage, and trends in PI&I and overall project timelines

2. Assessing whether our results are representative of timelines for all projects in these AHJs, through additional data sharing and analysis partnerships

3. Determining the cause(s) of recent timeline increases, especially for the design and installation phases

4. Analyzing the relationship between AHJ-level PI&I changes, AHJ installation volume, installer-specific timelines, and other factors on overall results.

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Appendix A

The figure and tables in this appendix provide additional statistical information for the phase timelines presented in the figures. All times listed are in business days, and 5 business days constitute 1 week for conversion purposes. A month varies from 20–23 business days. Additional summary results can be found in the public data file online at data.nrel.gov/submissions/160.

Table A-1. Project Phase and Overall Summary Statistics by Year for 0–20-kW PV-Only Projects in the SolarTRACE Dataset, Namely: Median | Mean (Standard Deviation)

Phase	2017	2018	2019	2020	2021	2022	2023
Design *(sign–submit)*	9 | 16 (26)	6 | 10 (18)	11 | 17 (21)	12 | 18 (24)	12 | 18 (21)	15 | 23 (29)	20 | 34 (54)
Review *(submit–approve)*	8 | 14 (21)	10 | 16 (24)	9 | 14 (20)	12 | 18 (25)	12 | 21 (32)	12 | 20 (25)	10 | 17 (22)
AHJ permit	6 | 10 (15)	5 | 9 (14)	5 | 9 (15)	8 | 13 (19)	8 | 15 (23)	7 | 12 (18)	2 | 8 (14)
Utility ATB	3 | 7 (16)	3 | 8 (15)	0 | 4 (8)	0 | 5 (13)	0 | 6 (13)	1 | 7 (14)	1 | 7 (13)
Install *(approve–install)*	11 | 18 (23)	14 | 22 (25)	15 | 23 (27)	12 | 19 (27)	13 | 25 (33)	17 | 32 (43)	15 | 28 (40)
Inspection(s) *(install–inspect)*	23 | 40 (57)	22 | 38 (48)	10 | 20 (35)	10 | 21 (35)	13 | 26 (38)	15 | 25 (31)	11 | 19 (23)
Post-inspection *(inspect–IX submit)*	13 | 24 (39)	11 | 21 (36)	3 | 6 (21)	3 | 8 (21)	3 | 13 (29)	3 | 11 (23)	2 | 8 (16)
Final IX/PTO *(IX submit–PTO)*	5 | 12 (23)	5 | 10 (18)	6 | 11 (22)	6 | 12 (22)	7 | 13 (23)	7 | 13 (20)	9 | 18 (24)
Total *(sign–PTO)*	**96 | 111 (96)**	**80 | 96 (63)**	**75 | 93 (65)**	**76 | 96 (71)**	**88 | 105 (69)**	**97 | 116 (74)**	**97 | 116 (83)**
Pre-install *(sign–install)*	35 | 46 (42)	35 | 44 (35)	40 | 52 (45)	41 | 54 (50)	46 | 58 (47)	54 | 71 (58)	58 | 77 (73)
Post-install *(install–PTO)*	54 | 66 (57)	35 | 49 (54)	28 | 42 (47)	28 | 42 (46)	35 | 49 (50)	36 | 49 (45)	34 | 44 (35)
Number of Projects	**45,865**	**87,612**	**87,132**	**96,369**	**149,055**	**202,599**	**100,420**

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Table A-2. Project Phase and Overall Summary Statistics by Year for 0–20-kW PV-Plus-Storage Projects in the SolarTRACE Dataset, Namely: Median | Mean (Standard Deviation)

Missing values lacked sufficient data for analysis.

Phase	2017	2018	2019	2020	2021	2022	2023
Design *(sign–submit)*	3 | 14 (31)	5 | 15 (27)	14 | 22 (27)	16 | 24 (28)	17 | 25 (27)	30 | 43 (40)	41 | 55 (48)
Review *(submit–approve)*	43 | 81 (112)	18 | 34 (48)	9 | 18 (32)	14 | 27 (40)	14 | 27 (43)	16 | 29 (36)	12 | 21 (30)
AHJ permit	24 | 39 (49)	6 | 13 (21)	6 | 11 (19)	10 | 18 (27)	10 | 18 (25)	9 | 17 (24)	7 | 13 (18)
Utility ATB	19 | 35 (47)	14 | 23 (32)	11 | 17 (22)	13 | 24 (37)	9 | 19 (35)	13 | 22 (29)	10 | 16 (19)
Install *(approve–install)*	39 | 50 (56)	51 | 60 (43)	23 | 32 (32)	23 | 33 (34)	27 | 38 (38)	35 | 53 (58)	30 | 49 (60)
Inspection(s) *(install–inspect)*	-	20 | 31 (39)	9 | 15 (22)	9 | 21 (35)	12 | 26 (40)	13 | 23 (29)	8 | 16 (22)
Post-inspection *(inspect–IX submit)*	-	4 | 9 (22)	3 | 7 (15)	6 | 13 (23)	9 | 21 (31)	8 | 18 (28)	11 | 19 (25)
Final IX/PTO *(IX submit–PTO)*	21 | 32 (46)	10 | 18 (27)	11 | 17 (24)	10 | 18 (27)	10 | 18 (24)	10 | 15 (21)	10 | 18 (26)
Total *(sign–PTO)*	**-**	**125 | 136 (67)**	**96 | 121 (84)**	**99 | 122 (82)**	**117 | 139 (85)**	**141 | 156 (81)**	**159 | 181 (102)**
Pre-install *(sign–install)*	-	95 | 100 (49)	59 | 78 (69)	55 | 69 (53)	66 | 78 (51)	93 | 107 (67)	110 | 132 (93)
Post-install *(install–PTO)*	72 | 81 (64)	29 | 39 (39)	29 | 40 (40)	37 | 51 (51)	47 | 61 (61)	42 | 53 (53)	38 | 48 (48)
Number of Projects	**669**	**4,541**	**8,395**	**12,854**	**27,013**	**33,124**	**19,172**

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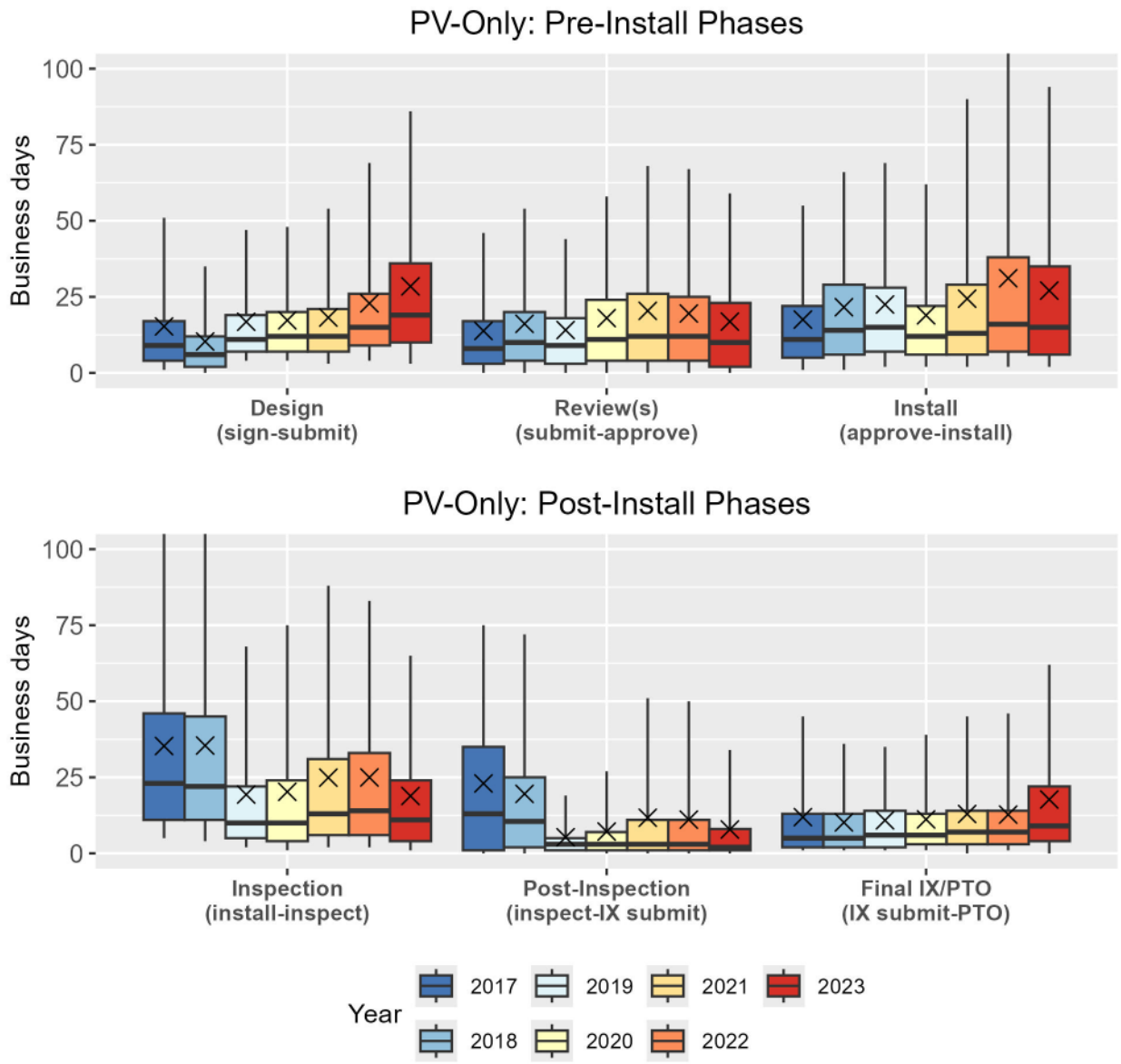

Figure 14. PV-only project timelines for each pre-installation and post-installation phase in the SolarTRACE data, inclusive of the 5th and 95th percentiles.

The box plots show the medians and quartiles. Averages are marked by an X. Whiskers show the 5th and 95th percentiles. The review phase includes both the AHJ permit and the utility pre-installation interconnection/ATB, where required.

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