



Residential Solar Adoption Timelines and Impacts from the COVID-19 Pandemic

Jesse R. Cruce,¹ Eric O'Shaughnessy,² Jenna Harmon,¹ Jesse Geiger,¹ and Jeffrey J. Cook¹

1 National Renewable Energy Laboratory

2 Clean Kilowatts, LLC

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List of Acronyms

AHJ	authority having jurisdiction
ATB	approval to build
CARES	Coronavirus Aid, Relief, and Economic Security
COVID-19	coronavirus disease 2019
IX	interconnection
NREL	National Renewable Energy Laboratory
PII	permitting, inspection, and interconnection
PTO	permission to operate
PV	(solar) photovoltaic
SolarAPP+	Solar Automated Permit Processing Plus
SolarTRACE	Solar Time-Based Residential Analytics and Cycle Time Estimator

Executive Summary

Most residential solar photovoltaic (PV) projects in the United States require several weeks to several months to complete, from contract signing to system operation. Integral to these timelines are the permitting, inspection, and interconnection (PII) processes administered by the local authority having jurisdiction (AHJ) and the utility. The significant expansion of the residential PV industry over the last decade—along with more recent challenges associated with the COVID-19 pandemic—has put pressure on the AHJs, utilities, and installers responsible for the PII and other install processes. However, state and local efforts to streamline and improve the PII process have also occurred during this timeframe and may be associated with the timeline decreases seen in several states prior to 2020.

For the study reported here, we used a project-level data set encompassing 131,000 projects installed between 2017 and 2021 that accounted for about 7% of U.S. residential installs across these years. The data set includes dates for relevant PII processes, along with dates for installation and contract signing. From these dates, we calculated timelines for phases of the PV adoption process and evaluated changes on a year-over-year and pre-pandemic/post-pandemic basis.

First, as seen in Figure ES-1, PV adoption processes and timelines are roughly evenly split between installer, AHJ, and utility. The project-level data set showed that typical projects took 70–100 business days (14–20 weeks, approximately 3½–5 months) from contract signing to system operation. However, overall project timelines in the data ranged from about 1 month to 9–10 months (30–180 business days). Individual phase timelines showed similar variability. For example, AHJ and utility application review timelines ranged from same-day to 3 weeks or more. Despite this variation between projects, since 2019, no single phase was a primary driver of overall timelines.

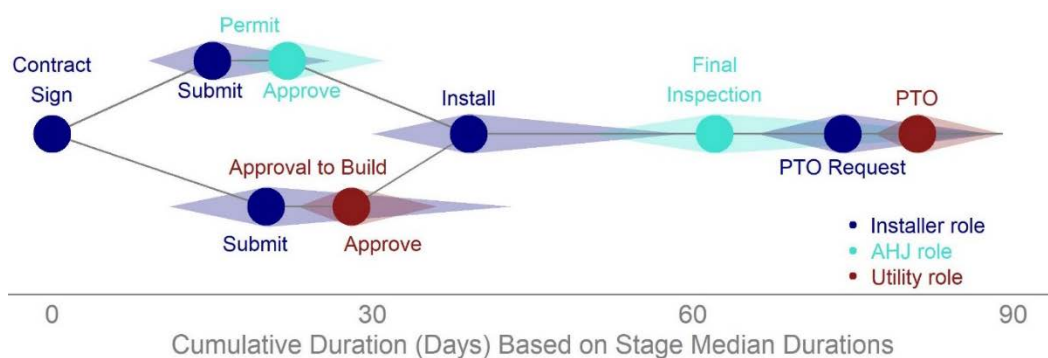


Figure ES-1. Major steps and typical timelines of the residential PV adoption process

Figure design adapted from O'Shaughnessy et al. (2022) using 2019 data from the present study. Points represent medians, and areas are the interquartile range. PTO is permission to operate, the final interconnection (IX) approval granted by the utility.

Next, the data show that overall project timelines (contract signing to operation) declined year-over-year since 2017 (Figure ES-2). This reduction appears to have been driven most strongly by significant decreases in post-install phase timelines—especially the install-inspect and inspect-PTO request. Analysis of pre- versus post-pandemic timelines showed that AHJ permit review times were the only phase affected by COVID-19. However, the impact was moderate: typical

permit review times increased by only 1–2 days, though variability in review times also increased at a given AHJ. These pre-install timeline increases were more than offset by the decreases in post-install timelines, and overall timelines continued to decline (albeit more slowly) in 2020 and 2021.

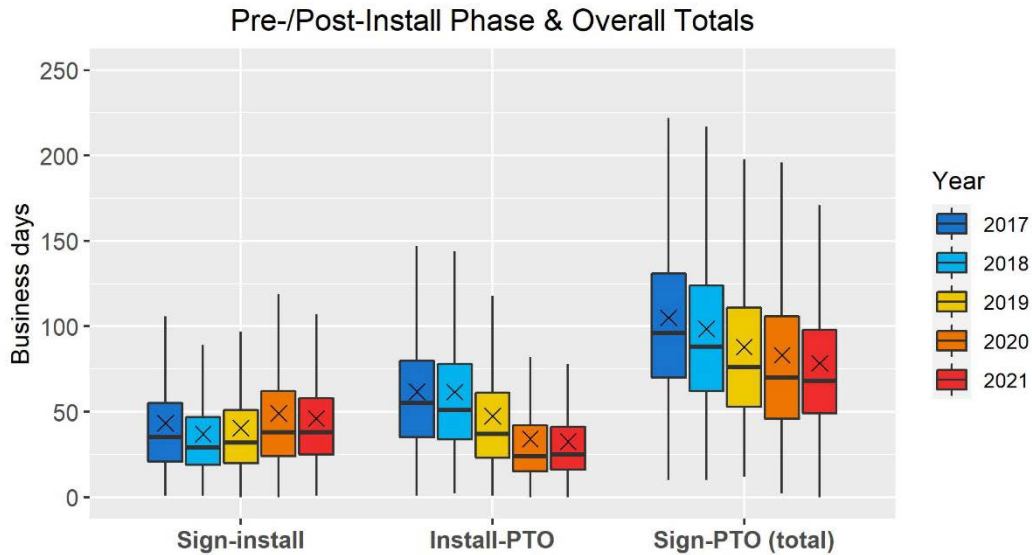


Figure ES-2. Annual pre-install, post-install, and overall project timelines in the data set

Boxplots show the data medians and quartiles, and averages are marked by an X.

Finally, the AHJ survey responses showed a clear shift from in-person permitting processes to online/electronic processes (Figure ES-3). Follow-up interviews suggested many AHJs were already making permitting and inspection changes—especially moving to online permitting—and that the pandemic accelerated or catalyzed this transition. About half of surveyed AHJs reported staffing challenges during the pandemic, and most of these challenges lasted 3 months or more (or were still ongoing at the time of the survey). Impacts to permit review timelines were the primary consequence of staffing challenges. However, interviewed AHJs noted that these challenges were primarily associated with their record permitting volume and the current hiring market rather than being a direct result of the pandemic.

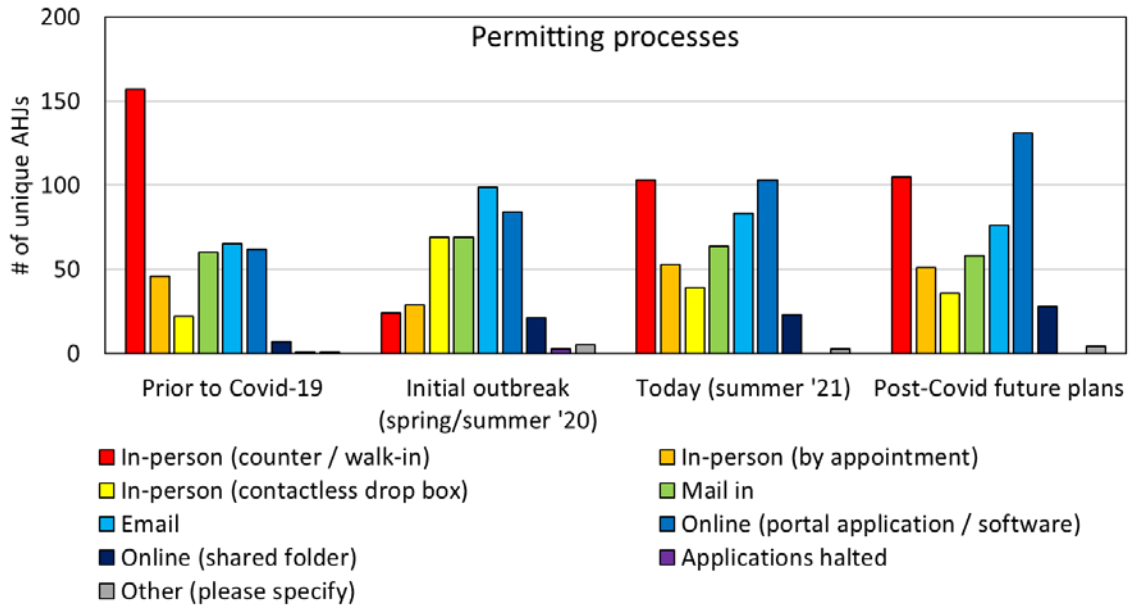


Figure ES-3. AHJ survey responses for permitting processes before, during, and after the pandemic

Overall, our findings suggest AHJ and installer challenges during the pandemic were fairly common. However, these challenges did not have a widespread impact on PV adoption timelines, at least for the AHJs, utilities, and installers in our data set. Our results suggest entities in the residential PV industry were largely resilient in their roles throughout the first year of the pandemic.

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1 Introduction

Residential solar photovoltaic (PV) projects in the United States typically require several weeks to several months from contract signing to system operation (Cook et al., 2021a; O’Shaughnessy et al., 2020). As part of the adoption process, most PV projects require review and approval from the local authority having jurisdiction (AHJ) and electric service provider/utility. AHJs also conduct inspections of the installed PV system prior to final approval for activation. This permitting, inspection, and interconnection (PII) process ensures installed systems meet national building, electrical, and fire codes and safety standards, along with other applicable state or local requirements.

The U.S. residential PV market has seen significant expansion over the last decade. Between 2010 and 2021, annual installs increased by a factor of 10 from about 50,000 to more than 500,000 systems per year (Davis et al., 2022). This increased volume has put pressure on AHJs and utilities responsible for PII processes. Meanwhile, installers must navigate the differing PII requirements and timelines across the tens or hundreds of AHJs in which they operate. However, the last decade has also seen numerous state and local efforts to streamline or otherwise improve PII processes. These efforts may be associated with the project timeline decreases seen in several states over the last decade (Fekete et al., 2022; O’Shaughnessy et al., 2020). Still, a more recent and widespread assessment of PV adoption timelines has not yet been conducted.

More recently, the COVID-19 pandemic created additional stressors for all entities involved in the residential PV adoption process. AHJs and utilities have had to navigate social distancing and work-from-home requirements amid record permitting/interconnection volumes and staffing challenges, while installers have faced supply-chain challenges, increasing costs, and project backlogs. Anecdotally, these issues have led to permitting delays and extended project timelines in some areas, but the overall impact across the United States has not yet been thoroughly evaluated (Davis et al., 2022).

In this study, we evaluate PV adoption process timelines from 2017 to 2021. We leverage time-stamped project-level data collected by the National Renewable Energy Laboratory (NREL) for the Solar Time-Based Residential Analytics and Cycle Time Estimator (SolarTRACE). Our work offers the first nationwide, longitudinal data set with PII timelines both pre-and-post-COVID-19. Uniquely, our data includes time stamps for non-PII processes that have seen less attention in literature, including the design, install, and post-inspection phases. To supplement our analysis, we also surveyed 171 AHJs about their experiences, challenges, and process changes during the first 18 months of the pandemic. Follow-up interviews were conducted with five AHJs from four states.

We find that overall project timelines from contract signing to final utility interconnection declined across all 5 years in the data, driven most strongly by improvements to the post-install timelines (install to final interconnection). We find that the pandemic may have moderately increased the duration and variability of pre-install timelines (contract signing to install), particularly in the permit review phase (permit submit to approval). However, post-install timelines may not have been impacted by the pandemic, as these timelines continued to decline from 2019 through 2021. The net result is that overall timelines also continued to decline, despite

the pandemic. Our findings suggest AHJs and installers faced challenges throughout the pandemic, but ongoing improvements in PII processes may have offset these pandemic-related challenges. Furthermore, the pandemic may have catalyzed widespread adoption of online/electronic permitting and other process efficiency improvements.

2 Background

Most residential PV systems go through permitting, installation, inspection, and interconnection as part of the adoption process and these activities can impact the overall adoption timeline (Figure 1). The adoption process and related timelines typically start when the customer signs a contract with the installer. After that, the installer completes the system design, prepares the PII application materials, and submits applications to the AHJ and the utility (the Design Phase). The AHJ and utility review their respective applications, request revisions if required, and approve and issue the necessary permits and approvals to build (ATBs) (the Review Phase).

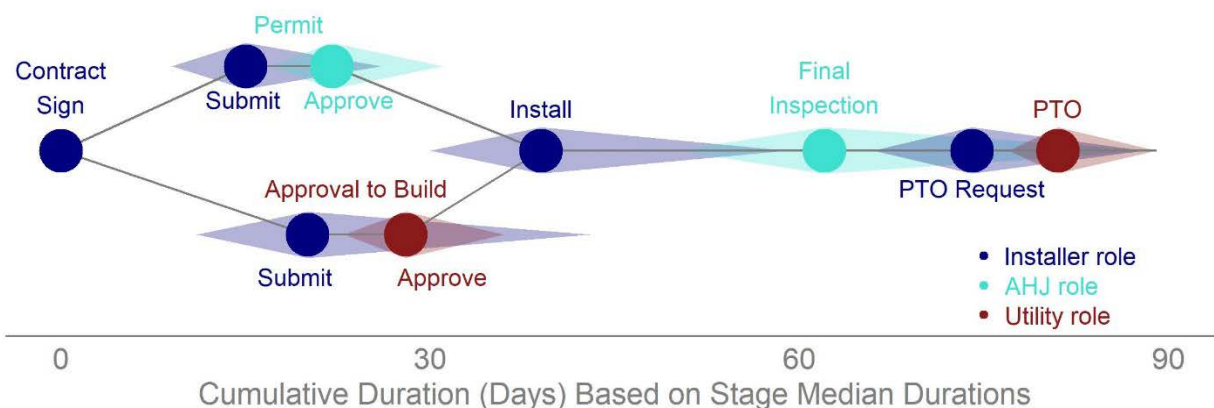


Figure 1. Major steps and typical timelines of the residential PV adoption process

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

Note that while most AHJs require approved permits prior to PV system installation, many utilities do not require pre-install approvals. Based on SolarTRACE data, at least 19 utilities in the United States—including the three largest investor-owned utilities in California—do not require pre-install approvals for residential systems. Though these utilities only make up 8% of the 238 utilities in the data set, they cover 54% of residential PV-only installs in 2017–2021.¹ Utilities that do not require pre-install approvals instead review interconnection applications as part of the final approval process prior to system operation (Fekete et al., 2022; NREL, 2022).

The Install Phase begins with the receipt of the approved AHJ permit(s) and/or utility ATB and continues through completion of the install. Most AHJs and some utilities require one or more inspections of the system before final approval (the Inspection Phase). Upon completion of all required inspections, the AHJ and/or installer submits the inspection results and final

¹ The three largest investor-owned utilities in California—Pacific Gas & Electric, San Diego Gas & Electric, and Southern California Edison—account for most of these installs, and cover 45% of install data for 2017–2021.

interconnection (IX) request submission to the utility (the Post-Inspection Phase). The utility reviews these documents and subsequently issues Permission-to-Operate (PTO, the Final Interconnection Phase).

2.1 Project Timelines and PII

Numerous studies over the last decade have examined timelines for phases of the PV adoption process (Table 1). The overall adoption process (from contract signing to PTO) typically takes 10–16 weeks, according to installers surveyed by Cook et al. (2021a). However, there is significant variation in individual phase timelines both within and between studies. For example, AHJ permit review timelines range from same-day approvals to almost 3 weeks in the literature. This variability in individual phases also affects overall project timelines, with one study (O’Shaughnessy et al., 2020) finding a difference of more than 2 months at the 25th and 75th percentiles of overall timelines.

Table 1. Description of Phases in the PV Adoption Process and Typical Timelines from Literature

Interquartile (25th to 75th percentile) or typical ranges are reported if available, and the median is shown if otherwise.

Phase	Phase Start/ End Dates	Activities	Typical Timeline (Days)
Design	Contract signing date to permit submit	Installer completes system design and then prepares and submits permit applications	7–19 ^a , 24 ^b
Review	Permit submit to approval	AHJ/utility review and approval of permit applications	AHJ: 0–9 ^c , 1–18 ^d , 1–24 ^e , 3–10 ^f , 4– 19 ^a , 11 ^b Utility: 1 ^g , 9 ^b , 18 ^{f,h}
Install	Permit approval to install completed	Installer schedules and complete system installation	17–30 ^b
Inspection	Install completed to last inspection	AHJ conducts one or more inspections of the system	4–6 ^g , 40 ^b
Post-Inspection	Last inspection completed to final IX submit	AHJ or installer submits final inspection results to utility, installer submits final IX/PTO request	<i>No data</i>
Final Interconnection	Final IX submit to PTO granted	Utility reviews final IX request and grants PTO	8 ^b , 10 ^h , 45 ^f
Total Project Time	Contract signing to PTO granted		70–112 ⁱ

^a Cruce et al., 2022, converted from business days to calendar days

^b O’Shaughnessy et al., 2022

^c O’Shaughnessy et al., 2020

^d Williams et al., 2022

^e Cook et al., 2022

^f Taylor, 2019

^g Fekete et al., 2022

^h Ardani et al., 2015

ⁱ Cook et al., 2021a

As illustrated in Figure 1, PV adoption timelines are roughly evenly split between processes led by installers, AHJs, and utilities. Though installers are also responsible for some of the variation in PV adoption timelines (O’Shaughnessy et al., 2020; Sinitskaya et al., 2019), we focus here on variation driven by AHJs and utilities via PII processes.

PII processes and requirements vary significantly across the United States, especially between AHJs. Many states set minimum PII requirements, generally by adopting a particular code-year for building, electrical, and fire codes. However, implementing and enforcing these codes is left to the AHJs, and many AHJs adopt more stringent local requirements (Stanfield et al., 2012). Application processes and requirements similarly differ, including for submission format (paper/in-person versus electronic/online); whether licensed engineering reviews are required (particularly structural reviews); and regarding specific limitations from zoning, homeowner associations, historic districts, and fire marshal requirements. Installers must navigate these differing requirements and processes across all jurisdictions that they serve.

Particularly burdensome PII requirements increase installation costs (Burkhardt et al., 2015; Cruce et al., 2022; Dong and Wisser, 2013) and project timelines (O’Shaughnessy et al., 2020, 2022). When surveyed, installers consistently cited AHJ permitting as a cause for both project delays and cancellations (Cook et al., 2021a), though Cruce et al. (2022) find no timeline differences between the majority of successful versus canceled projects. Furthermore, half of surveyed installers report avoiding AHJs with particularly onerous PII requirements. Half of installers also report charging higher prices in AHJs with burdensome PII, with a third of these charging a price premium of 10% or more (Cook et al., 2021a).

2.2 Improvements to Project Timelines

Recent literature has examined how PV adoption timelines have changed over the last decade. O’Shaughnessy et al. (2020) find that permit submit to inspection timelines decreased by 50% in Hawaii, New York, and Florida between 2010 and 2018. Those authors note that this trend aligns with an earlier trend in California, in which permit streamlining led to initial reductions in timelines before stabilizing. Those authors also find evidence that some of these reductions are attributable to AHJs becoming more experienced with PV permitting, offset by challenges from increased permit volume and variation between installers. Similarly, Fekete et al. (2022) find that average interconnection timelines in five states declined by 57%–100% based on a comparison of timelines in 2012–2014 and 2017–2019. However, neither of these studies evaluated the overall project timelines from the customer’s perspective (i.e., from contract signing to system operation). Only Cook et al. (2021a) reported on overall project timelines, though their findings are self-reported averages from installers and did not evaluate potential changes over time.

Several studies have also evaluated specific PII processes and improvements that may benefit project timelines. O’Shaughnessy et al. (2022) evaluated permitting and inspection activities and found faster project timelines in AHJs that have online permitting systems, require fewer departments to review a given permit, and/or have implemented best practices from the U.S. Department of Energy SolSmart program. Recent studies of AHJs implementing the SolarAPP+² platform—an online, instant permitting system for residential rooftop PV projects—corroborate

² The Solar Automated Permit Processing Plus platform (<https://solarapp.nrel.gov>)

these findings. Based on median durations, two studies found that projects using SolarAPP+ are installed and inspected 12–13 days sooner than other projects (Cook et al., 2022; Williams et al., 2022). Both these studies and O’Shaughnessy et al. (2022) find that implementing these types of streamlined permitting practices also does not appear to drive post-install delays (i.e., delays attributable to failed inspections for issues that may not have been identified through the expedited permit review process). Furthermore, O’Shaughnessy et al. (2022) found that more rigorous pre-install review processes add delays at the front end without timeline reductions or benefits to post-install phase timelines.

For utility interconnection, O’Shaughnessy et al. (2022) found faster timelines for utilities that offer online portals for applications and those with response targets (i.e., state- or utility-imposed targets for the maximum number of days to respond to an interconnection query). Similarly, Fekete et al. (2022) find that some utilities have streamlined their review processes and associated approval timelines by implementing similar best-practices such as online applications and payment and/or eliminating pre-install review requirements.

2.3 Impacts from COVID-19 on the Solar Industry

Though studies over the last decade have identified PII best practices and evaluated their potential impacts on project timelines, their analysis is mostly limited to before 2020. No study thus far has evaluated the impacts from the pandemic on these best-practices or on project timelines. COVID-19 created an unprecedented disruption across many industries. For residential PV, the first few months of the pandemic led to an industry downturn, with fears of significant decline in the industry workforce, decreased deployment, and PII challenges due to work-from-home orders (SEIA, 2020). However, after an initial downturn in the second quarter (April–June 2020), residential PV demand surged along with interest in home improvement projects in general. The second half of 2020 and all of 2021 set records for residential PV demand and showed the highest annual growth since 2015 (Davis et al., 2022).

Despite the rebound in demand, the pandemic still created challenges for all entities involved in the residential PV adoption process. Many AHJs have had to adjust their permitting and inspection processes to adapt to work-from-home and social distancing requirements. These challenges are especially true for the large number of AHJs that had previously not offered electronic permitting. AHJs have also faced worker shortages amid record-level permitting volumes. Meanwhile, installers have faced supply chain issues that worsened throughout 2021, which contributed to system price increases for their customers. Altogether, these challenges led to permitting delays and extended timelines in some areas and for some projects (Davis et al., 2022).

Our work provides a comprehensive review of residential PV timelines over the last 5 years. This report updates previous studies on PII timelines to include timeline data through 2021. It also includes timelines for non-PII processes, which have received much less attention in the literature, including the design, install, and post-inspection phases. By including these non-PII processes, we can assess the full project timeline experienced by the customer (i.e., from contract signing to system operation). Additionally, because the pandemic occurred during the timeframe of our study, we are uniquely able to assess timeline changes pre-pandemic versus post-pandemic. To supplement our analysis, we also surveyed and interviewed AHJs about challenges and impacts from the pandemic.

3 Methods

We used the project-level data set previously reported on and published as part of SolarTRACE.³ The data set provides project timelines from 2017 to 2021, along with information about AHJ-level PII processes and requirements. Impacts from COVID-19 were assessed via data analysis, a survey of AHJs in summer 2021, and follow-up interviews with five AHJs in autumn 2021.

3.1 Project-Level Data Set and Timeline Analysis

Since 2019, NREL has collected project-level data from installers related to residential PV timelines. To date, 13 installers representing a range of sales volumes have provided data, including time stamps for contract signing, AHJ permitting, utility interconnection, installation, inspection, and final interconnection/PTO. The data include project size (in kilowatts, kW), type (e.g., PV-only and PV+storage), and location (e.g., state, AHJ, and utility). SolarTRACE summarizes the data and reports results at the AHJ and utility levels for the last 5 years (2017–2021) (Cook et al., 2021b; NREL, 2022).⁴

We focus on residential rooftop PV systems by limiting the data to systems that were 10 kW or less and standalone PV (i.e., without storage). We used a subset of projects with records for contract signing, AHJ permit submission and approval, installation and inspection completion, and final interconnection/PTO request submission and approval dates.⁵ Also, we removed projects that did not list an associated AHJ. To reduce the impact of statistical outliers, we also excluded any project with a total timeline of longer than 260 business days (1 year) from the subset and subsequent analysis. Our final data set comprises records on 131,384 installs across 938 AHJs and 238 utility service territories in 29 states; it represents about 7% of all U.S. installs over the study period.

Installers also provided data related to AHJ-level permitting and inspection requirements and processes before the pandemic. These data are included in SolarTRACE and are summarized by O’Shaughnessy et al. (2022). Based on the SolarTRACE data and responses from the AHJ survey, three categories of AHJs were created:

- AHJs known to have *offered online/electronic* permitting prior to COVID-19 (i.e., by the end of 2019)
- AHJs known to have *offered online-instant* permitting prior to COVID-19
- AHJs known to have *required in-person-only* permitting with no electronic options prior to COVID-19.

³ Available at solarapp.nrel.gov/solarTRACE and data.nrel.gov/submissions/160.

⁴ Earlier versions of this data set were used for previous timeline analysis, including by Cruce et al. (2022), Fekete et al. (2022), and O’Shaughnessy et al. (2022).

⁵ Because many utilities do not require pre-install interconnection approvals-to-build (ATBs), these dates were not used as a criterion to subset the data. However, pre-install interconnection timelines were still assessed for those projects that included them.

AHJs in these three categories are summarized in Table 2. (AHJs known to have switched from in-person-only permitting to online during COVID-19 were tracked as part of the AHJ survey and are reported on in the results section.)

Table 2. Pre-COVID-19 Permitting Processes for AHJs in the Subset Data

Pre-COVID-19 Process	Number of AHJs in data set	Percentage of 2019 installs	Avg. Number of Installs per AHJ in 2019
Online	309	48%	39
Online-instant	8	4%	131
In-person-only	535	46%	21
(no data)	86	2%	5
Total	938	—	27

We analyzed project timelines in two ways. First, we assessed annual timelines and changes across all projects. Project timelines were bucketed to their corresponding year via two methods: the design and review phases were categorized by the date of permit submission, and the install and all post-install phases were categorized by the date of install.⁶ Total project timelines, including pre-install and post-install phase totals, were also based on the install date. Second, using a pre-/post-pandemic regression model, we analyzed COVID-19 impacts on overall timelines and relative to pre-pandemic permitting process.

3.2 AHJ Survey of COVID-19 Impacts

To better understand the initial and long-term impacts related to the pandemic, we developed a survey of AHJs conducted in August and September 2021. The survey asked AHJs about their PII processes and challenges during four timeframes: prior to COVID-19 (before March 2020), during the initial impacts from COVID-19 (spring/summer 2020), at the time of the survey (summer 2021), and post-COVID-19 (future plans, if known). The survey questions covered permitting processes, inspections, staffing challenges, impacts to review timelines, and changes to PII processes to adapt to COVID-19 restrictions. A full list of the survey questions is included in Appendix A.

The survey was sent to permitting/building department officials at the top 500 AHJs based on 2020 PV install volume, as determined from the Tracking the Sun data set from Barbose et al. (2021). The survey received 180 responses, representing 171 unique AHJs in 16 states. AHJs in California represented 55% of unique respondents (compared to California’s 36% of 2020 installs). In comparison, response volumes from other states roughly correlated to those states’ individual shares of 2020 U.S. install volume (e.g., Florida represented 6% of survey respondents and 7% of 2020 residential installs).

⁶ Given that projects take weeks to months from contract signing to operation, projects permitted in the later part of one year may not get installed or inspected until the early part of the next year. Thus, our method helps ensure the year bucket for permit review or inspection timelines corresponds to when the AHJ is conducting those processes. This division is particularly important for projects started at the end of 2019 that stretched into the early phases of the COVID-19 pandemic.

We conducted targeted interviews with certain survey respondents in December 2021 to clarify and further discuss their responses. Interviews were prioritized for AHJ responses indicating challenges or PII process changes during the pandemic and to ensure diversity in states and regions represented. In all, five interviews were conducted with AHJs across four states (Arizona, California, Florida, and Illinois).

3.3 Study Limitations

As with previous analysis conducted using the SolarTRACE data set, this study is limited by its sources and applicability of results. Though it is one of the most comprehensive residential PV project-timeline data sets built thus far, our data set covers less than 10% of the U.S. market and does not cover every state, utility, or AHJ in the country. Our results are heavily weighted by the larger installers in the data set, and so timeline changes or improvements may be due to internal company processes at these larger installers and may not represent trends across all installers in the U.S. market.

Similarly, previous studies such as O'Shaughnessy et al. (2020) have found that permitting review timelines within a given AHJ can also vary by installer. Thus, the review and inspection timelines we find here may not fully represent timelines seen by all contractors for projects at AHJs both included and not included in our data set. Finally, we have very little temporal data on PII process changes over time, and thus, we cannot develop a causal link between PII process requirements and timeline changes, either before or during the pandemic. Other than our survey and interviews, we do not attempt to conduct case studies of individual AHJs and the impacts from PII process changes or the pandemic.

4 Results

Study results are presented as follows. First, project timelines and changes are summarized on an annual basis for each year from 2017 through 2021. Next, COVID-19 impacts on timelines are evaluated via a regression model and in week-by-week changes to AHJ-specific permitting times. Finally, we discuss results from the AHJ survey and follow-up interviews.

4.1 Project Timelines

Annual project phase timelines are presented first in this section, followed by discussion of impacts from the pandemic. Based on the AHJ survey and interviews, we hypothesized that project timelines would increase between 2019 and 2020/2021. We expected significant impacts to AHJ permit review timelines, especially for AHJs that had previously had in-person-only permitting processes.

The results show that overall project timelines on average decreased every year in the data. This decline is most strongly driven by significant improvements in post-install timelines, particularly between 2018 and 2020. We found that the pandemic had a moderate but statistically significant impact on permitting timelines. AHJs that were already online before the pandemic fared slightly better than those with in-person-only processes. We also found increased variability in AHJ permit review times, though changes in the average/median review time for a given AHJ remained small.

4.1.1 Project Timelines by Year

Project phase and overall timeline results are summarized by year in Table 3. Additional statistical results are shown in Figure 2 (page 11) and Figure 3 (page 12) and are tabulated in Appendix B.

As seen in Table 3, a typical project required 70–100 business days (14–20 weeks, approximately 3½–5 months) between contract signing and PTO. Post-install timelines were much longer than pre-install timelines in earlier years of the data set, though more recently, post-install timelines have become shorter than pre-install timelines. Additionally, average timelines for individual phases were 1–2 weeks (4–10 business days) longer than the medians, suggesting projects with much slower-than-typical timelines skewed the averages upward.

Table 3. Median and Mean (parentheses) Project Phase and Overall Timelines for the Subset Data

All values are in business days.

Phase	2017	2018	2019	2020	2021
Design (<i>sign-submit</i>)	9 (14)	7 (11)	9 (14)	10 (15)	12 (16)
Review (<i>submit-approve</i>)	8 (12)	8 (12)	7 (12)	10 (15)	9 (12)
AHJ permit	5 (9)	5 (9)	5 (9)	6 (10)	6 (9)
Utility ATB	5 (8)	7 (9)	5 (8)	5 (8)	4 (6)
Install (<i>approve-install</i>)	10 (15)	8 (14)	9 (16)	10 (21)	9 (18)
Inspection (<i>install-inspect</i>)	22 (37)	22 (36)	15 (26)	9 (18)	10 (16)
Post-inspection (<i>inspect-IX submit</i>)	14 (23)	16 (21)	9 (15)	3 (8)	3 (7)
Final IX/PTO (<i>IX submit-PTO</i>)	5 (10)	4 (9)	4 (8)	5 (10)	7 (10)
Total (<i>sign-PTO</i>)	96 (105)	88 (99)	76 (88)	70 (83)	68 (78)
Pre-install (<i>sign-install</i>)	35 (43)	29 (37)	32 (40)	38 (49)	38 (46)
Post-install (<i>install-PTO</i>)	55 (62)	51 (62)	37 (47)	24 (34)	25 (33)

Timelines for pre-install and post-install phases are shown in Figure 2. As seen, review phase (submit-approve) timelines typically required 2–18 business days (i.e., up to 3 weeks) between permit/interconnection application submission to approval. Most notably, review phase timelines remained fairly consistent over the 5 years in the data: AHJ review timelines increased by only 1–2 business days between 2019 and 2020/2021, while the (more limited) data suggest utility pre-install interconnection timelines decreased slightly over the same period.

Design phase (sign-submit) timelines increased somewhat since 2018 and took 1–3 weeks or more between contract signing and permit/interconnection submission. While median install phase (approve-install) timelines showed little change from 2019 through 2021, the average and 75th percentile timelines both increased by a week during 2020, though both timelines decreased to roughly 2019 levels in 2021.

In comparison, inspection and post-inspection phase timelines were by far the longest and most variable steps in the PV adoption process. In 2018, a typical project waited 2–9 weeks between installing the PV system and completing all required inspections. Obtaining the completed inspection paperwork and submitting it to the utility with the final interconnection/PTO request (the post-inspection phase) similarly required 2–5 weeks. However, inspection timelines have halved since 2018, while post-inspection timelines decreased by 60%–80%—corresponding to timeline savings of 1–3 weeks or more compared with typical projects in 2018.

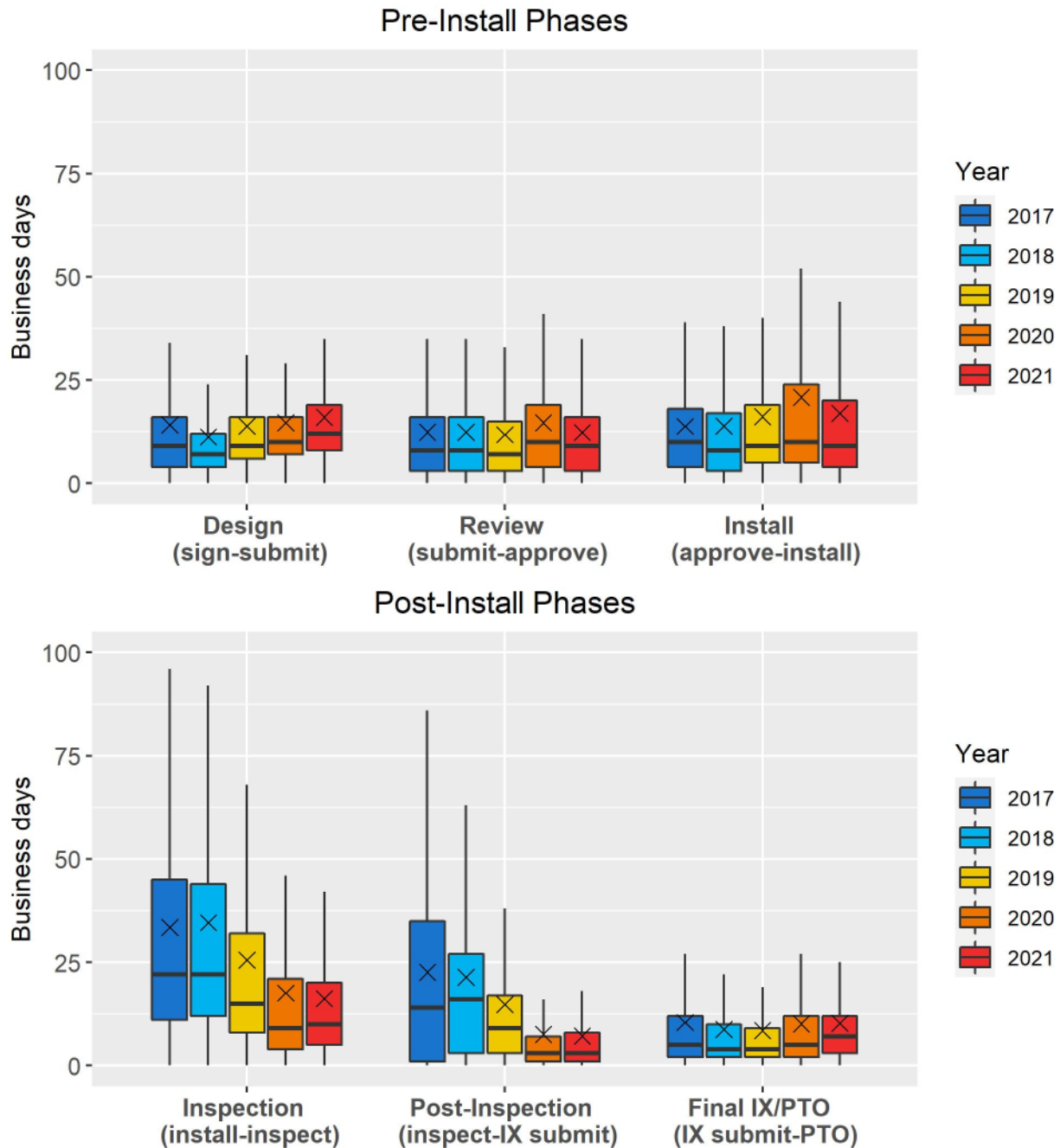


Figure 2. Pre-and-post-install phase timelines

The boxplots show the medians and quartiles, while averages are marked by an X.

Figure 3 shows timelines for the pre-install and post-install phases, along with overall (total sign-PTO) project timelines. As noted, typical projects took 70–100 business days (14–20 weeks) from contract signing to PTO. However, the range across total project timelines is significant: the quartiles (25th to 75th percentiles) span 50–110 days (10–22 weeks), while the 5th and 95th percentiles span 30–180 days or more; thus, most PV projects in the data took anywhere from 5 weeks to 9–10 months between contract signing and system operation.

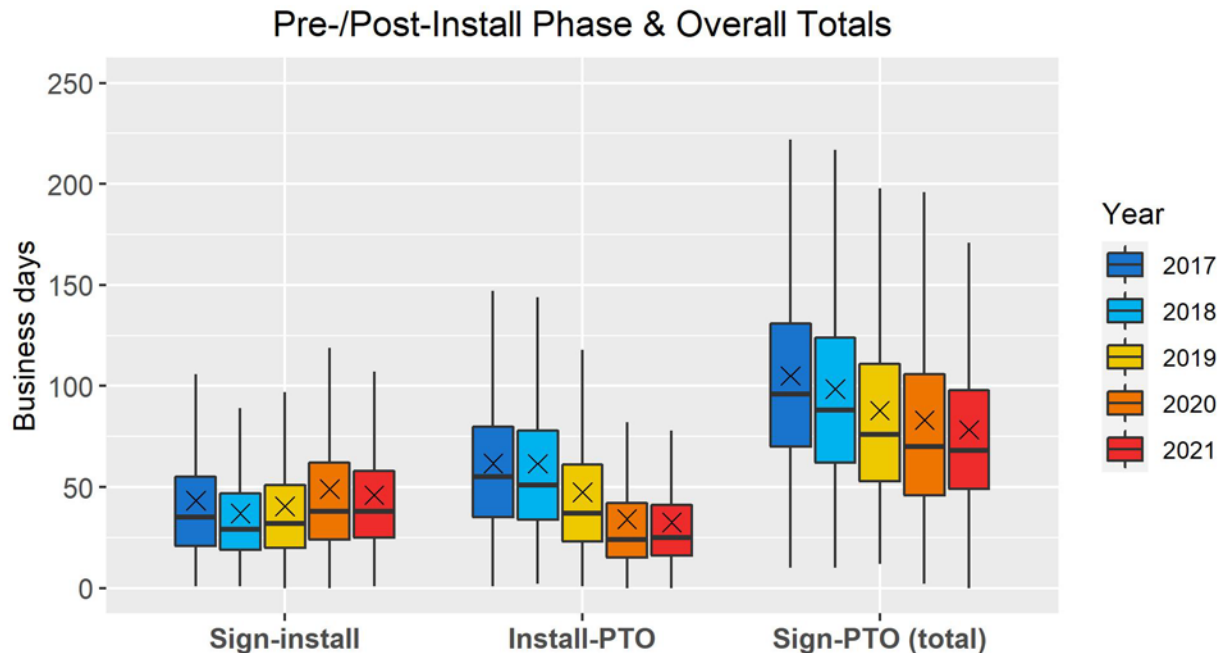


Figure 3. Overall timelines for all pre-install (sign-install) and post-install (install-PTO) phases, along with total project time (sign-PTO)

The boxplots show the medians and quartiles, while averages are marked by an X.

Altogether, our data show that, before the pandemic, overall project timelines had already decreased by about 20 days (4 weeks) between 2017 and 2019. Again, this reduction is associated with significant timeline decreases for the post-install phases, especially between 2018 and 2019. Though continued reduction in overall timelines slowed during the pandemic, overall timelines notably did not increase; on average, moderate increases in pre-install timelines were offset by continued improvements in post-install times. Impacts from the pandemic related to the increase in pre-install timelines is discussed in the Section 4.1.2. However, the drivers of the continued decrease in post-install timelines are currently unknown and remain a question for future work.

4.1.2 Pandemic Impacts on Timelines

Though the initial results from the previous section suggest some timeline impacts associated with the pandemic, they do not answer the question of causality—namely, did COVID-19 cause the increase in pre-install timelines? To explore this question, we used a pre- versus post-pandemic regression model to assess statistical significance. We also assessed permit review time changes at the AHJ-level.

Regression Model

Identifying the impacts of the pandemic on permitting timelines requires controlling for other factors that may have affected those timelines before and during the pandemic. Isolating COVID-19 impacts is complicated by the fact that the pandemic affected all AHJs and utilities. That is, we lacked a counterfactual case to compare changes in permitting timelines for AHJs and utilities that were unaffected by the pandemic. In lieu of a counterfactual, we implemented a simple before/after regression to assess the impacts of the pandemic on different timelines while

controlling for other factors. We modeled durations of the different phases as a function of an indicator variable for whether those phases began before or after March 2020,⁷ which roughly corresponds to the beginning of pandemic lockdowns in the United States. We controlled for a time trend and used fixed effects to control for variations in durations during different months of the year, across AHJs, and across installers. If COVID-19 had a significant impact on phase durations, the model coefficient for the before/after indicator variable should be positive and statistically significant.⁸

Table 4 presents the model coefficients for the different phases. Consistent with the descriptive results, the permit review phase (submit-approve) was the only phase where the model suggested a statistically significant, positive impact of COVID-19 on PV installation timelines. The model suggested approve-install timelines declined significantly during the pandemic, though this result is largely explained by the fact that approve-install timelines were anomalously high in the months preceding the pandemic.

Table 4. COVID-19 Before/After Model Results

Phase	Coefficient
AHJ permit review (submit-approve)	2.04 ^a
Install (approve-install)	-8.70 ^a
Inspection (install-inspect)	-0.77
Install-PTO	2.56
Total (sign-PTO)	2.61

^a p<0.05

One way to visualize the model results is to plot model residuals (i.e., the difference between observed durations and the durations predicted by the model). Figure 4 depicts these residuals before and during the pandemic. It shows a sharp jump in submit-approve residuals around March 2020 that is followed by consistently high residuals through the end of the year. In the post-review phases, the figure suggests there may have been a short and small pandemic-driven bump in approve-install and install-PTO timelines around March 2020. However, whatever effect the pandemic had on post-review timelines, the impact was short-lived and was quickly offset by longer-term trends. The net result is that there was no discernable immediate impact from the pandemic on overall project timelines (Figure 5). Full timelines did increase significantly around 2021, but this increase is not dissimilar from similar short-term spikes (e.g., around summer 2018) and thus cannot be confidently attributed to the pandemic.

⁷ For each phase, we use the month of the first step as the basis for the indicator variable. For instance, for the submit-approve phase, we use the permit submission month.

⁸ Formally, the model is $d_{pm} = \alpha + \beta c_m + T + F + \varepsilon_{pm}$, where d_{pm} is the duration of phase p in month m , c_m is an indicator variable for whether month m is before or after March 2020, T is a time trend (monthly), and F is a vector of month, AHJ, and installer fixed effects. β is the coefficient of interest, representing the marginal impacts of the pandemic on durations.

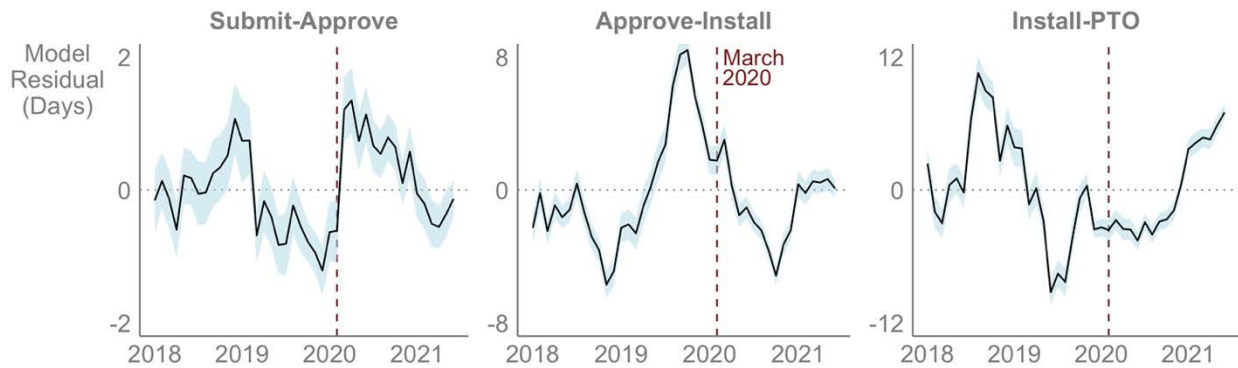


Figure 4. COVID-19 before/after model residuals at different phases

Bands depict 95% confidence intervals. Note that the three charts have on different y-axes.

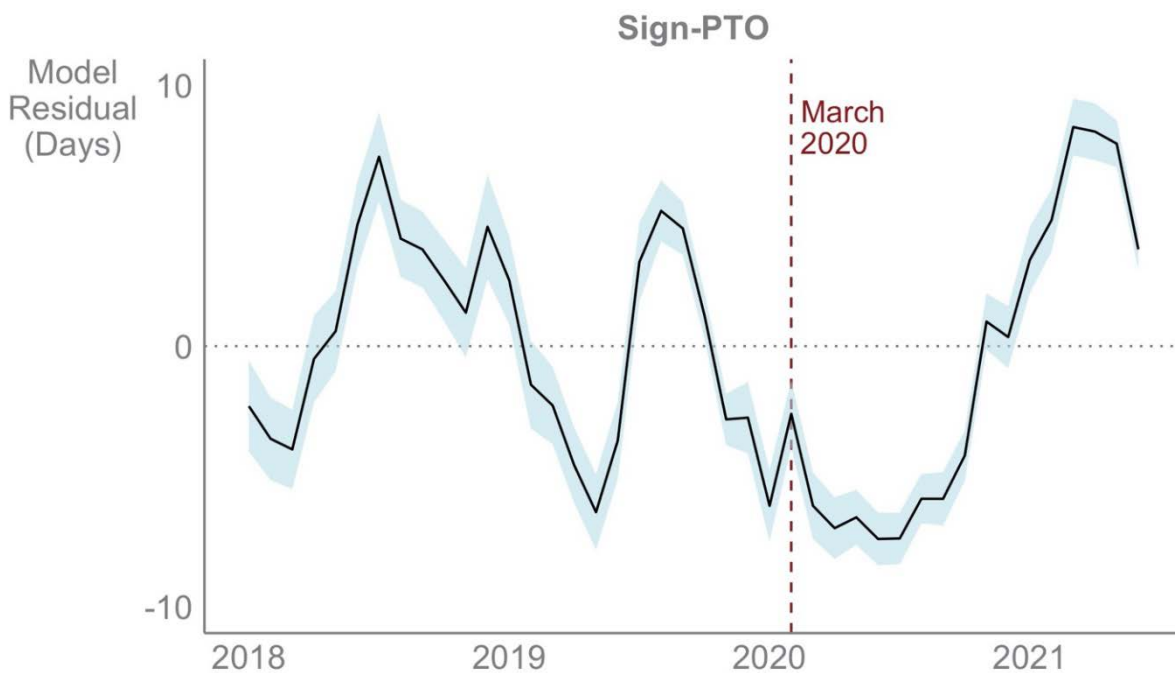


Figure 5. COVID-19 before/after model residuals for overall project timelines (sign-PTO)

Bands depict 95% confidence intervals

Overall, the results suggest the pandemic had a modest impact on permit review times, increasing typical submit-approve durations by around 2 days during the pandemic. However, the pandemic had no discernible impact on post-review timelines. Further, post-review timelines generally declined during the pandemic, most likely due to trends preceding the pandemic. The net result is that the pandemic had no appreciable impact on overall PV installation timelines (sign-PTO).

AHJ-Level Impacts

We can also use before/after models to explore whether online permitting helped some AHJs maintain steady permit review timelines during the pandemic. To test this, we used an interaction term in the model described above between the before/after indicator variable and an indicator for AHJs with online permitting before the pandemic. The coefficient on that interaction term was -1.83 and statistically significant, suggesting permit review times in AHJs with online

permitting before the pandemic increased less during the pandemic than in AHJs without online permitting.

Changes in AHJ-level review timelines are further shown in Figure 6. It shows project-level difference in AHJ-review timelines on a week-by-week basis throughout 2020. Specifically, for a permit submitted in a given week, the figure shows the difference between that permit’s approval time and the 2019 median for that project’s AHJ in 2019. Permits submitted in January or February of 2020 showed a distribution typical of permits throughout all of 2019, namely:

- A median review time difference of about 0 days (as expected)
- Approval of most permits within ± 2 –3 days of the median
- A few permits with differences of up to ± 8 days from the median.

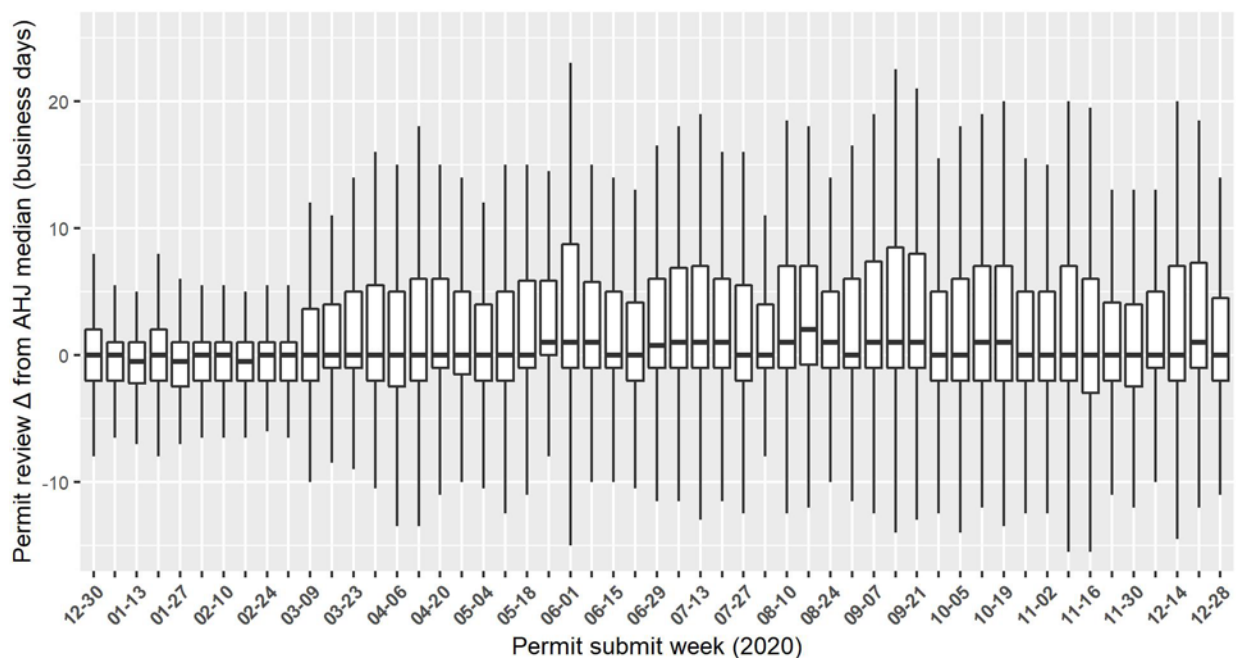


Figure 6. Project-level difference in 2020 permit review time relative to the 2019 median review time for that project’s AHJ

Distributions shown for permits submitted in January/February 2020 are representative of distributions throughout all of 2019 (not shown). Pandemic impacts are visible starting in March 2020. Trends in the second half of 2020 are also representative of trends throughout 2021.

AHJ permitting impacts from the pandemic appeared in early March, most noticeably in the week of March 9. The first impact was increased variability in permitting timelines, with an increased number of permits taking up to a week longer than their AHJ’s previous median and significantly more variation in timelines beyond the quartiles (boxes in the figure), both faster and slower. The median review timeline increased slightly at the end of May, and these trends continued throughout the rest of 2020 and all of 2021.

Trends in AHJ-level timeline changes for other phases of the adoption process also generally aligned with previous findings in this study and are thus not shown. These trends included a

continued year-over-year decrease in inspection, install-to-PTO, and total project times and a slight increase in sign-to-install times.

4.2 AHJ Reported Impacts from COVID-19

Both the AHJ survey and follow-up interviews focused on three primary topics: permitting processes and changes, inspections, and staffing or other challenges. Generally, AHJs reported more process changes and longer timelines for permitting than for inspections. About half of AHJs reported staffing challenges, and most staffing challenges persisted for 3 or more months (or were still ongoing at the time of the survey). Both the survey and the interviews suggested some PII process changes due to the pandemic are permanent, particularly the switch to online/electronic permitting.

4.2.1 Survey Results

The survey results show that at least half of the 171 AHJ respondents made PII process changes or experienced other challenges related to the pandemic. Though a few AHJs have since reverted their changes (i.e., only made temporary adaptations), most others have maintained or plan to adopt changes to make their processes more efficient, including allowing online/electronic permitting and virtual or photo-submission inspections.

Permitting

In our survey, we asked AHJ respondents to identify permitting process they used before the pandemic, during the initial outbreak (spring/summer 2020), as of summer 2021, and their future plans if known. The results are shown in Figure 7. With the initial outbreak, the responses showed a clear shift from in-person permitting to distanced options, particularly contactless paper-permit drop boxes and electronic options such as email, online portals, and online file hosting/shared folder services, such as Dropbox. While in-person permitting options returned as the pandemic progressed, adoption of or interest in online/electronic permitting options continued to increase and in many cases replaced the email option that in-person AHJs had adopted initially.

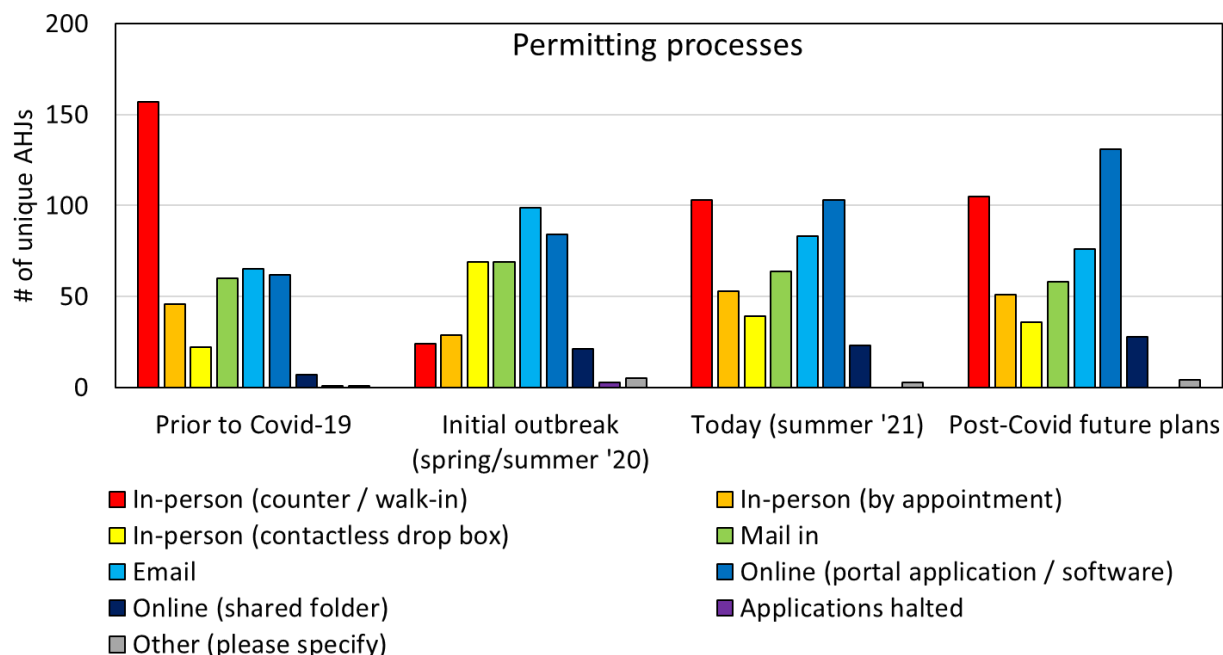


Figure 7. AHJ survey responses for permitting processes before, during, and after the pandemic

Only responses from unique AHJs are shown (i.e., multiple responses from the same AHJ were coalesced into a single response).

The shift from in-person-only permitting to providing online permitting options can be clearly seen in Table 5. Before the pandemic, AHJs that required in-person-only permitting represented about 40% of the survey respondents. With the initial outbreak, two-thirds of those AHJs shifted to allowing some form of online/electronic permitting. When future plans are accounted for, over 90% of AHJ respondents now offer (or plan to offer) online permitting options, with two-thirds of these AHJs offering online permitting in tandem with in-person options.

Table 5. Number of AHJs Offering Online Permitting Options During Each Phase of the Pandemic

Permitting Option	Pre-Covid-19	Initial Outbreak	Summer 2021	Future Plans
Online option	101	146	149	158
In-person-only	70	25	22	13
Switched to online ^a		45	48	57

^a Three respondent AHJs that switched to online/email permitting during the initial outbreak phase later reverted back to in-person-only permitting

Inspections

Figure 8 shows the survey results related to inspection processes. Nearly all AHJ respondents conducted in-person inspections before the pandemic, though 9 AHJs also offered photo submissions and/or virtual inspections as an alternative. With the initial outbreak, another 59 AHJs began offering photo and/or virtual inspections, for a total of 68 AHJs, or nearly 40% of respondents. In contrast to their changes for in-person permitting, most AHJs (140 respondents) continued to conduct in-person inspections during the initial outbreak phase, while 11 AHJs

temporarily halted inspections or waived inspection requirements. Nearly all AHJs had returned to normal in-person inspections by summer 2021, though over 30% (53 respondents) plan to continuing offering photo and/or virtual inspection options.

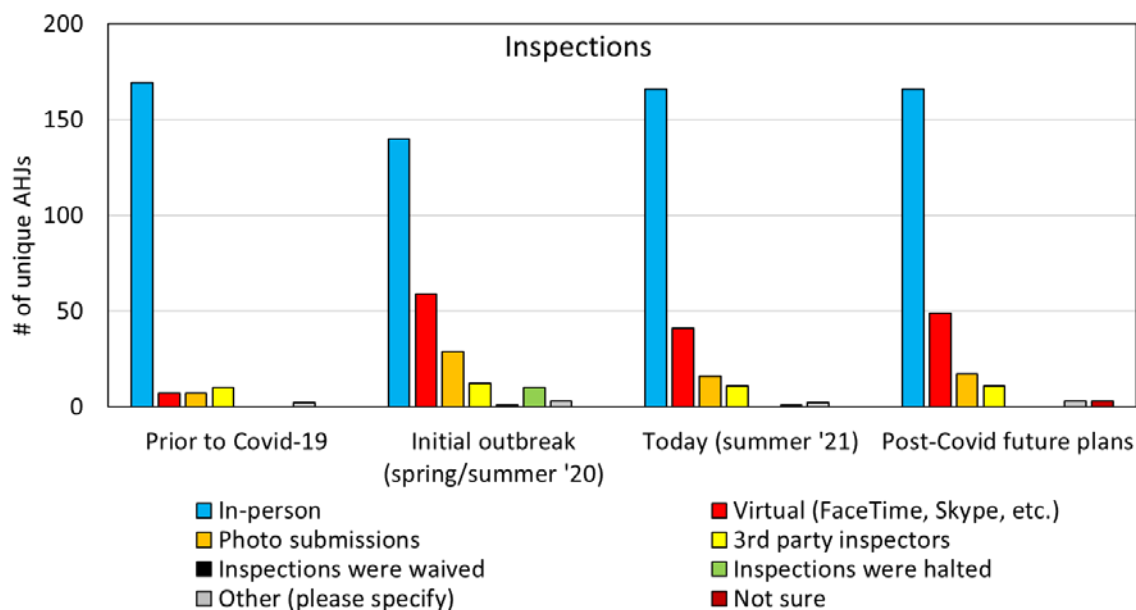


Figure 8. AHJ survey results for inspection processes

Staffing and Other Challenges

More than half of AHJs reported having staffing challenges related to permitting and inspecting during the pandemic. Responses about specific types of challenges are shown in Figure 9. The most cited challenge related to increased permitting volume (30% of respondents), likely associated with the rebound in PV demand and increase in building permits in general. Notably, 20% of AHJs reported already having staffing challenges before the pandemic, which were then exacerbated. Lesser-cited challenges included those related to remote work and staff reassignments.

Rather than being relatively temporary, most AHJs that reported staffing challenges also reported that the challenges persisted for 3 or more months (Figure 10). Furthermore, more than 20% of all AHJ respondents reported that staffing continues to be a challenge for them.

AHJs were also asked whether restrictions (e.g., state health orders and lockdowns) were placed on solar permitting, installation, or inspection activities. Most AHJs reported that these activities were allowed to continue and/or were designated as essential business. For the 14 AHJs that reported restrictions, 4 reported that permits were not accepted, 6 reported that permits were not approved/issued, 3 reported that PV installations were not allowed, and 9 reported that inspections were not conducted (see “Inspections halted” in Figure 8).

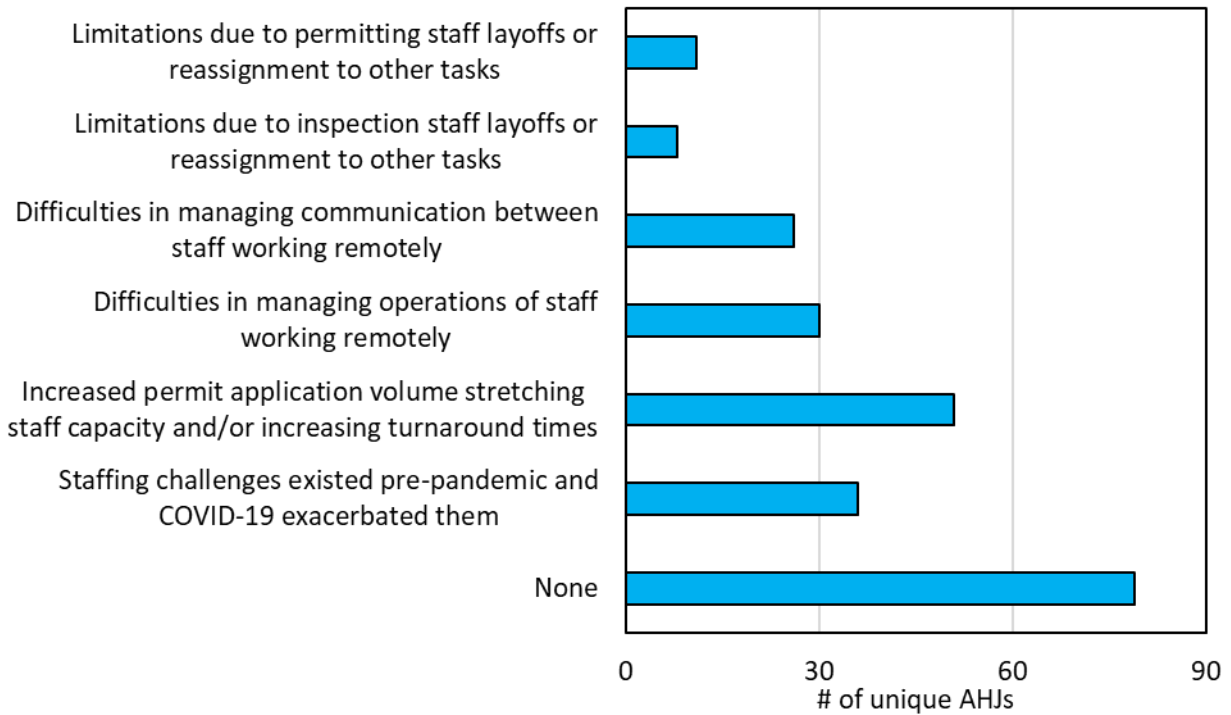


Figure 9. AHJ-reported staffing challenges related to permitting and inspection during the pandemic

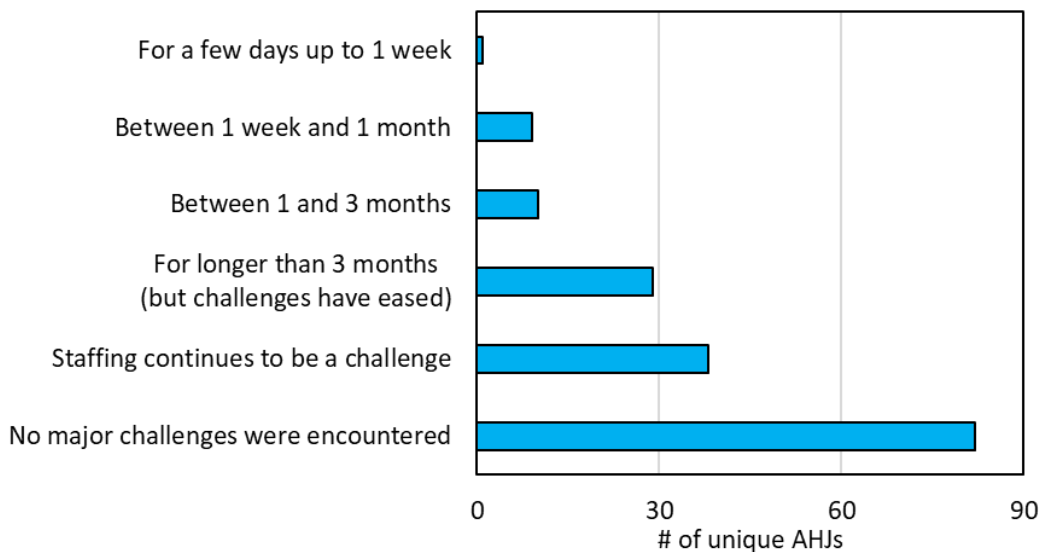


Figure 10. Duration of AHJ-reported staffing challenges during the pandemic

Timeline Impacts

Slower permit review/approval times were the most cited impacts of staffing challenges (53 respondents, 34%), followed by longer wait times for inspections (20 respondents). Only 6 AHJs reported making changes to permitting requirements to expedite the review process. Again, about half of AHJs reported no staffing challenges or impacts.

AHJs were also asked to estimate the overall impacts to their average permitting and inspection timelines during the initial outbreak period (Figure 11). As seen, 39 AHJs (23%) reported permitting timelines that were 1–5 days slower than average, while 25 AHJs (15%) reported delays of a week or more. In contrast, 5 AHJs reported faster permitting timelines: all 5 AHJs had in-person permitting before COVID-19 (3 also offered email permitting at the time), and all 5 had switched to online portals/software by the time of the survey.

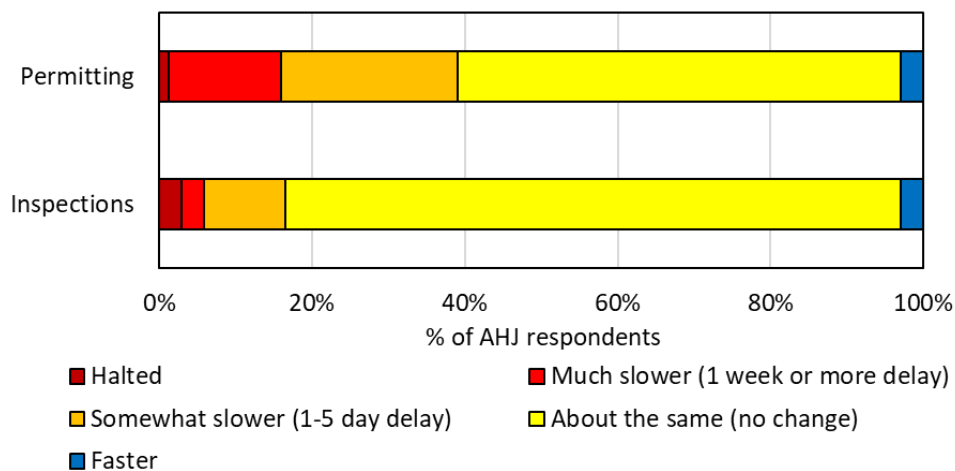


Figure 11. AHJ-reported impacts to average/typical permitting and inspection timelines during the initial COVID-19 outbreak period (spring/summer 2020)

Impacts to average inspection timelines generally aligned with responses to other questions: 23 AHJs (14%) reported longer inspection timelines, while 5 AHJs reported that inspections were halted. In contrast, 5 AHJs reported faster inspection timelines, including 3 of the AHJs that had reported faster permitting times. The remaining AHJs generally reported little to no change to average inspection timelines.

4.2.2 Interview Highlights

Permitting processes and changes were the first topic of follow-up interviews. In general, interviewees suggested AHJs that previously offered online/electronic permitting—or were already in the process of conversion to online—fared much better during the initial lockdowns than AHJs who had been exclusively focused on in-person-only processes. Of the interviewed AHJs, two already had online portal permitting systems,⁹ two were in-person/paper-only, and one offered both in-person and email (scanned application) submission options. However, all three AHJs with in-person/paper permitting both (1) already had electronic permit tracking systems for internal use and (2) already were in the process of transitioning to electronic permit submission. These AHJs all reported that the pandemic accelerated their timelines for conversion to online submissions; most had planned a longer beta-testing/rollout phase. Instead, the two in-person-only AHJs went live with online/email submission systems in April 2020 (2–3 weeks after lockdowns started), while the third AHJ continued their email and paper drop box options

⁹ One of the previously online AHJs was also an early adopter of the SolarAPP+ system, which they piloted during the pandemic. They noted the significant staff time savings from the online-instant platform, even compared with their existing online permit processes.

until their online portal came online. Though AHJs faced some challenges during the transition to online, most interviewees considered themselves fortunate to already be in the process of conversion when the pandemic occurred. In contrast, two interviewees noted the challenges faced by neighboring AHJs who had not been preparing for the transition or lacked electronic tracking systems.

Though inspections also faced some challenges during the pandemic, all interviewed AHJs continued to conduct in-person inspections while also allowing more flexible inspection requirements. Many AHJs significantly increased options for virtual inspections, and one AHJ reported that 50% of inspections were now virtual. Another AHJ reduced the number of required inspections from two or three to a single final inspection. One AHJ reduced the burden on its inspection staff by temporarily allowing contractors to sign a “COVID affidavit” in lieu of requiring an in-person inspection for some kinds of non-PV work. The affidavit affirmed that the work was completed to code and was only used for permits that did not require plan reviews.

As with the survey responses, all five interviewed AHJs reported staffing challenges during the pandemic. However, AHJs also noted that these challenges were related to permitting volume and general trends in the hiring market rather than specific impacts from COVID-19. In alignment with the trends in Davis et al. (2022), interviewed AHJs reported that permitting volume saw a downturn for 1–2 weeks in March (initial lockdowns), followed by a return to record high permitting volume. At the same time, AHJs lost permit technicians,¹⁰ plan review staff, and inspection staff to retirements and turnover, and some struggled to fill open positions. Some adaptive measures have helped, including the switch to online permitting—which often requires less staff time for intake, as the applicant enters required permit information into the tracking system, rather than a permit technician. Other AHJs also suggested more-flexible video and fewer required inspection processes (both during and post-install) helped mitigate the impacts of the pandemic and high permitting volume. Even so, longer permit application review timelines were again the most cited effect of staffing challenges.

Some interviewed AHJs offered best practices or lessons learned from their experiences with COVID-19. Recommendations included:

- Separating out PV permits from general building permits
- Focusing on staff well-being and serving customers better
- Searching for as many permit process efficiencies as possible
- Working with neighboring AHJs to develop best practices for application formats and review processes.

¹⁰ Many AHJs have permit technicians (tech staff) who do initial permit application review for completeness. For AHJs that use in-person-paper or email applications, technicians may also input the permit information into the internal electronic-tracking system before it goes for substantive reviews by building, electrical, zoning, or other officials.

Conclusions

Our study used a project-level data set representing approximately 7% of U.S. residential solar PV installs from 2017 through 2021. It included dates of relevant phases of the PV adoption process, from which timelines for these phases were calculated. Annualized summaries of phase and total timelines for each year were compared. Impacts from the COVID-19 pandemic were explored through a survey of 171 AHJs and follow-up interviews with five AHJs. Finally, pandemic impacts on phase timelines were assessed.

Key takeaways from this work include:

- In the last 3 years, typical residential PV projects took 10–22 weeks (50–110 business days) between contact signing and system operation, and 95% of projects were completed within 32 weeks (160 business days). Permit review typically took about 1 week, though the 95th percentile for review times was 6 weeks. Significant variability in overall project timelines existed across the data, even within the same AHJ.
- Residential PV project timelines have generally improved since 2017, driven most strongly by improvements to post-install processes, especially for the inspection and post-inspection (inspect-IX submit) phases. Since 2019, no single phase of the adoption process has been the primary driver of overall timelines.
- The pandemic had only a moderate impact on pre-install timelines. Typical permit review times increased by 1–2 days, with increased variability in review times at a given AHJ. AHJs that previously offered online/electronic permitting saw smaller timeline increases than those that previously required in-person-only permitting, though the effect was small relative to the already existing variability in review times between AHJs. Other phase timelines were not significantly impacted by the pandemic.
- Despite the challenges reported by AHJs, the pandemic did not significantly affect overall project timelines (sign-PTO). Increases in permit review timelines were more than offset by continued improvements in post-install timelines, and overall project timelines continued to decrease.
- Of the AHJs surveyed, 40% required in-person-only permitting before the pandemic, but almost all these AHJs began offering or planned to offer online/electronic permitting options after the pandemic started. In general, the pandemic appears to have catalyzed or accelerated widespread adoption of online/electronic permitting options.
- About half of AHJs surveyed reported staffing challenges during the pandemic, and 40% of AHJs reported slower permit review timelines. Most staffing challenges lasted 3 or more months or were still ongoing at the time of the survey and interviews. Staffing challenges were associated with both the hiring market (finding enough qualified staff) and record-level permitting volumes over the last 2 years.

Altogether, our findings suggest that while AHJ and installer challenges during the pandemic were fairly common, these challenges did not have widespread impacts on PV adoption process timelines. Of course, our findings are limited by our data, and thus are likely not representative of all installers or all AHJs. Regardless, this study suggests the residential PV industry, AHJs, and utilities were largely resilient in their roles after the pandemic began.

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Appendix A. AHJ Survey Questions

Section 1: Respondent Information

1. Email
2. Name
3. Phone number
4. Title/role
5. Department
6. Jurisdiction name (please specify city, county, town, village, borough, et cetera)
7. State (two-letter abbreviation)

Section 2: Permit Submission, Review, and Approval Processes

1. Approximately how many building/construction permits of any kind did your jurisdiction process in 2019? (open answer)
2. Of the building/construction permits in 2019, approximately how many were residential solar PV permits? (Please specify either number or percentage.) (open answer)
3. Currently (summer 2021), approximately how many building/construction permits of any kind is your jurisdiction processing per month? (open answer)
4. Currently, approximately how many of these are residential solar PV permits? (Please specify either a number or percentage.) (open answer)
5. On average, how many business days does it take to review and approve a typical residential solar PV permit application (from submission of initial complete application to final approval and issuance)? (open answer)
6. During the initial COVID-19 outbreak period (spring and summer 2020), how were average timelines for residential solar permitting and inspection impacted in your jurisdiction? (Select one per row.)

Table A-1. Section 2 Question 6: Impacts to Average Timelines

Phase	Halted	Much slower (1 week or more delay)	Somewhat slower (1–5 business day delay)	About the same (no change)	Faster	Not Sure
Permit review and approval	X	X	X	X	X	X
Inspection	X	X	X	X	X	X

7. Did your jurisdiction or state place business operations limits on residential solar at any point during the Covid-19 pandemic? Select all that apply.
 - A. Yes, permit application submissions were not accepted.
 - B. Yes, permits were not approved and/or issued.

- C. Yes, PV systems were not allowed to be installed.
 - D. Yes, inspections of completed installations were not conducted.
 - E. No, residential solar permitting, installation, and inspections were allowed to continue as usual or as an “essential business.”
8. How long did pauses or restrictions on residential solar permit applications, reviews, or issuance last? Select one.
- A. For a few days up to 1 week
 - B. Between 1 week and 1 month
 - C. Between 1 and 3 months
 - D. More than 3 months
 - E. No restrictions on these activities were put in place.
9. Which processes did your jurisdiction use for residential solar permit application submissions before, during, and after the COVID-19 pandemic? Select all that apply from each row (scroll right for more options). (Note: table direction reversed here for visible clarity.)

Table A-2. Section 2 Question 9: Residential PV Permit Application Processes

Phase	Prior to COVID-19 (before Feb 2020)	Initial COVID-19 Outbreak (spring/ summer 2020)	Today (summer 2021)	Post COVID-19 (future plans, if known)
In-person (counter/walk-in)	X	X	X	X
In-person (by appointment)	X	X	X	X
In-person (contactless drop box)	X	X	X	X
Mail in	X	X	X	X
Email	X	X	X	X
Online (portal application/software)	X	X	X	X
Online (e.g., Dropbox)	X	X	X	X
Applications halted	X	X	X	X
Other (please specify)	X	X	X	X

10. If you specified “Other” above, please describe your jurisdiction's permitting process and any changes due to COVID-19. (open answer)
11. Does your jurisdiction plan to keep changes made to the residential solar permitting application, review, or approval process in response to COVID-19? (Select one.)

- a. Yes, the jurisdiction adopted online permitting and plans to continue to do so (including email, web-based software, and/or a Dropbox-like folder hosting and sharing platform).
- b. Yes, some other changes were adopted and will be maintained.
- c. No, changes made have been reversed or will be in the future.
- d. The jurisdiction is neither keeping nor reversing the changes but is instead adopting new processes altogether.
- e. No changes were made to the residential solar permitting process.
- f. Not sure
- g. Other (open answer)

12. If you answered “Yes, some other changes were adopted” or “The jurisdiction is adopting new processes altogether,” please describe these changes. (open answer)

Section 3: Inspections

1. How were residential solar PV inspections conducted by your jurisdiction before and during the COVID-19 pandemic? Select all that apply in each row, assuming a typical residential rooftop system (scroll right for more options). (Note: table direction reversed here for visible clarity.)

Table A-3. Section 3 Question 1: Residential PV Inspection Processes

Phase	Prior to COVID-19 (before Feb 2020)	Initial COVID-19 Outbreak (spring/ summer 2020)	Today (summer 2021)	Post COVID-19 (future plans, if known)
In-person	X	X	X	X
Virtual (e.g., FaceTime or Skype)	X	X	X	X
Photo submissions	X	X	X	X
3rd party inspectors	X	X	X	X
Inspections were waived	X	X	X	X
Inspections were halted	X	X	X	X
Other (please specify)	X	X	X	X
Not sure	X	X	X	X

1. If you specified “Other” above, please describe your jurisdiction's inspection process and any changes due to COVID-19. (open answer)

Section 4: Staffing and Other Challenges

1. What kinds of staffing challenges did your jurisdiction face during COVID-19 as related to residential solar permit reviews and inspections? Select all that apply.
 - A. Limitations due to permitting staff layoffs or reassignment to other tasks
 - B. Limitations due to inspection staff layoffs or reassignment to other tasks
 - C. Difficulties in managing communication between staff working remotely
 - D. Difficulties in managing operations of staff working remotely
 - E. Increased permit application volume stretching staff capacity and/or increasing turnaround times
 - F. Staffing challenges existed pre-pandemic and COVID-19 exacerbated them
 - G. None
 - H. Other (open answer)
2. How long did these staffing challenges persist? (Select one.)
 - A. For a few days up to 1 week
 - B. Between 1 week and 1 month
 - C. Between 1 and 3 months
 - D. For longer than 3 months (but challenges have eased)
 - E. Staffing continues to be a challenge
 - F. No major challenges were encountered
3. How did these staff challenges impact the residential solar permitting and/or inspection processes? Select all that apply.
 - A. Slower permit review and approval times due to staffing limitations/availability
 - B. Longer wait times for inspections
 - C. Delays associated with availability of non-permitting staff (i.e., IT staff)
 - D. Changes in permitting requirements to expedite review process (e.g., fewer reviews and approvals required)
 - E. No major staffing challenges were encountered
 - F. Other (open answer)
4. Did your jurisdiction use COVID-19 emergency relief funding, such as through the American Rescue Plan or CARES (Coronavirus Aid, Relief, and Economic Security) Act, to support residential solar permitting? Select all that apply.
 - A. Yes, relief funding was used to support permit review and/or inspection staff (i.e., staff availability or resources directly associated with permitting).
 - B. Yes, relief funding was used to support changes to the permit application submission and/or issuance processes (e.g., switching to online permitting).

- C. No, relief funding was not directly used to support solar permitting.
 - D. Not sure
 - E. Other (open answer)
5. Please describe any other ways the pandemic or your community has influenced residential solar permitting review times over the past 18 months. (open answer)
 6. Would you be willing to participate in a follow-up interview with NREL researchers about the impacts of COVID-19 on your jurisdiction and its residential solar permitting and inspection processes? (If so, we will use the information provided at the start of this survey to contact you.) (yes/no.)

Appendix B. Phase Timeline Results

The tables in this appendix provide additional statistical information for the phase timelines presented in Figure 2 and Figure 3. All times listed are in business days, and 5 business days constitute 1 week for conversion purposes.

B.1 Individual Phase Timelines

Table B-1. Design Phase Timelines, from Contract Signing to Submission of First Application^a

^a Either the AHJ permit or the utility pre-install/approval to build, where required

Design Phase	2017	2018	2019	2020	2021
5th percentile	1	2	3	4	4
Q1 (25th)	4	4	6	7	8
Median	9	7	9	10	12
Q3 (75th)	16	12	16	16	19
95th percentile	46	33	39	41	43
Mean	14	11	14	15	16
Std. dev.	18	14	15	15	15
Count	22,616	22,500	29,586	28,062	25,249

Table B-2. Review Phase Timelines, from First Application Submission to Last Approval

These timelines include both the AHJ permit and the utility pre-install interconnection applications.

Review Phase (total)	2017	2018	2019	2020	2021
5th percentile	0	0	0	0	0
Q1 (25th)	3	3	3	4	3
Median	8	8	7	10	9
Q3 (75th)	16	16	15	19	16
95th percentile	41	41	39	47	38
Mean	12	12	12	15	12
Std. dev.	16	17	16	18	14
Count	22,621	22,541	30,084	28,277	25,295

Installers may submit both the AHJ and utility applications on the same day, but not always. Additionally, faster AHJs do not necessarily correspond with faster utilities, hence the timeline differences between this table and Tables A3 and A4 (AHJ-only and utility-only timelines, respectively).

Table B-3. AHJ Permit Review Phase Timelines, from Application Submission to Approval

AHJ Permit Review	2017	2018	2019	2020	2021
5 th percentile	0	0	0	0	0
Q1 (25 th)	2	2	2	2	1
Median	5	5	5	6	6
Q3 (75 th)	11	11	11	13	12
95 th percentile	30	30	29	35	29
Mean	9	9	9	10	9
Std. dev.	11	13	13	14	11
Count	22,618	22,536	30,061	28,228	25,255

Table B-4. Utility Approval to Build (ATB)/Pre-Install Interconnection Application Review Timelines, from Submission to Approval

Many utilities do not require an ATB prior to install, thus the lower project counts for this phase relative to other phases.

Utility ATB	2017	2018	2019	2020	2021
5 th percentile	1	1	0	0	0
Q1 (25 th)	3	3	2	2	1
Median	5	7	5	5	4
Q3 (75 th)	9	13	10	10	8
95 th percentile	24	24	24	24	21
Mean	8	9	8	8	6
Std. dev.	9	10	9	10	9
Count	10,246	8,317	8,533	13,458	11,126

Table B-5. Install Phase Timeline, from Last Application Approval to Completion of Installation

Install Phase	2017	2018	2019	2020	2021
5 th percentile	1	1	1	2	1
Q1 (25 th)	5	3	5	5	4
Median	10	8	9	10	9
Q3 (75 th)	20	17	19	24	20
95 th percentile	47	47	56	80	66
Mean	15	14	16	21	18
Std. dev.	17	17	21	32	28
Count	23,134	22,410	26,739	30,498	28,603

Table B-6. Inspection Timelines, from Completion of Installation complete to Completion of Final Inspection

Many AHJs require multiple inspections as part of this phase.

Inspection	2017	2018	2019	2020	2021
5th percentile	5	5	3	2	2
Q1 (25th)	11	12	8	4	5
Median	22	22	15	9	10
Q3 (75th)	46	45	32	21	20
95th percentile	106	110	84	64	52
Mean	37	36	26	18	16
Std. dev.	49	39	28	23	18
Count	23,128	22,400	26,695	30,049	28,283

Table B-7. Post-Inspection Phase Timelines, from Last-Completed Inspection to Submission of Final Interconnection/PTO Request

Post-Inspection	2017	2018	2019	2020	2021
5th percentile	0	0	1	0	0
Q1 (25th)	1	3	3	1	1
Median	14	16	9	3	3
Q3 (75th)	35	27	17	7	8
95th percentile	72	72	55	30	30
Mean	23	21	15	8	7
Std. dev.	27	25	21	14	13
Count	20,887	21,243	25,881	30,249	28,390

Table B-8. Final Utility Interconnection/PTO Request Timelines, from Submission to PTO Granting

Final IX/PTO Request	2017	2018	2019	2020	2021
5th percentile	1	1	1	1	1
Q1 (25th)	2	2	2	2	3
Median	5	4	4	5	7
Q3 (75th)	12	10	9	12	12
95th percentile	41	32	31	36	33
Mean	10	9	8	10	10
Std. dev.	16	14	13	15	13
Count	23,112	22,390	26,528	29,702	27,863

B.2 Overall Timelines

Table B-9. Total Pre-Install Phases Timelines, from Contract Signing to Completion of Installation

Pre-Install Total	2017	2018	2019	2020	2021
5 th percentile	11	9	11	12	13
Q1 (25 th)	21	19	20	24	25
Median	35	29	32	38	38
Q3 (75 th)	55	47	51	62	58
95 th percentile	107	91	100	126	107
Mean	43	37	40	49	46
Std. dev.	32	28	30	37	32
Count	23,132	22,410	26,732	30,489	28,600

Table B-10. Total Post-Install Phase Timelines, from Completion of Inspection to PTO Granting

Post-Install Total	2017	2018	2019	2020	2021
5 th percentile	16	16	13	8	8
Q1 (25 th)	35	34	23	15	16
Median	55	51	37	24	25
Q3 (75 th)	80	78	61	42	41
95 th percentile	134	146.6	119	98	84
Mean	62	62	47	34	33
Std. dev.	37	40	35	30	25
Count	23,134	22,409	26,738	30,384	28,513

Table B-11. Overall Project Timelines, from Contract Signing to PTO Granting

Total Project Time (contract to PTO)	2017	2018	2019	2020	2021
5 th percentile	43	37	33	28	32
Q1 (25 th)	70	62	53	46	49
Median	96	88	76	70	68
Q3 (75 th)	131	124	111	106	98
95 th percentile	200	200	186	190	162
Mean	105	99	88	83	78
Std. dev.	47	49	47	50	41
Count	23,134	22,410	26,739	30,498	28,603

B.3 Timeline Impacts in 2020/2021 Versus 2019 AHJ-level Median

Table B-12. Project-Level Timelines in 2020/2021 Compared to Median 2019 Timelines for that Project's AHJ (i.e., actual 2020/2021 Project-Level Timeline Minus AHJ 2019 Median Time)

Positive values indicate an increase in 2020/2021 compared to 2019.

Delta from AHJ 2019 Median	Permit Review		Total Project Time	
	2020	2021	2020	2021
5th percentile	-4	-6	-72	-75.5
Q1 (25th)	0	-1	-42	-37
Median	+1	+1	-21	-16
Q3 (75th)	6	6	7.5	12
95th percentile	24	22	81	69
Mean	4.6	3.9	-12.7	-11.0
Std. dev.	11.3	9.8	46.7	44.6

Table B-13. AHJ-Level Difference in Median Permit Review Timelines (2020 Median versus 2019 Median)

Positive values indicate an increase in median timelines from 2019 to 2020.

Δ Median Permit Review Time, 2020 vs. 2019	Entire Subset	Online	Online- Instant	In- Person- Only
5th percentile	-8	-9	0	-6
Q1 (25th)	-1	-2	0	-1
Median	+1	0	0	+1
Q3 (75th)	4	3	3 ^a	5
95th percentile	14	13	5 ^a	13
Mean	1.5	1.0	1.6	2.0
Std. dev.	6.7	6.5	2.5	7

^a Of the six online-instant AHJs, two saw permitting timeline increases in the 2020 data, though the cause is unknown and is not present in the 2021 data.