Final Technical Report (FTR)

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Executive Summary

To help SETO/DOE achieve its goals, the IBTS team proposed a project addressing system reliability by improving installation standards and quality management. The proposed approach was designed to help achieve measurable reductions in installation defect density and improvements in the performance of PV systems by optimizing design and installation of residential and commercial PV systems. This approach addressed the soft costs associated with installations and quality management.

The project demonstrated improved system reliability and reduced PV system installation costs. The software developed improved operations, decreased risk, and increased the overall value of PV systems across their lifecycle.

The project used several data collection methods, including extensive industry surveys, face-to-face high-level interviews at industry conferences, stakeholder teleconferences, and in-depth interviews conducted by IBTS staff. Results from the research found the industry needs a uniform assessment method for national providers to be more efficient; the software should support both code officials and installers; most industry stakeholders would find value in a centralized software system that allows them to collect, report, and review information on in-process and completed solar installations; and mobile solutions that bridge existing knowledge gaps with inspectors and integrate with existing methodologies (such as permitting software) are of great value.

The software solution developed is web-based, allowing for national access, and is built on a Google Firebase platform that can handle significant users and data. It can be used onsite or remotely, allowing for code compliance to continue despite ongoing pandemic related delays or shutdowns for local economies. The information provided by the software tool allows users to uniformly assess a system for compliance and use that aggregated data to identify training topics or create internal process designed to improving issues and reducing occurrence.

This solution has multiple benefits in managing quality at time of use and promoting an increase in future safety and quality through education. Perhaps most importantly, this software increases public safety by ensuring compliance of installed systems and allows for local AHJs to remotely engage specialized and qualified solar specific expertise for oversite of the installation in their jurisdictions. Data analysis provides the quality-feedback loop identifying the root cause of failure and drives installation practices to improve through training and education, resulting in systems with higher performance, greater reliability, and reduced operations and maintenance costs.

With the successful completion of this project, the industry can expect reduced soft costs and increased performance and safety and will ultimately benefit from longer performing systems that cost less to operate.

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Background

The Institute for Building Technology and Safety (IBTS) is the leading provider of quality management (QM) services for the residential and commercial photovoltaic (PV) installation industry. Working primarily through national, third-party ownership installers and state government incentive programs, we have helped ensure quality on hundreds of megawatts (MW) of distributed generation by inspecting over 50,000 projects across the U.S. and its territories. More than 38% of the operating PV systems that IBTS has inspected, after local authority having jurisdiction (AHJ) approval, have at least one code violation, with 15-20% having critical issues that can affect safety, performance, and reliability. The 10-year average constant in industry quality means that either installers and officials do not understand what they are doing wrong or cannot pinpoint it to efficiently make improvements. Additionally, we have found during workforce training for code officials that there are more than 15,000 jurisdictions all enforcing a slightly different codes, which can lead to confusion or inability to track defects in installation and system quality.

The project detailed in this report—"Application of Manufacturing Quality Management Principles to PV System Installations" sought to address these issues by expanding IBTS' national solar quality management program to benefit local and regional stakeholders in the PV industry. This report provides an account of work completed for this project, including a summary of the concept, stages of development, and outcomes associated with completion of the statement of project objectives (SOPO) milestones.

The project team, including IBTS, the North American Board of Certified Energy Practitioners (NABCEP), and software developers Sustainabilist, engaged in a two-year effort to engage PV industry stakeholders to identify needs and scope the development of a software tool that would provide quality management through intake and aggregation of data, resulting in sophisticated quality management processes available locally and regionally.

The project used several data collection methods, including extensive industry surveys, face-to-face high-level interviews at industry conferences, stakeholder teleconferences, and in-depth interviews conducted by IBTS staff.

Results from the research included:

- The industry needs a uniform method of assessment for national providers to be more efficient
- The software would perform best if it had opportunity to support code officials and installation teams alike.
- The majority of industry stakeholders would find value in a centralized software system that allows them to collect, report, and review information on in-process and completed solar installations.
- Mobile solutions that bridge existing knowledge gaps with inspectors and integrate with existing methodologies (such as permitting software) are of great value.

This input drove the scoping and architecture process, and provided the information needed for working group discussions on final system functionality.

The software solution is web-based, allowing for national access and is built on a Google Firebase platform that can handle significant users and data. As a web-based application, it can be used onsite or remotely, allowing for code compliance to continue despite ongoing pandemic related delays or shutdowns for local economies.

The information provided by the software tool allows users to uniformly assess a system for compliance and use that aggregated data to identify training topics or create internal process designed to improving issues and reducing occurrence.

This solution has multiple benefits in managing quality at time of use and promoting an increase in future safety and quality through education. Perhaps most importantly, this software increases public safety by ensuring compliance of installed systems and allows for local AHJs to remotely engage specialized and qualified solar specific expertise for oversite of the installation in their jurisdictions. Data analysis provides the quality-feedback loop identifying the root cause of failure and drives installation practices to improve through training and education, resulting in systems with higher performance, greater reliability, and reduced operations and maintenance (O&M) costs.

With the successful completion of this project, the industry can expect reduced soft costs and increased performance and safety and will ultimately benefit from longer performing systems that cost less to operate.

Project Objectives

This project focused on the development of a cloud-based software platform that allows sophisticated quality management (QM) processes to be accessible to local and regional stakeholders, including solar installers, building/code officials, and inspectors.

The project largely focused on providing the industry with a tailored solution that will ensure safety and promote efficient use of time and reduction of associated soft costs. Doing so through uniform data aggregation supported a follow-up objective to allow for feedback and improvement through education and workforce development. The project will ensure that the fast-growing PV industry and its stakeholders have a mechanism for measuring quality and ensuring compliance.

The project objectives were in support of the project goal for software development and national adoption. These included:

- Research stakeholder needs and create software scoping requirements.
- Create a scope and architecture document that will identify needs and guide software development.
- Maintain a working group to support stakeholder engagement for research and development (R&D), technical expertise, and final adoption.
- Through the working group, create an inspection form to guide end users in national compliance variables.

- Coordinate with stakeholders to ensure training topics and other industry solutions are incorporated or considered if relevant.
- Develop and test software.
- Conduct user acceptance testing and final software build out.
- Release software to the industry, ensuring national spread and minimum engagement and adoption.

Quality management processes have traditionally been applied primarily to the manufacturing process as a way to reduce costs and meet international standards. Most larger PV installation firms have some level of quality control and quality assurance processes in place, largely as a result of due diligence requirements of finance providers, but even with these processes in place IBTS continues to see unacceptable levels of installation issues. Local and regional installation firms struggle to implement and maintain quality management processes if they have any at all. Consumers are led to believe that minimum contractor licensing requirements and local AHJ approval will ensure safe and reliable system installations. Information and inspection data that is collected by installation firms, utilities, and state incentive programs is treated as proprietary/confidential and is not publicly available. Internet review sites are the only places that consumers can look to for any indication of quality or customer satisfaction related to potential installers. Additionally, most home inspectors are not qualified to assess the status of a PV system during the sale of a property.

The outcomes from the project reduce many of the burdens that prevent installation firms from implementing an effective QM program by making third party oversight of system installation more affordable, accessible, and easier to act on using current day easy to access technology. PV installation company management and executives can easily and remotely oversee the work of their installation crews using unbiased third-party review of system installation. The software tool developed provides specialized subject matter expertise to AHJs and home inspectors who may not themselves have the expertise, time, or capability to thoroughly inspect PV systems. By collecting data on system quality for large numbers of PV systems using a standardized intake, review, and scoring process that the installation firms understand and support, the potential exists for an installer quality rating system to be used by consumers, investors, and other stakeholders. Recent reports by EnergySage show that consumers are more likely to choose component quality over price when selecting a solar installer.

The technology approach is one that results in increased system reliability and PV system cost reduction. By making quality management more accessible and affordable, system installation defects are reduced as installation firms are monitor installation crews and address issues with process, procedures, tools, and techniques. The software has improved operations, decreased investor risk, and increased the overall value of PV systems in the initial lifecycle.

The most challenging risk in the development of the program is making it useable by the key stakeholders. To mitigate the risk, stakeholders were involved in the development and testing process to identify key functionalities and operational characteristics.

Problems in solar PV system construction are a significant driver of soft costs in the industry. Quality management (QM) tools such as IBTS' QM Field Inspection Technology (FIT^{QM}) software, allow jurisdictions and installers to improve installation process and reduce failure rates resulting in a lower overall cost of PV system installation. QM through quality control (field inspections), compliance review, and data driven workforce development are key contributors to increase in quality. With more than 40 years of experience performing assessments, audits, and on-site inspections for federal, state, and local governments, we have successfully provided unbiased, third-party oversight, completing in excess of 85,000 technical inspections and desktop quality reviews. We believe QM is essential for public safety, managing risk for financial markets, and creating a culture of continuous improvement that results in greater delivery efficiency and fewer defects.

During the pandemic when the solar industry was struggling to retain jobs and ensure proper compliance with shutdowns and remote requirements, the Interstate Renewable Energy Council (IREC) held a webinar to showcase the benefits of remote technologies and other various inspection tools. One of the downfalls of other non-specific software solutions is that they are often generic off-the-shelf software tools that require some expertise to operate or customize/create assessment criteria. This left stakeholders hopeful but still navigating the necessary criteria that are key to measuring compliance and also identified another need in the industry; a uniform inspection checklist and data analysis. Despite enforcing the same code, it was often in various different years and included amendments that were confusing or left to interpretation by unqualified individuals and the industry lacked a standardization of residential PV inspection as they have achieved in other similar projects. The team also included a standardized and uniform inspection checklist in the working group task list.

Project Results and Discussion

The project team has successfully completed the development of the software tool to align with the accepted specifications created during initial scoping. User adoption has been primarily installation firms to date with many jurisdictions engaging for demonstration and integration into their process.

Project objectives were accomplished over two budget periods. Budget Period 1 (BP1) focused on designing and building the initial software platform including alpha stage functionality using design guidance and support from a group of industry stakeholders. Software development continued scoping and architecture design through the completion of alpha development and testing. Budget Period 2 (BP2) focused on beta software development, continuous software testing, and managing the use of the software platform with the final task being user adoption.

The final product is a production version of the quality management software and initial implementation of a quality scoring system for installations. This allows initial users and jurisdictions to get the needed remote and expert support they need built into a turnkey solution that increases quality, accuracy, and reduces overall cost of overseeing PV

system installation through a uniform inspection platform and quality management process. The final software facilitates a quality management protocol including a quality-feedback loop that will reduce the levelized cost of energy (LCOE), decrease financial risk, and make solar more price competitive through measurement and education.

In budget period one we coordinated a group of stakeholders to participate in steering the design and testing of the software, and ensure that all stakeholder groups had representation in the process. Throughout the first half of budget period one, we engaged intended users and studied market needs through market analysis and industry outreach. The team developed the overall scope and architecture, identified software specifications and requirements, completed initial mockups, and completed alpha software development for testing and ultimately release alpha software at the end of BP1 after thorough user acceptance testing (UAT).

After production release for beta phase, the operational use of the software was underway by the test group in budget period 2. During this budget period, the additional data functionalities and application programming interfaces (APIs) were configured to provide the high-level feedback intended. The team will collect all feedback from users at the midway point for final clean up and system edits as reported by the users. Before the end of the award, the awardee engaged and received commitment from members of each stakeholder group to use, or support the use of this software and method for providing quality control and quality oversight.

Stakeholder Engagement: Key stakeholders were engaged throughout the project and at all stages of software development and testing to ensure the system will meet user requirements. Stakeholder acceptance and support for the project was critical to ensuring long-term goals for adoption, use, and overall impact. Efforts were also made to engage with existing and future partners in the installation, asset management, and workforce development/training sectors to disseminate best practices and share content.

Business plan development and validation: The team developed and implemented a business plan to inform stakeholders about the system and sign-up users for beta testing the pilot program. Tasks included creating a competitive analysis, developing a draft go-to-market strategy, and conduct qualitative research in the form of focus groups or in-depth interviews with participant and non-participant stakeholders to test delivery, pricing and distribution.

Software Scope and Architecture: The team created a development roadmap from stakeholder engagement efforts that illustrated the specific software functionality requested by the initial stakeholder outreach.

Requirements Development: We identified UX recommendations and created wireframes to illustrate needs, user interface (UI), data infrastructure, and business rules by interviewing stakeholders and engaging them to validate the contents. For UX/UI, interviews were conducted as to the required features, and wireframes were constructed that were used during the usability testing phase. Business rules as a topic

were part of the user interviews and detailed process maps document these. Results from these efforts and feedback guided development of software specifications and initial mockups that alpha testers and stakeholder groups reviewed for final acceptance. The outcome of this review period created the final specifications and functionality that were included in the final development plan.

Software Development: The team built and tested an initial version of the software platform based on specifications and mockups. Initial focus was on pieces of software that are independent of the business rules, such as back-end platform development and database setup. As the business rules analysis concluded the data architecture and front-end prototyping was included to develop alpha version.

Complete Initial Alpha Build: The team implemented software designs based on specifications and mockups. The working group and steering committee with assistance from the development team completed alpha testing of initial software functionality. Alpha software was tested against the detailed requirements, both in checklists form and for the purposes of achieving the functions validated by a team of committed testers. Each alpha tester provided feedback via user acceptance testing (UAT) logs after thoroughly testing the system operation. As testing continued through the end of Budget Period 1, we conducted any needed remediation or revisions prior to the launch of Beta software.

Production Release for Beta Phase: The team launched the final pre-production software revisions based on alpha testing feedback. Code underwent final quality assurance and quality control (QA/QC) checks at the modular level (unit testing). A finalized production version was released, with appropriate rules in place for monitoring system logs, enabling uptime, and implementing further improvements using a staging and production branch system.

Budget period 2 included primarily software development tasks as summarized herein. The team revised and debugged the software based on feedback from alpha testing to create a beta version. Beta testing included a larger group of key participants than included in alpha test. The team revised the software plan, updated requirements, and fixed problems identified in the alpha release. Continued to make improvements in the front-end, back-end and data processing systems; and implement data architectures that correspond with these improvements. The beta version with advanced functionality was developed and released for use and testing. API functionality included the ability to coordinate with other platforms for the sake of additional data or user interaction. Additional effort was taken at this time to coordinate with third party software in development by teams at the New York State Energy Research and Development Authority (NYSERDA) and the National Renewable Energy Laboratory (NREL) (e.g., SolarAPP). Ultimately, AP keys were developed based on key information retained within the system and its functionality, and were created on platforms that promote interoperability in the case of future inclusion of data sources or electronic information such as plan reviews. After final debugging and UAT the team created user guides as the base of a pilot program to guide all participants in the use of the platform. The team

analyzed the results, implemented improvements based on pilot user feedback and launched the final version.

Key stakeholders were engaged throughout the second budget period. Activities focused on education regarding the functionality of the system and the benefits it can bring users as well as demonstration of features other interactions with beta testers and future users. Stakeholder acceptance and support for the project was critical to ensuring long-term goals for adoption, use, and impact were met.

As part of the milestones for the project, the team had to demonstrate the final software and capabilities to representatives from municipalities using technology such as webinars in addition to in person demonstrations. Due to the COVID-19 pandemic shutting down much of the in-person coordination during the development phase, much of this effort was done remotely. Two results came of this that somewhat offset each other in that, the pandemic lessened the opportunity to coordinate face-to-face but in turn created a need for a remote software that could increase efficiency and accountability. The additional benefit of data analysis will further help promote individual and industry growth and education.

After user stories, mockups were constructed with the assistance of the UX/UI team. Mockups took place in two stages - a wireframe diagram that showed user flow, followed by a more detailed mockup after discussion and user feedback.
As the mockups were constructed, they were presented stakeholders and target end users who provided feedback on them in order to steer the next stage of mockup development. The final pre-development mockups and user stories were presented to the working group and pilot group and they were allowed to provide feedback on the designs one last time. *See appendix C for more mockups and screenshots.*

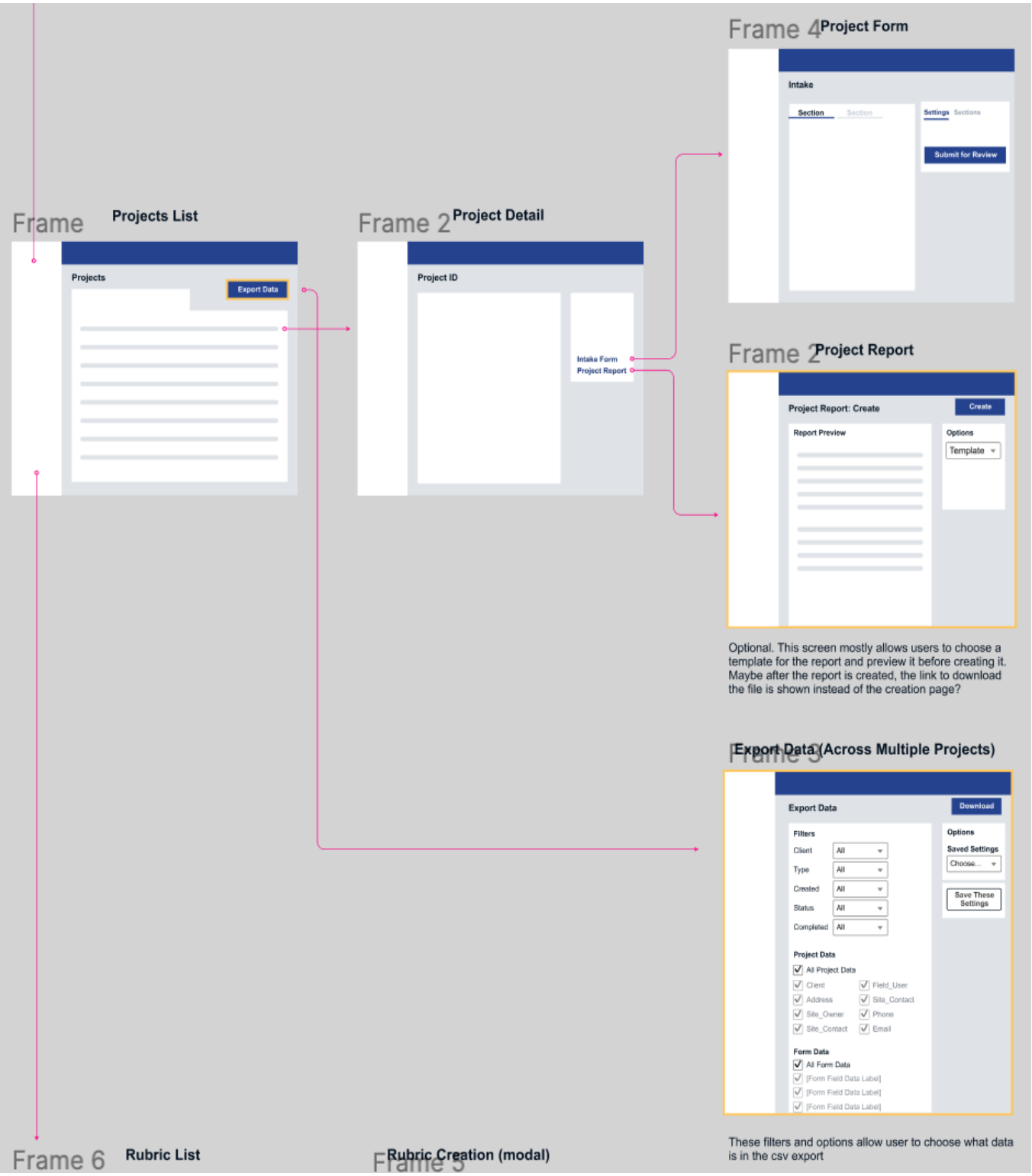


Figure 1 *After user stories, mockups were constructed with the assistance of the UX/UI team. Mockups took place in two stages – this figure demonstrates the first, a wireframe diagram that shows user flow.*

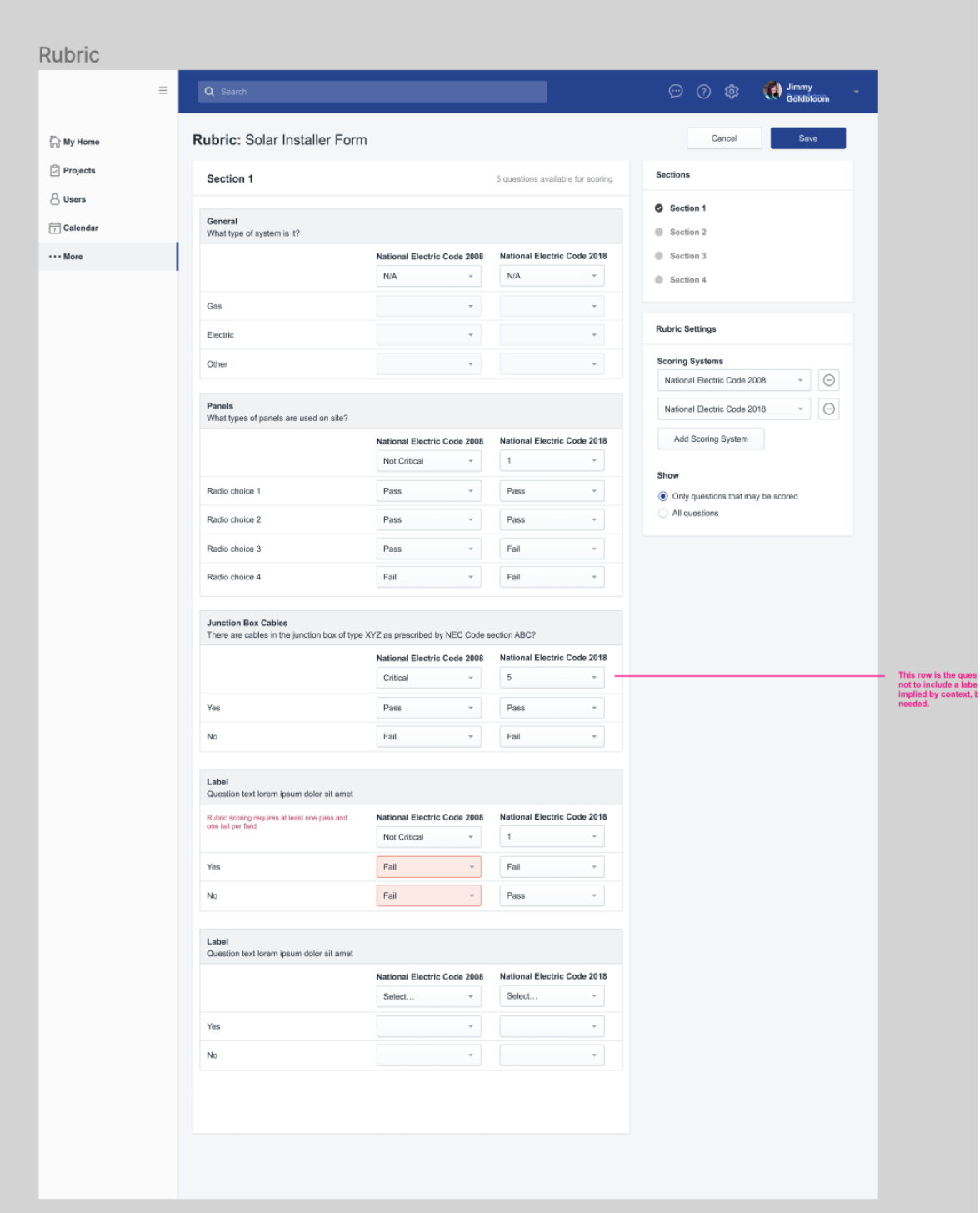


Figure 2 *After user stories, mockups were created with the assistance of the UX/UI team. Mockups took place in two stages – this figure demonstrates the second, a more detailed mockup after discussion.*

Web App Overview

Functional Architecture - The following illustration outlines the functional architecture of the FIT^{QM} application.

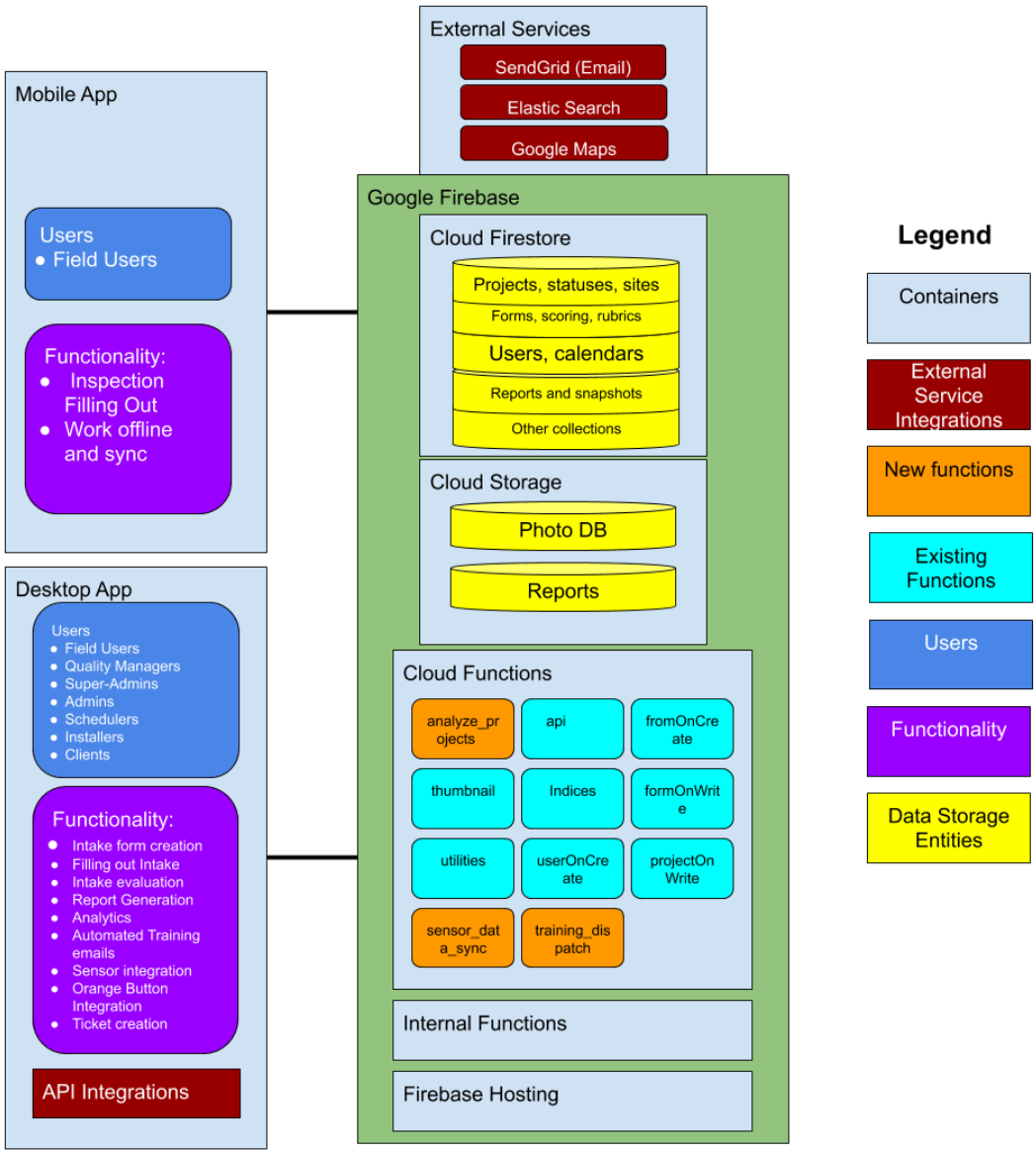


Figure 3: *Functional architecture diagram*

Top Level Flow Chart

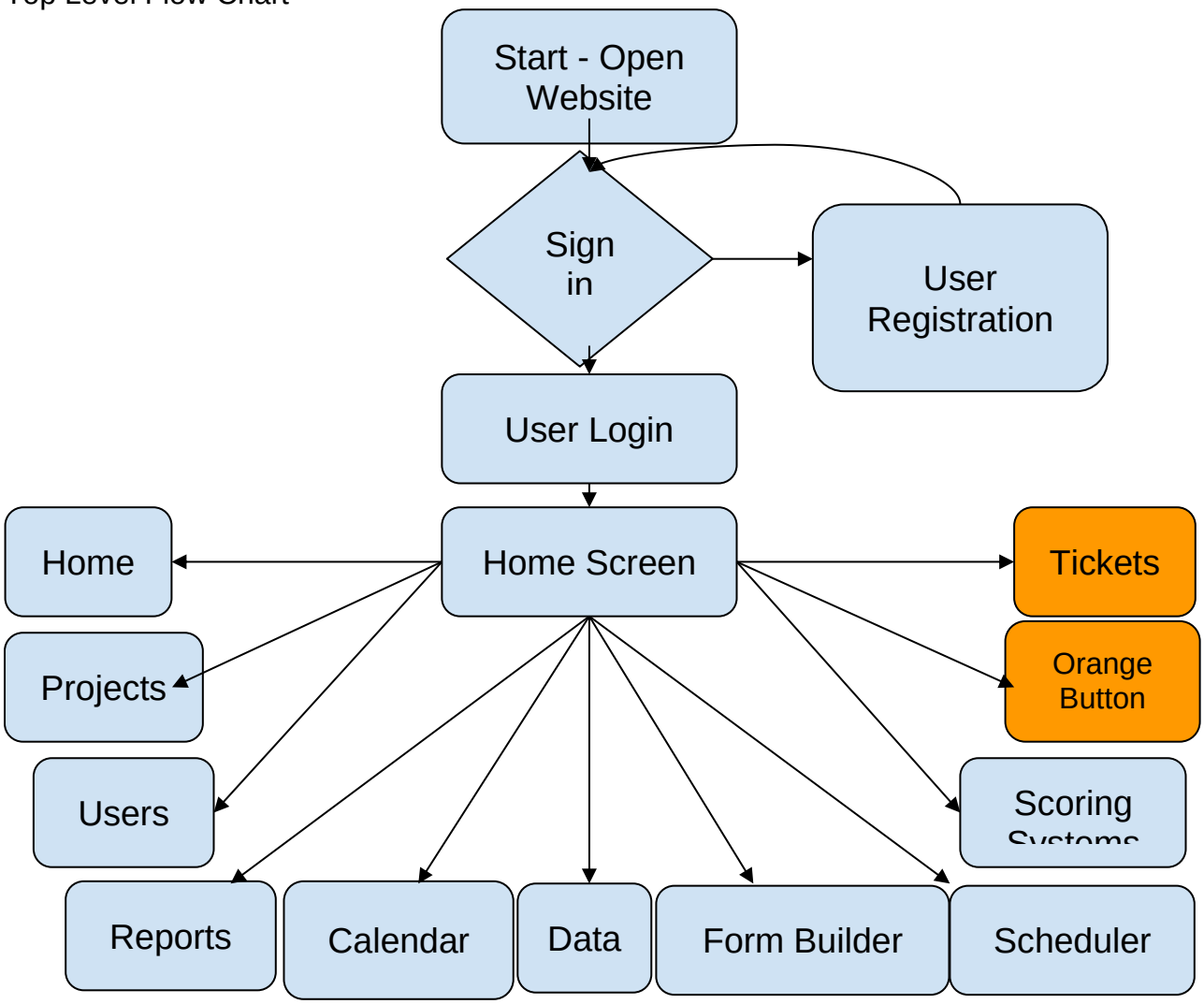


Figure 4: *Business architecture starting at / path*

Mobile App Overview

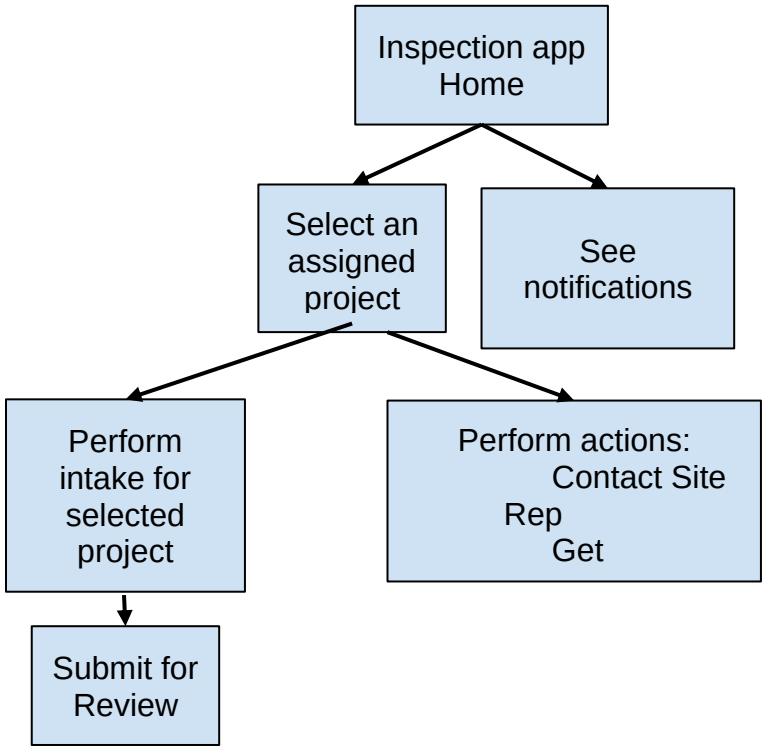


Figure 5: *Business architecture of mobile application*

The FIT^{QM} mobile app contains a subset of the full web application's functionality, and is designed for field users to be able to fill out intake forms while on the inspection site. It therefore has limited functionality in comparison to the desktop application. The functions available in each platform are shown in the following table.

NOTE: all functions that are noted as available in mobile are for **field users only**, regardless of the users that have permission in the desktop application.

Advanced features of the software tool include:

- Pareto charts – Visual representation of data to quickly and efficiently identify recurring measurements and target those with most significant outcomes.
- Bias detection among reviewers – Helps to ensure the measurement process is controlled and ensure uniformity among various users completing a similar task.
- Automated trend detection for installers – Identifies points of measurement that are statistically better or worse than the sample set, allowing identification of needs for process improvement or validation.

- Automated educational material targeting based on the former three points – With the ability to view relevant data, installers and local program leaders are able to identify training needs that will most efficiently reduce failures and prioritize learning topics for the individual groups.
- PDF reports for inspectors, site owners, and reporting agencies – This report provides written and visual record of the individual intake. This can be used to show code compliance or lack thereof and serve as a tool to manage quality between parties/stakeholders.
- Deficiency summaries – Provides explanation of deficiency promoting quick mitigation and code compliance as well as learning.
- Robust issue reporting, ticketing and support – Additional software tool that allows for issuance of a report with repair or deficiency “tickets” that can be assigned to the responsible party and tracked within the system to ensure full compliance and project flow.

During calendar year 2021 the project team provided demonstrations during the NABCEP Continuing Education conference and was scheduled to demonstrate at Solar Power International conference as well, although that was ultimately cancelled due to the COVID-19 pandemic. The team also coordinated with other organizations like NREL to promote along with SolarAPP, providing the necessary inspection follow-up for the automated plan review software. Together they offer an entirely remote and partially automated process for ensuring compliance. This coordination drove the budget period two discussion on added value for API functionality increases to promote communication and automation between the inspection software and other widely used software currently in use.

The resulting outcome is reduced costs through more efficient staff utilization, increased quality through uniformity and the data feedback loop, and increased accountability through data retention.

Significant Accomplishments and Conclusions

IBTS and NABCEP engaged the stakeholder working group and the industry at large to complete a product alignment study. The objectives of the product alignment study were as follows:

a. Ensure the product or tool’s functions and proper use of the product build comprehension and ability related to the performance domains, tasks, and knowledge statements outlined in the JTA(s)
b. Prevent information overload and extraneous time spent on activities that do not contribute to the knowledge, skills, and abilities related to uniform standards of practice in the JTA(s)
c. Confirm that each of the product or tool’s functions align with at least one task or knowledge statement within the JTA(s)

The outcome of the alignment study illustrated the thoroughness of the uniform, inspection checklist, and ensures that it is relevant to the topic being assessed. This ensures efficient and accurate intake data sets are created, and promotes increased certification levels by those individuals completing the tasks.

Overall, the team achieved all of the goals requested in the SETO award by providing at minimum at tool for efficiently measuring a product to a standard, and compiling those results for analysis. The software has already benefited the Department of Defense in providing remote and live inspection and analysis of systems installed on five military bases in the southeast region of the U.S., as well as providing data and training content to Solar Energy International (SEI), NYSERDA, and on island in Puerto Rico in both English and Spanish translated versions of the inspection and assessment forms.

Path Forward

IBTS has an in-house technology and development team that will continue to support and maintain the software to ensure long term operation is achieved. A regular process for collecting user feedback and considering for future updates is part of the overall software management scope of work helping to ensure that industry advancements are accommodated. The mobile application will continue to be supported with updates occurring as needed.

Stakeholder members periodically reviewed inspection form content and will remain engaged during the system operation phase, further promoting adoption and relevant feedback.

A public facing web page at Solarquality.org will be regularly updated with national data aggregation and additional links to trainings, forum discussions, links to webinars and other software or content that is intended at supporting higher quality and reduction of soft costs. Ongoing coordination with NABCEP and SEI will ensure that training and certifications are aligned with the onsite data collection and confirming the topics covered are measuring key performance indicators.

Inventions, Patents, Publications, and Other Results

This project did not produce any inventions or patents. No articles included in publications or otherwise created or developed during the funding period.

Appendix A: Stakeholder Engagement Survey Demographics and Comments

This section summarizes findings from in-depth interviews (IDIs) conducted with solar PV industry stakeholders throughout the first 4 months of budget period 1. IDIs were conducted in-person and via phone with industry stakeholders, including building code officials and inspectors, engineers, installers, manufacturers, and financiers, first responders, and representatives of certification organizations.

The purpose of the IDIs was to determine current challenges and gaps in the solar PV installation and quality management processes, and reactions to the concept of the Quality Management Field Inspection (FIT^{QM}) platform IBTS is currently developing through this award. Results from this effort were combined with results from the online survey and intercept surveys previously conducted for the effort in December 2019 and January 2020.

- **The installers we spoke with were very engaged with quality control processes on their installations but perceived themselves as different in this regard from many in the industry.** Specifically, they noted that many installers do not perform sufficient quality control, due to lack of sufficient training, experience, and oversight, combined with a desire to cut costs and pressure to expedite the schedule.
    - An O&M stakeholder reiterated this sentiment, noting that installers are "a weak link" in the industry. "If the installer is separate from the designer, they're interpreting [the design] in the field, they're not specific. Cutting corners, cheaper materials, not understanding code requirements."
    - However, installer training varied somewhat by region. An O&M provider in Minnesota noted that installers have few quality processes in place, but the workforce is well trained enough that it does not create problems.

  "I don't think installers are doing quality management very well. But from my perspective it's all about functionality. In Minnesota, you need to be a licensed electrical contractor. The journeymen are pretty well trained. The installers are pretty well trained. There is not a lot of shoddy work out there." - *O&M provider; MN*

- **Installers interviewed expressed high levels of confidence in their own quality control processes. However, they agreed that there is a lack of standardization in quality control processes.** Most noted that they use manual processes and spreadsheets.

  "We have this process of paper and MS Excel tracking our projects for utility connections and rebates…[and] Accela tracking services for permit work." - *AHJ inspector, CO*
  "We are interested in quality management tools. We go in the field, capture a ton of pictures, we write up stuff, we write up a report that is sent to installers. It's all manual at this point." - *Engineer, CT*

- **Interviewees agreed that solar PV inspections conducted by the AHJ (authority having jurisdiction) are insufficient in determining installation quality.** Several noted that the AHJ inspector lacks understanding and knowledge of solar PV installations; the installer may feel that they are in the position of having the educate the AHJ about the installation. Interviewees noted that AHJ inspectors do not go on the roof to inspect systems, but they also do not require documentation that may assist with quality assurance, such as photographs or proper documentation.

  > "We don't go on the roof, so I have concerns about what we don't see. Contractors will put in a production meter when we told them not to, leave connections exposed. Battery installations in some cases with multiple battery inverters not communicating." - *AHJ inspector; CO*

- **Interviewees saw potential for the FIT^{QM} software for both AHJ inspectors and installers.** Interviewees viewed installers and AHJ inspectors as creating the largest gaps in quality control in the industry and, accordingly, saw significant potential for the **FIT^{QM}** platform to help these stakeholders improve how they contribute to solar PV installation quality.

  > "The AHJ is the biggest knowledge gap. A checklist would allow them to have some smarts behind it. It's easy for them to say, 'ok do I see cracks on the modules?' for example." - *O&M provider; Tucson, AZ*

  > "Our inspectors find a lot more than inspectors at the municipal level. In some cases, [the AHJ inspectors] almost just drive by. It would be really handy if the app had a checklist with photos, this is what it should look like. [The AHJ inspectors] could really use something like that. Installers would absolutely have a need for this too. We have manual checklists for installers now. They're supposed to have photographs." - *Engineer, CT*

- **However, some interviewees struggled to see the value in the FIT^{QM} platform for themselves.** For these stakeholders, confidence in their existing processes may limit interest in adopting the **FIT^{QM}**, even if their existing processes are mostly manual, spreadsheet-based, etc. These interviewees asked questions about how easy the system would be to implement and use, the level of customization it can accommodate, and what the associated costs might be.

  > "There's not really much value for me. First off, there would have to be enough demand for it [from our customers]. If it's free sure but if you're charging for it, I don't think there's much value." - *O&M provider; MN*

  > "A platform for improving installer QC [is something] we've thought about a lot. We've implemented some of this on our own. In theory, there are a are

a lot of things you can do, but then if its cumbersome, people stop using it." - *O&M provider; Tucson, AZ*

- **The features interviewees were most interested in including checklists, photos, remote inspection services, and note-taking.** The AHJ inspector had the most detailed vision of how his jurisdiction could use the platform to improve their processes and the overall quality of solar installations. According to this inspector, whose jurisdiction uses Accela and Excel for installation tracking, there is a significant opportunity for streamlining their tracking processes and improving the information they are able to collect.

  "I'd like to be able to have our technicians complete their test form on an iPad on site, all that documentation to be able to be filed together with the application materials, for us to have that photographic information of install numbers, the configuration of the electrical equipment on the customer's house, documenting differences between plans and the install. If we ever have to go back out for a reinspection (e.g., when an inverter is installed) - we could track that data relative to the premises – it would be nice to track all that." - *AHJ Inspector; CO*

  "The [best] format we've seen is really a simple checklist. Here are the tasks, subtasks, take a photo, make notes." - *O&M provider; Tucson, AZ*
  "If there could be some national standardization, a baseline of what every system should have verified, that would be [useful]. Some uniform requirements. If the software suite were customizable enough to have a, b, c, or d criteria, if section A doesn't apply to your AHJ, you can skip it. It would be nice to see unified expectations nationwide. So, if seismic applies, then ok you do it or if not, you skip it." - *O&M provider; MN*

  "DOE has created a free tool for residential and mf energy audits. We capture hundreds of photos. But it's cumbersome. They don't allow you to take photos on your phone and attach. Photos are really important for our customer service people, so it needs to have that." - *Engineer, CT*

  "One of the biggest challenges is that [installers] don't use the tools that are available to them…but this could be useful. If there was some kind of software platform [where the installer] finishes a job and the workers are supposed to document with photos – the AHJ could offer this software to make that easy." - *Manufacturer's quality specialist; NJ*
  "How well does it interface with what the AHJ is using? A lot of the AHJs may not redline the plans like they used to – a lot of individuals are looking for a solution." - *Installer, UT*

An engineer who performs solar PV inspections also noted that inspectors would find a great deal of value in being able to align findings with specific codes. By being able to

point out the regulation that mandates the finding, inspectors would have an easier time-sharing information with installers.

> "Also, when you're doing an inspection, items should be aligned with a code. If the app referenced sections of the code – and reference sections of the code, that would be useful. If we send an electrician, we send them a list of things that need to be fixed, and they're like 'we think it's fine.' We want to be able to reference the things they are looking at." - *Engineer, CT*

- **Interviewees were interested in the platform's data collection capabilities, but in some cases did not immediately recognize how they would apply it to their own benefit.**

> "I'm interested in data that shows installers, yes they need a calibrated tool and need to go through every installation, showing by region, by weather, that impacts torque. If there is information about the failure rate, for example, for optimizers, that is useful – currently, we tell people to plan for 2-3% failure, just out of the box. Another deficiency we see a lot is weather stations for systems, for a small system or residential, no one is going to have these, but then when it comes time to figure out why their system is underperforming, we don't have the right information." - *O&M provider; Tucson, AZ*

> "Back-end data would be useful, if a little outside our responsibility. I don't think we're interested in being a watch dog for customers. It would be useful to see if there are problems with certain modules, inverter module numbers, etc. We want to know about recalls. We do use the California equipment approval database, if it's approved there, we green light it here. So additional data is useful, but not something we need to know." - *AHJ inspector; CO*

> "I'd sure like to see trends, best practices, absolutely. I'd love to see what other people are doing, especially ways that are clever and innovative. What is failing either as expected or not expected." - *O&M Provider, MN*

> "If you're not tracking quality scores by individuals or crews, then you're not progressing. But then it must be fluid enough to adjust as the market has turnover… A lot of times, the turnover ratio, crew size, job size – those are the challenges. When you're trying to do an OSHA field report, location roof type steepness of the pitch, you want to be able to say that was a determining factor. We had snow, we had four ppl instead of five. If you're tracking, you should be able to track how that crew is doing." - *Installer, UT*

All interviewees were interested in learning more about the FIT^{QM} platform and providing additional reactions and feedback to the initial design concepts and interface.

Stakeholder Survey, Interview, and Intercept Demographics - Stakeholder feedback from the industry survey is summarized in this report within the Appendix A. The following tables highlight the number of respondents, their identified stakeholder type, as well as their physical location if the information was provided while filling out the survey. Appendix A summarizes individual responses to the survey questions and highlights the general thought process of those who completed the survey.

Most respondents of the initial survey indicated that they do not have a formal training plan for inspections. For those that indicated they do have a more formalized training approach, the results indicate that it is an internal team training program rather than the use of an external 3rd party training provider. Across all the organizations, inspections are utilized for code compliance as well as internal process improvements. Of the respondents who organize and manage inspections, including reviews of completed projects, most respondents have their staff review the information. This highlights the need for a more standardized inspection protocol and cements the need for a standardized training plan, preferably developed by a third party to ensure consistency and industry relevance.

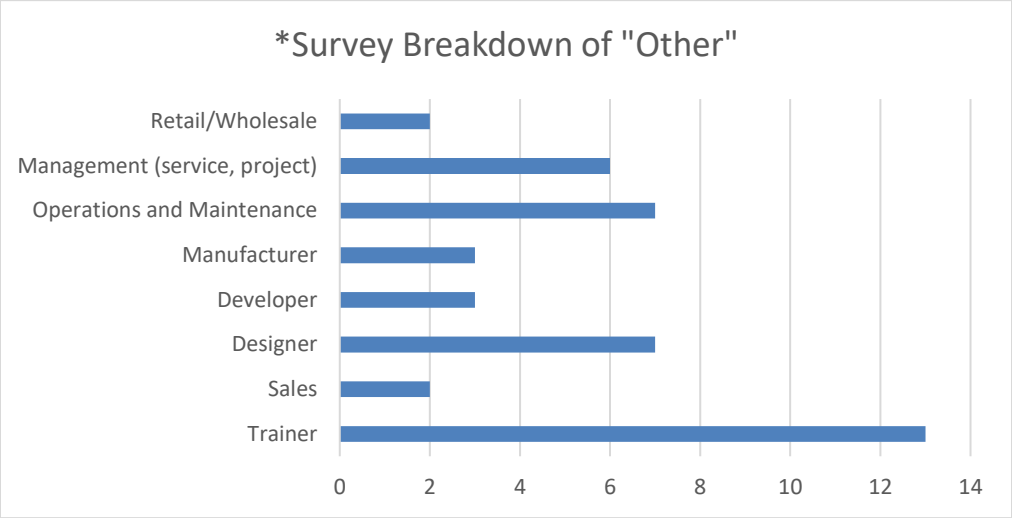
It is indicated in the survey results that most respondents, from each category, don't have a municipality that uses software to conduct inspections. The data from the survey indicates that, while a small percentage of organizations have reported using software for quality management, those that use software indicate significant gains across all categories covered in the survey.
Equally as important, an even larger number of respondents *believe* that there are positive gains to be achieved with the use of a software system.

Demographic Overview – Total Participants

Research Effort	Survey	Interviews	Intercepts	TOTAL
TOTAL	99	7	14	120

Stakeholder Participation

Stakeholder Type	Survey	Interviews	Intercepts	TOTAL
Building/Code official or inspector	7	2	0	9
Engineer	20	0	2	22
Financier	1	0	1	2
Installer	37	1	1	39
Other*	30	4	10	44
TOTAL	95	7	14	116



Regional Representation of Participants

Region	Survey	Interviews	Intercepts	TOTAL
Midwest	15	1	1	17
Northeast	19	3	2	24
South	16	0	0	16
West	45	3	7	55
Unknown	0	0	4	4
TOTAL	95	7	14	116

State Representation of Participants

Region	Survey	Interviews	Intercepts	TOTAL
AK				0
AL				0
AR	1			1
AZ	5		1	6
CA	17	1	8	26
CO	9	1		10
CT	6	1		7
DE				0
FL	1			1
GA				0
HI	1			1
IA	1		1	2
ID		1		1
IL	4			4
IN	2			2
KS	1			1
KY				0
LA				0
MA	2			2
MD	1			1
ME				0
MI				0
MN				0
MO	1			1
MS				0
MT	2			2
NC	1			1
ND				0
NE				0
NH		1		1
NJ	2		1	3
NM	1			1
NV	2	1		3

Region	Survey	Interviews	Intercepts	TOTAL
NY	5		1	6
OH	1			1
OK	1			1
OR	1			1
PA	3			3
RI				0
SC	1			1
SD				0
TN	3			3
TX	4			4
UT	6	1		7
VA				0
VT	1			1
WA				0
WI	2		1	3
WV				0
WY				0
TOTAL	88	7	13	108

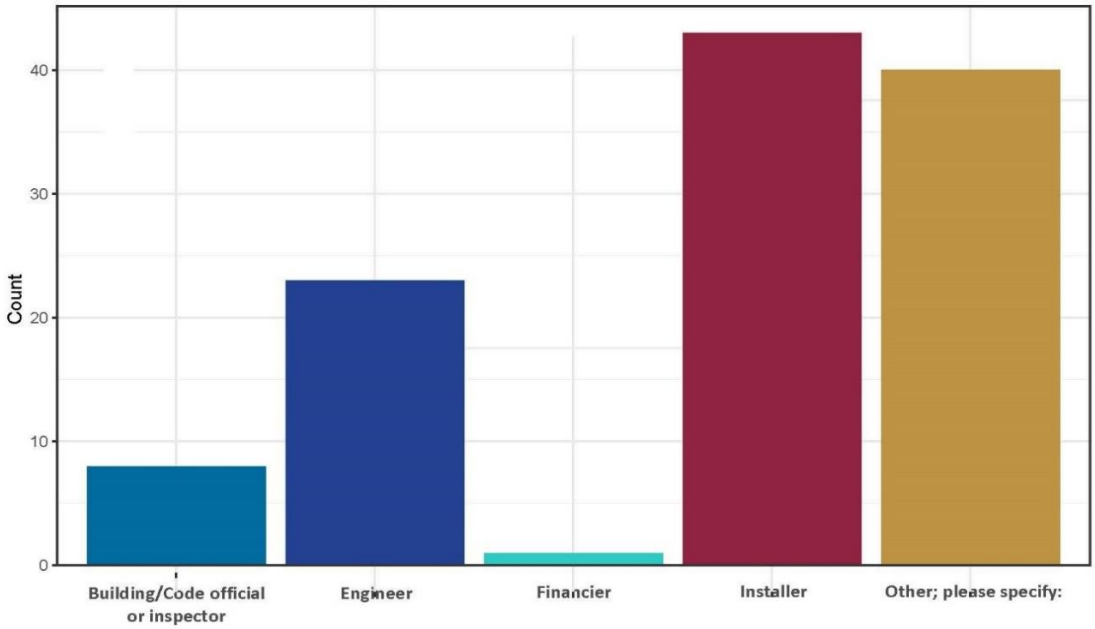
Stakeholder Working Group Demographics - The Stakeholder working group consists of individuals from a variety of stakeholder positions. This group was active in the development of the initial software design and provided feedback based on their respective industry roles.

Stakeholder Working Group Type	
Installation	34
Engineering	14
Installation / O&M	9
Data Source	8
Finance	8
Components/Manufacturers	5
Inspection	5
Building Code Officials	2
Asset Management	1
College, University	1
First Responders, Certifications	1
Manufacturer	1
Nonprofit trade group	1
Outreach	1
State Program Admin	1

Appendix B Stakeholder Survey Data Results

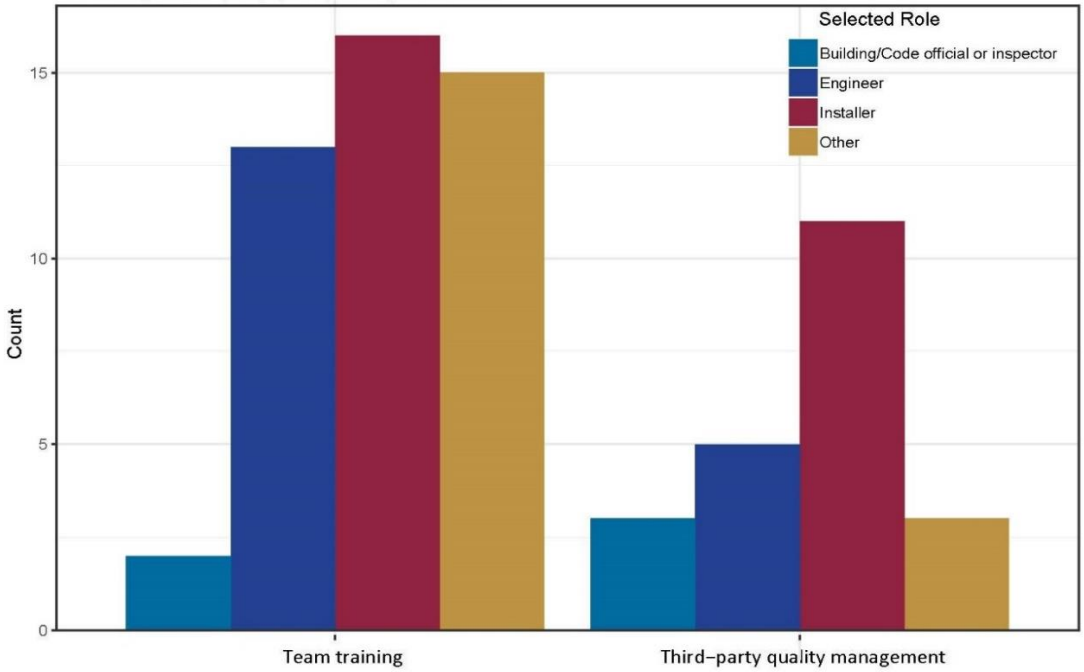
Q2 Which of the following best describes your role as it relates to the solar PV industry?

Number of Respondents: 115
Percentage Other; please specify: 35%
Percentage Installer: 37%
Percentage Engineer: 20%
Percentage Building/Code official or inspector: 7%
Percentage Financier: 0.87%



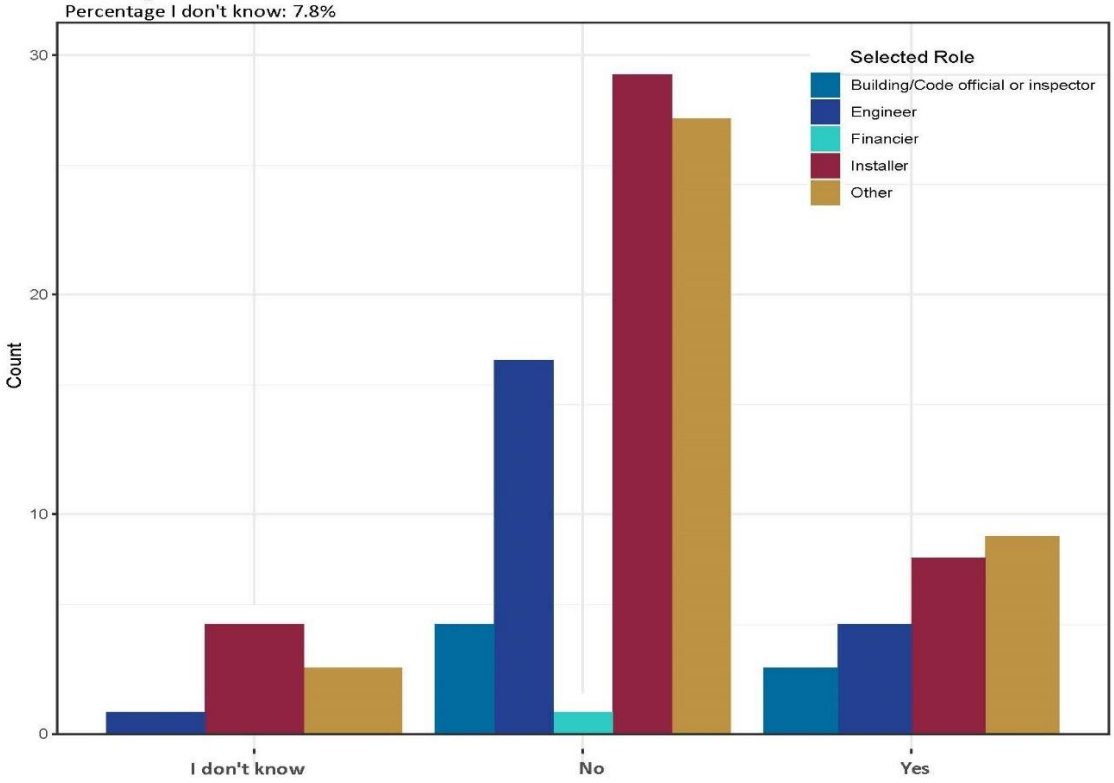
Q3 Which of the following best describes how you train your team members to conduct inspections? Select all that apply.

Number of Respondents: 59
Percentage Team training: 78%
Percentage Third-party quality management: 37%



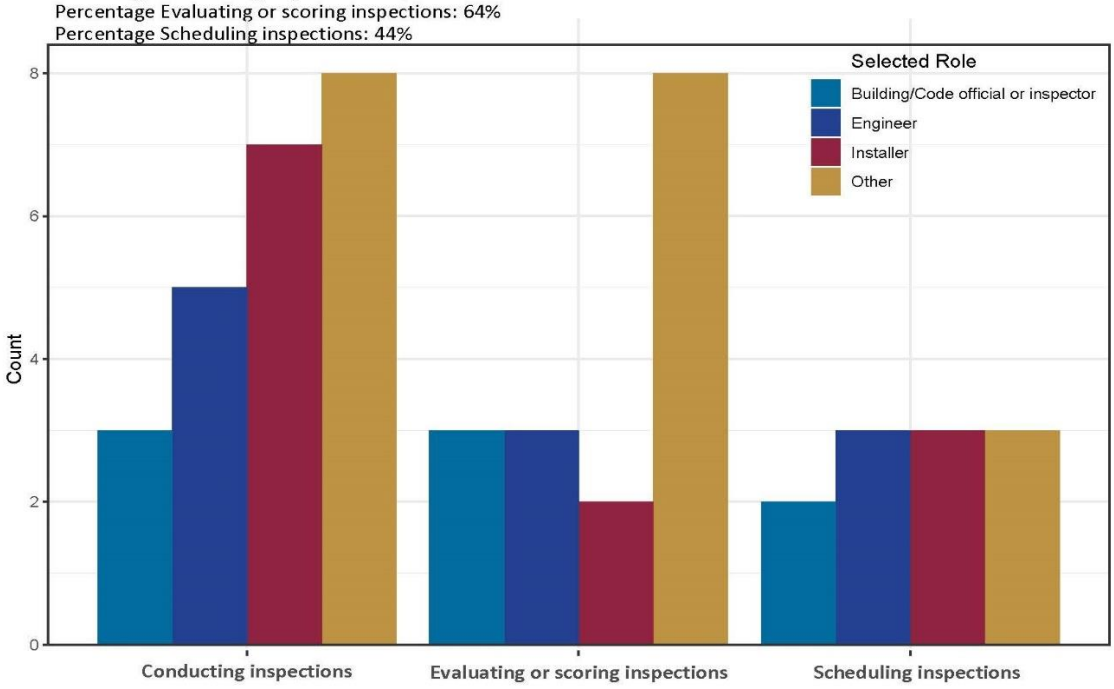
Q4 **Does your municipality/organization currently use software for solar PV inspections?**

Number of Respondents: 115
Percentage Yes: 22%
Percentage No: 70%
Percentage I don't know: 7.8%



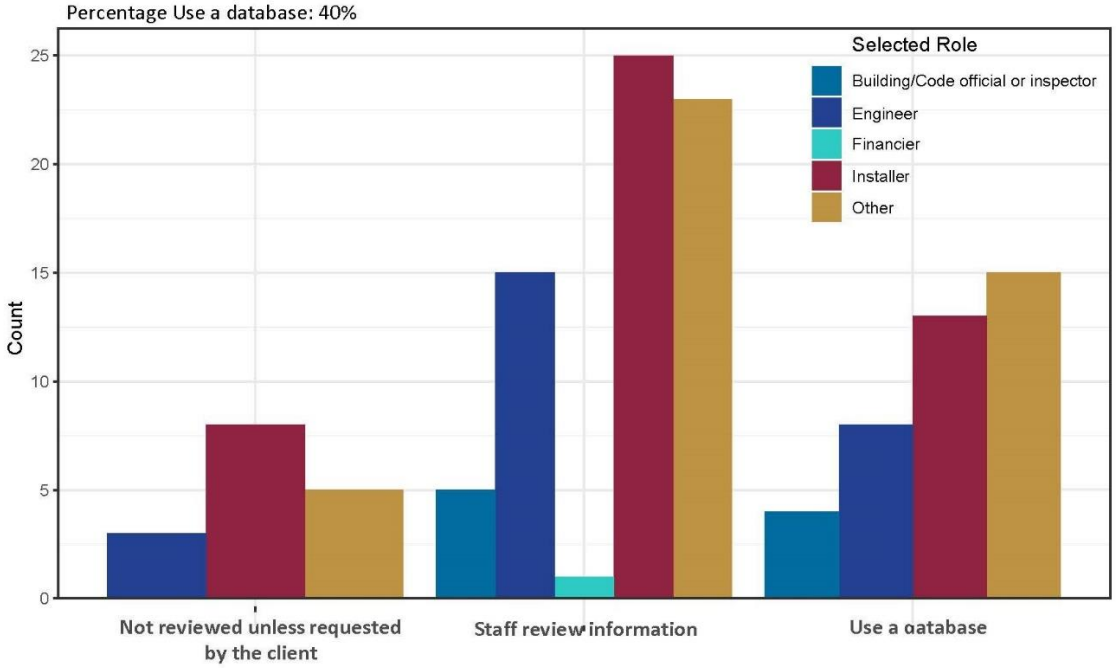
Q6 **You selected that your municipality/organization currently uses software for solar PV inspections. From the list below; please select what tasks you use this software to complete.**

Number of Respondents: 25
Percentage Conducting inspections: 92%
Percentage Evaluating or scoring inspections: 64%
Percentage Scheduling inspections: 44%



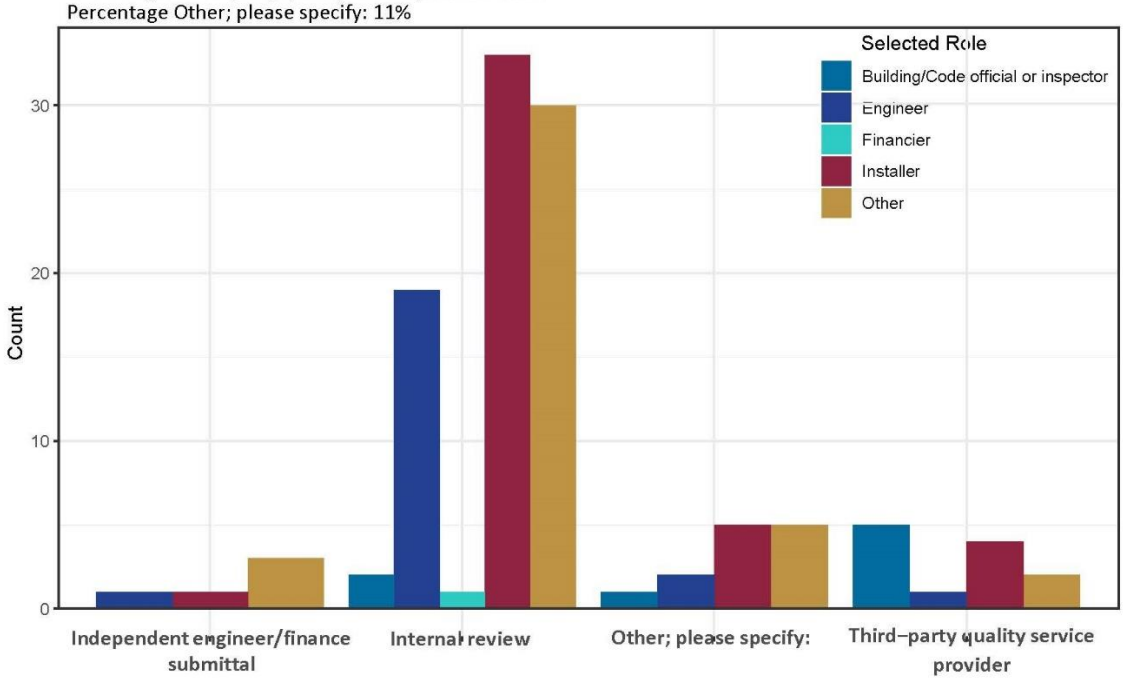
Q9 Which of the following describes how you or your municipality/organization manage information collected during the inspection process?

Number of Respondents: 101
Percentage Not reviewed unless requested by the client: 16%
Percentage Staff review information: 68%
Percentage Use a database: 40%

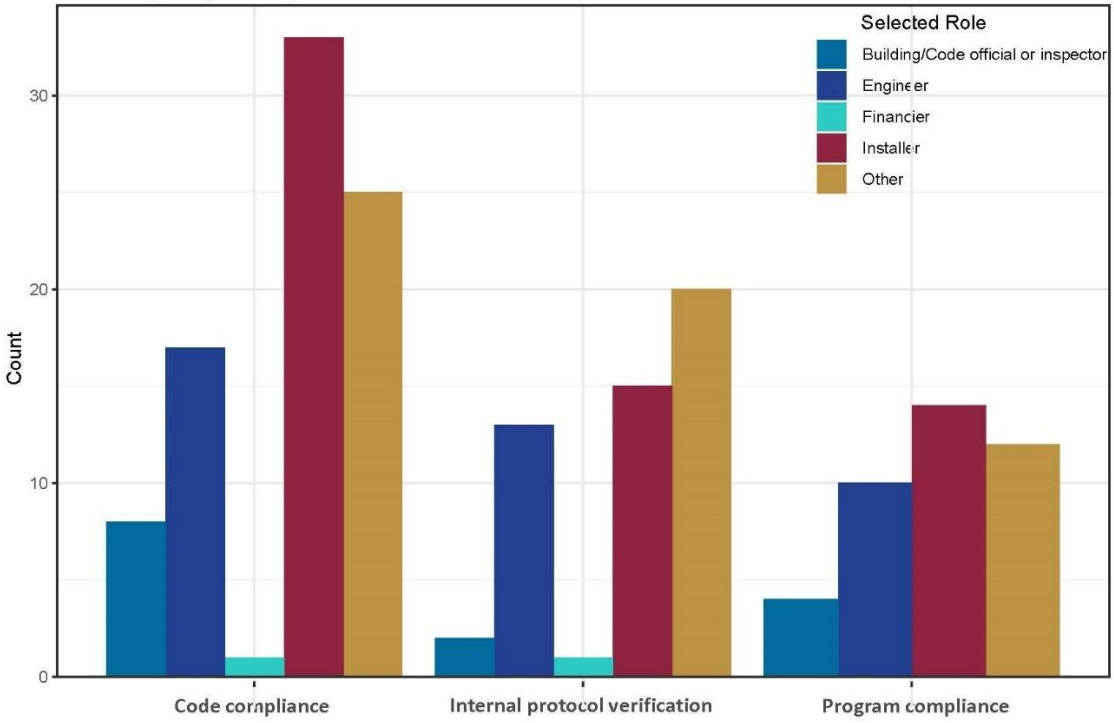


Q10 Which of the following best describes how your municipality/organization reviews inspection methodologies for quality?

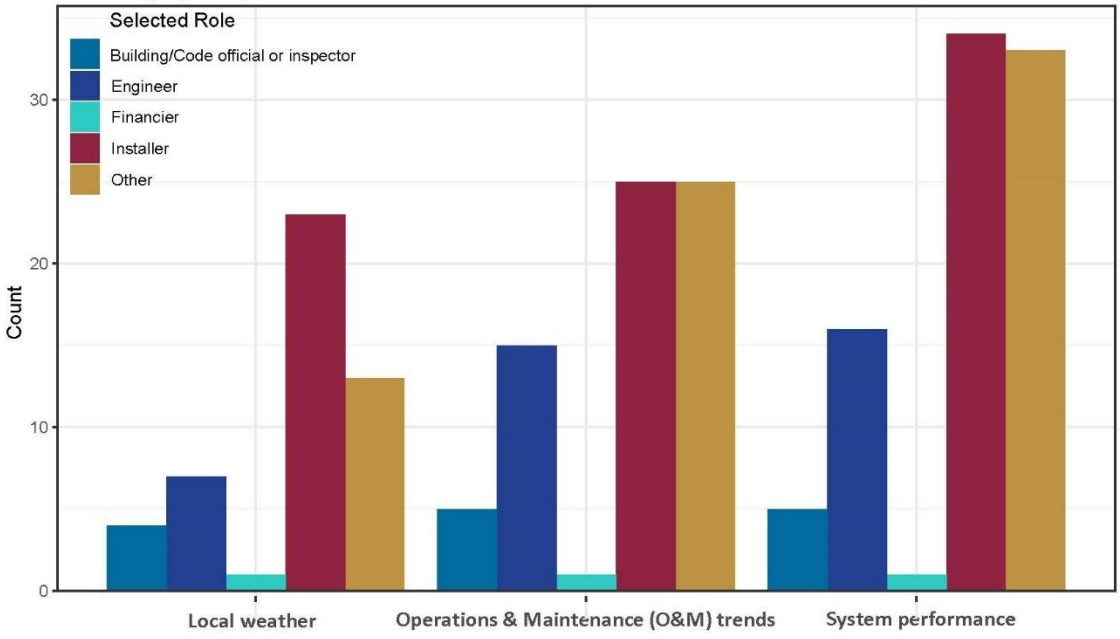
Number of Respondents: 115
Percentage Internal review: 74%
Percentage Independent engineer/finance submittal: 4.3%
Percentage Third–party quality service provider: 10%
Percentage Other; please specify: 11%



Q11 **Which of the following describes how your municipality/organization uses the output of completed inspections?**
Number of Respondents: 107
Percentage Code compliance: 79%
Percentage Internal protocol verification: 48%
Percentage Program compliance: 37%

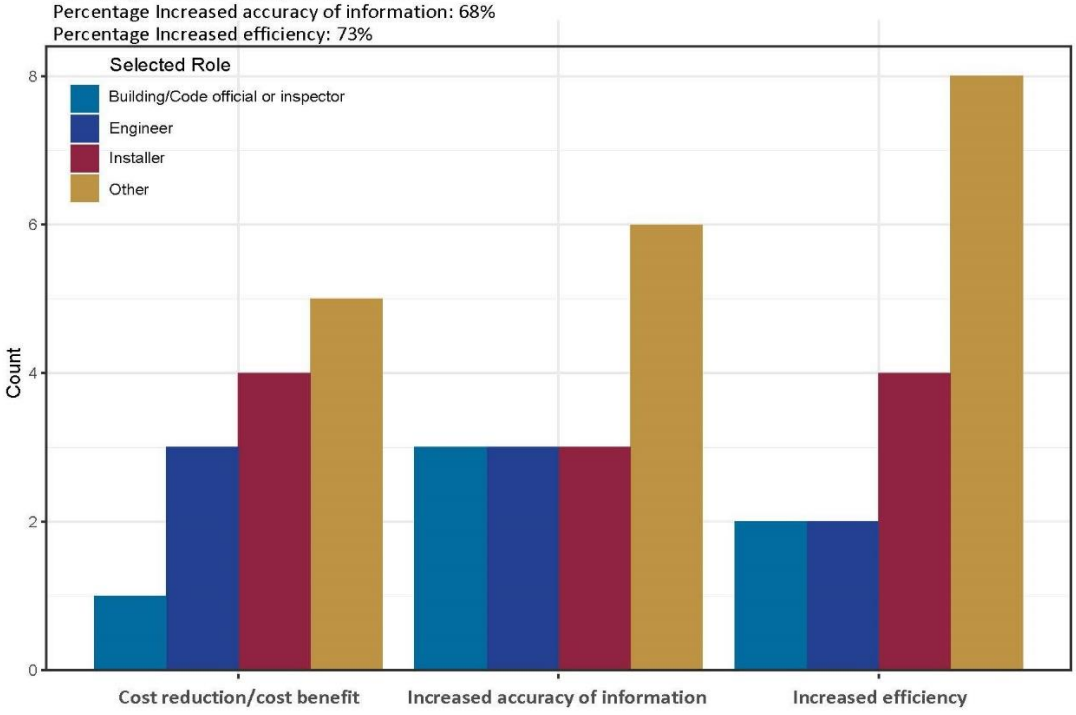


Q16 **In addition to installation quality; which of the following data types would you like to see recorded in solar PV installation software?**
Number of Respondents: 106
Percentage Local weather: 45%
Percentage Operations & Maintenance (O&M) trends: 67%
Percentage System performance: 84%



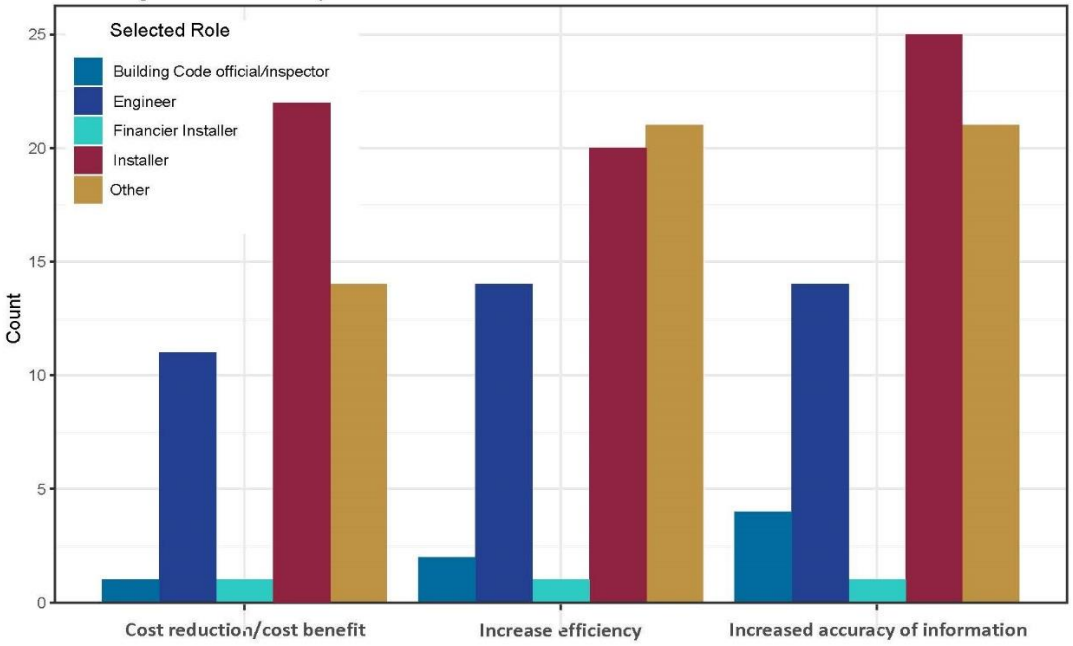
Q18 **How has your municipality/organization benefited from using solar PV inspection software?**

Number of Respondents: 22
Percentage Cost reduction/cost benefit: 59%
Percentage Increased accuracy of information: 68%
Percentage Increased efficiency: 73%



Q19 **If your municipality/organization began using solar PV inspection software; how do you expect that you or your municipality/organization would benefit?**

Number of Respondents: 82
Percentage Cost reduction/cost benefit: 60%
Percentage Increase efficiency: 71%
Percentage Increased accuracy of information: 79%



Appendix C: Web/Mobile Interface, Software Features

Figure 6: *Screenshot of iOS app login*

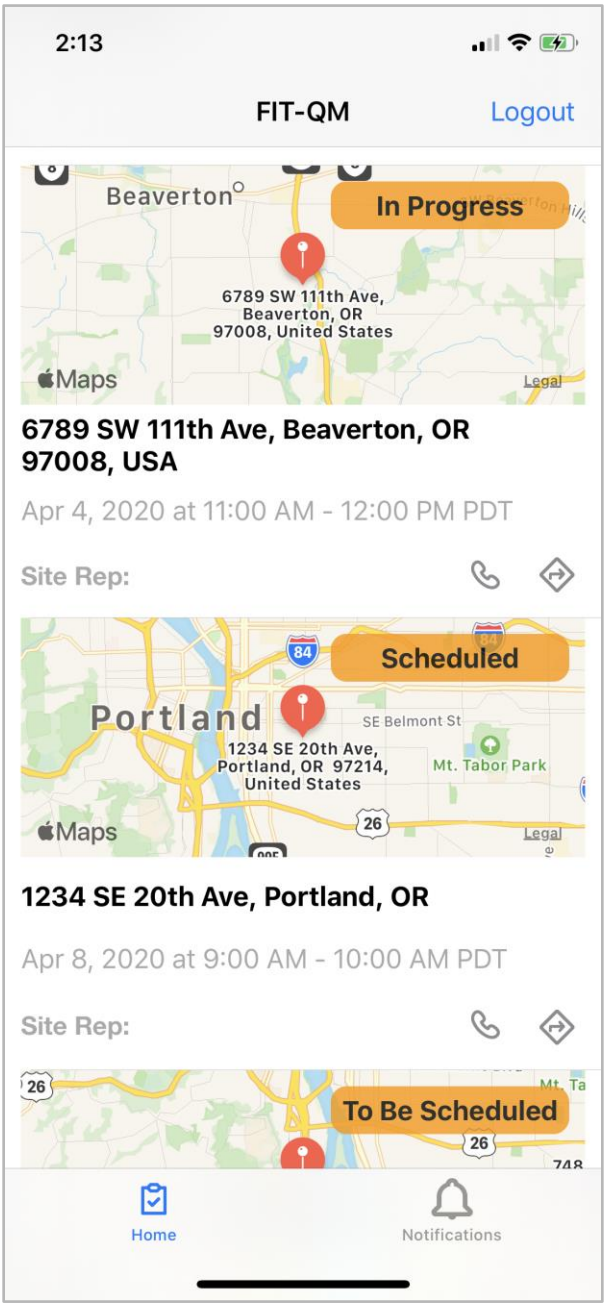


Figure 7: *Screenshot of iOS projects list*

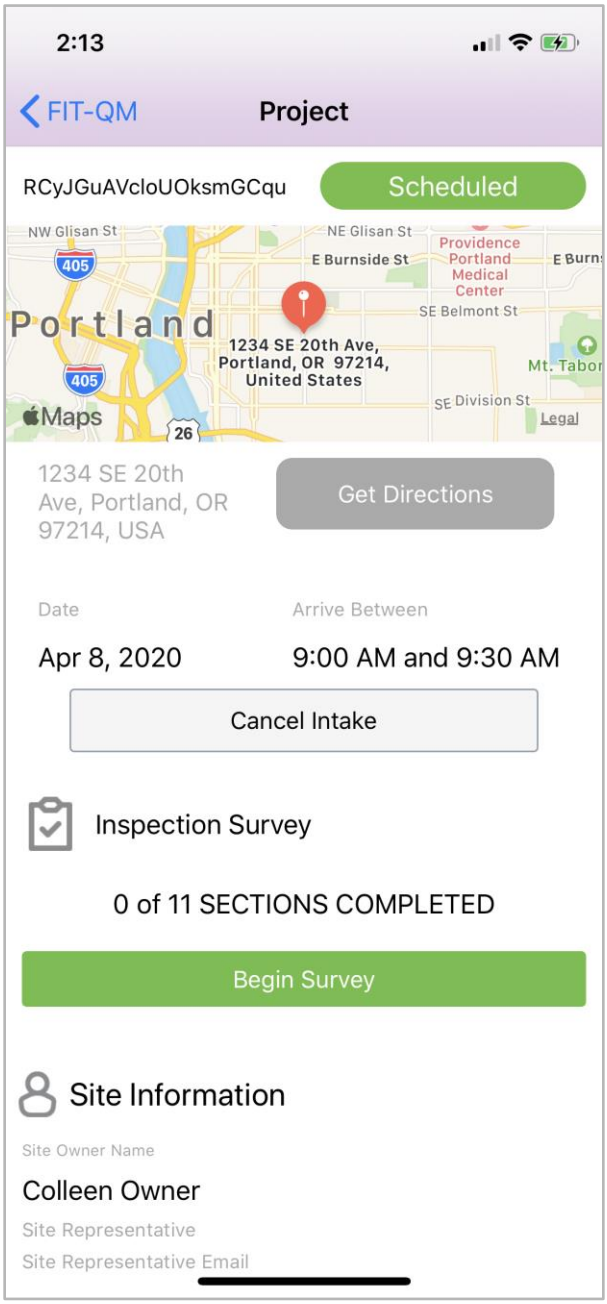


Figure 8: *Screenshot of project detail view on iOS app*

Figure 9: *Screenshot of intake on iOS app*

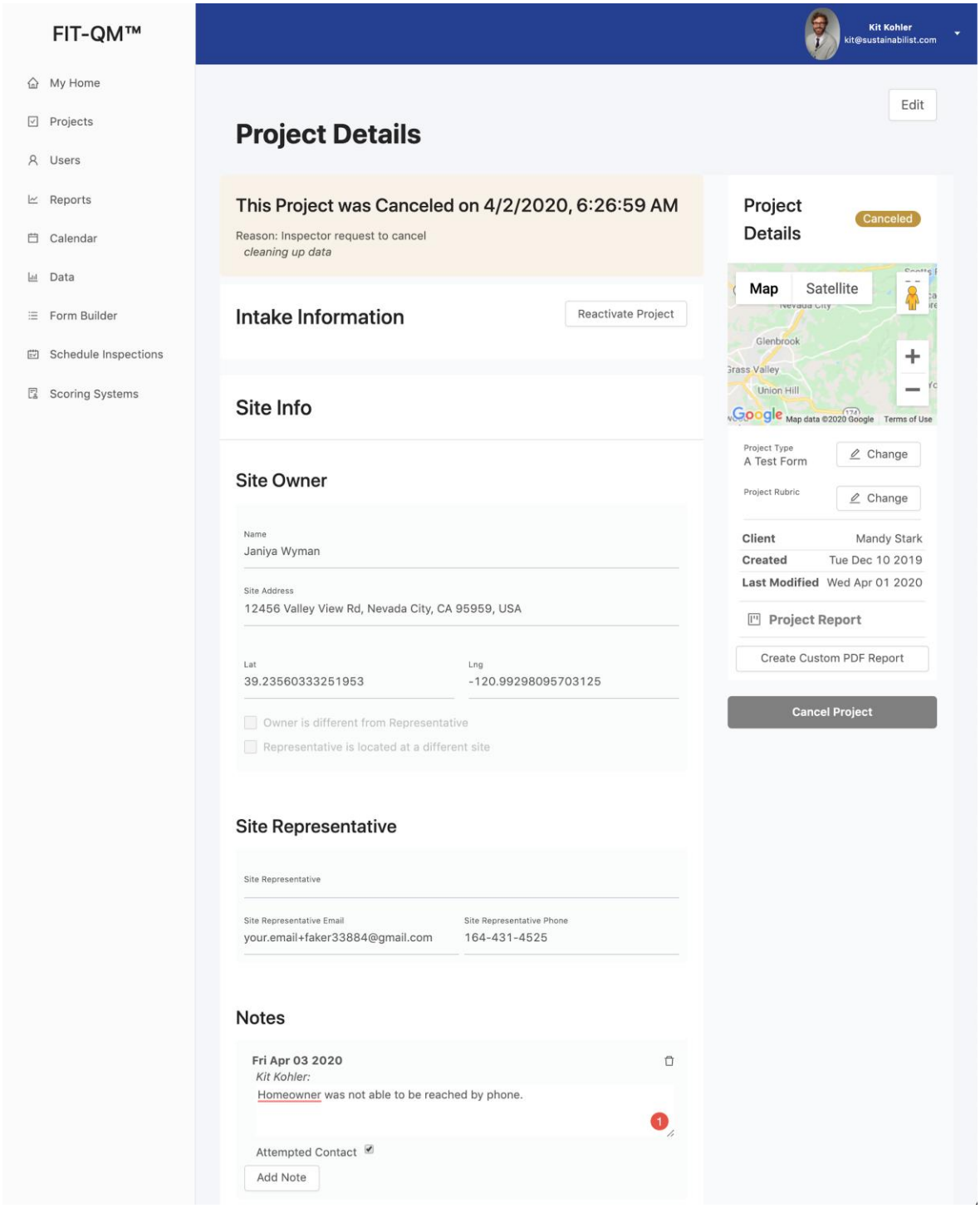


Figure 10: *Screenshot of project detail view*

Function	Web App	Mobile App
User login	✓	✓
Add new users	✓	
View data trends	✓	
Create and edit forms, rubrics, and scoring systems	✓	
View calendar and add availability	✓	
Schedule (or reschedule) intakes	✓	
View all assigned projects	✓	
View assigned projects that are To Be Scheduled, Scheduled, or In Progress	✓	✓
View notifications for assigned projects	✓	✓
Cancel projects	✓	✓
Contact site representatives	✓	✓
Get directions to inspection sites	✓	✓
Cancel intakes	✓	✓
Add site notes	✓	✓
Fill out intake forms	✓	✓
Attach photos to intake questions	✓	✓
Sort and delete photos	✓	
Submit intake forms for review	✓	✓
Review intake forms	✓	
Finalize intake forms or mark them as needing corrections	✓	
View and download reports	✓	
Create, submit, and verify tickets	✓	

Figure 11: *Feature comparison between desktop and mobile apps*

When the quality manager or admin reviewing the ticket is satisfied with it, they verify it. The ticket then has status “Complete.”

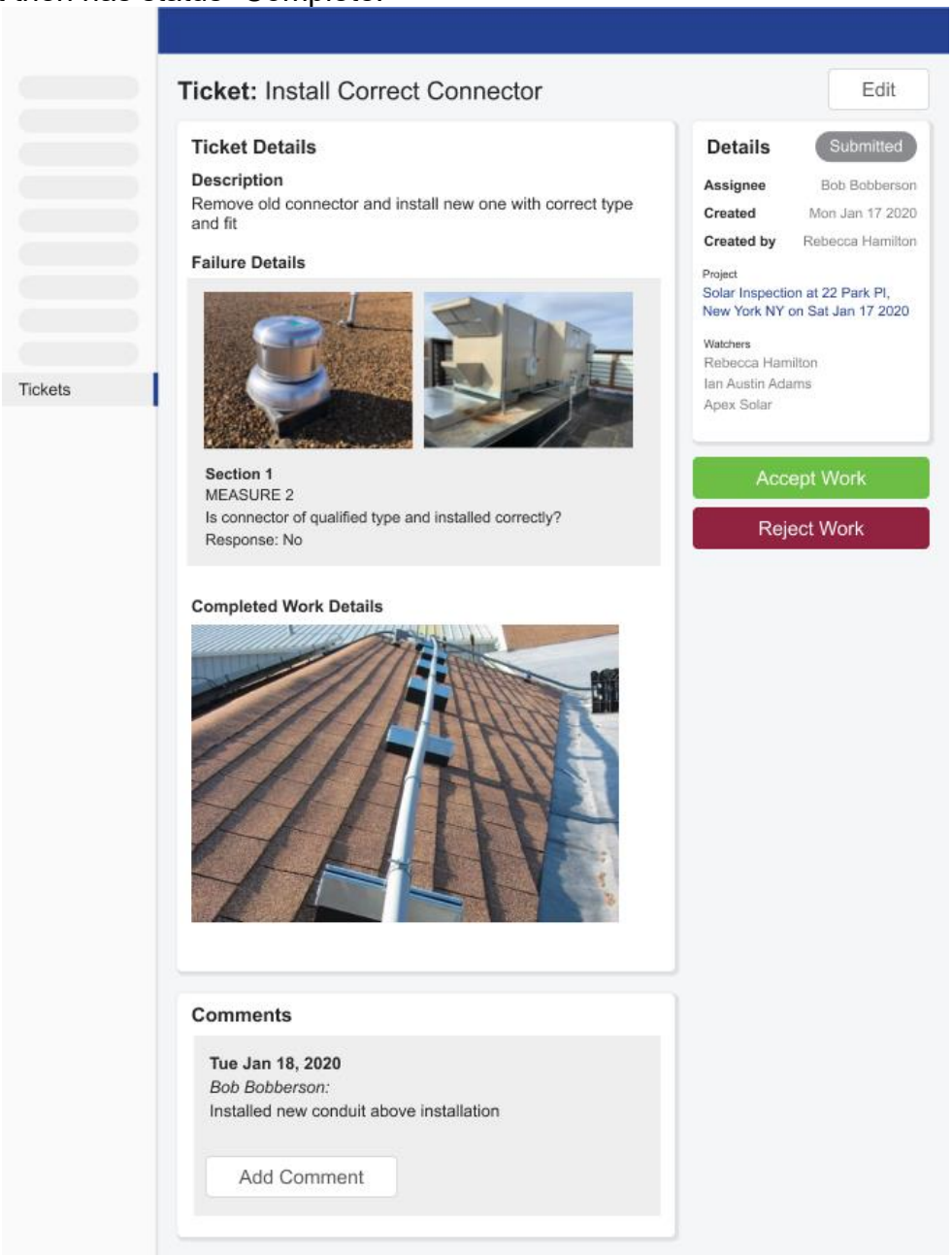


Figure 12: *Mockup of view of ticket review and verification*.

The standard ticket flow is illustrated below.

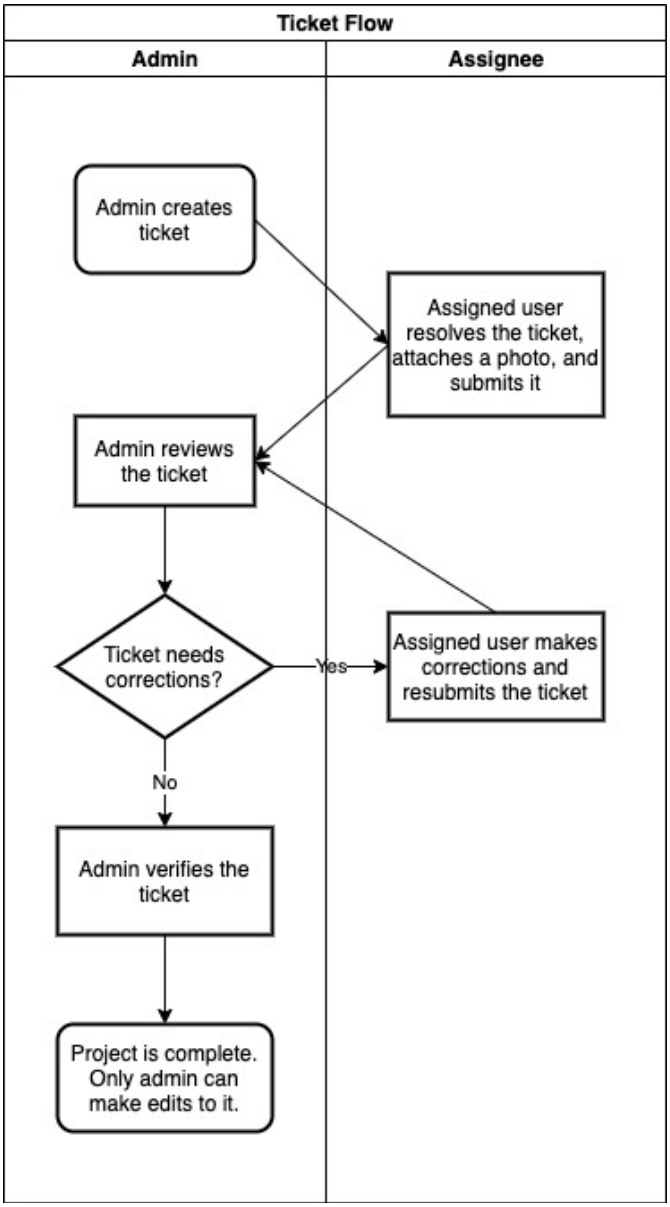


Figure 13: *Swimlane diagram of typical ticket flow in* FIT^{QM}