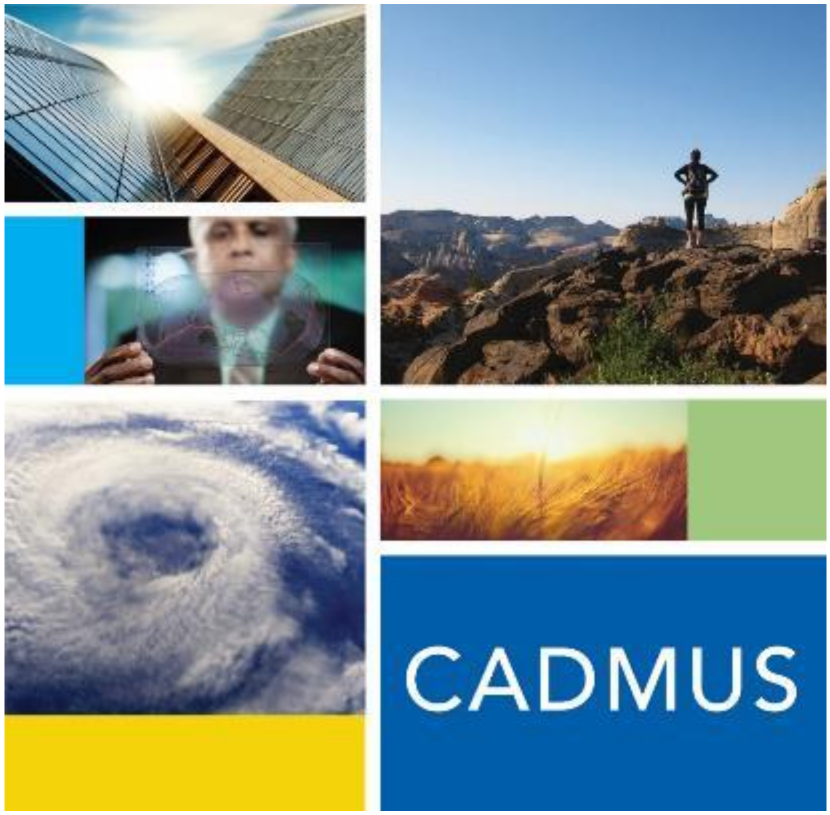

Study of Renewable Energy Installation Quality in the Renewable Energy Growth Program

April 20, 2017

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Acknowledgements

The project team would like to thank Shauna Beland of the Rhode Island Office of Energy Resources and the Rhode Island Distributed Generation Board for their support and input prior to and during this study. The team would also like to thank the staff at National Grid, without whose support and willingness to provide key data this study would not have been possible.

Executive Summary

The Cadmus Group, Inc. (Cadmus), working under contract to the Rhode Island Office of Energy Resources (OER), completed an independent installation quality evaluation on projects installed through the Renewable Energy Growth (REG) program. A tariff-based program, the REG program supports development of renewable energy systems across Rhode Island, with a goal of supporting 160 MW of renewable energy development.

Cadmus completed 90 inspections on solar PV systems installed through the REG program, using a standardized inspection process and Cadmus' proprietary PV Quality Evaluation and Scoring Tool (PVQUEST)—an online secure database application that tracks and reports on more than 800 of the most common PV installation deficiencies. Inspections focused heavily on compliance with codes and standards, including the National Electrical Code (NEC) and the International Building Code. For all inspections conducted as part of this study, after each project received approvals from the relevant authorities and permitting agencies.

The study's key findings include the following:

- **41% of renewable energy systems inspected exhibited major or critical installation deficiencies.** Major and critical deficiencies are those expected to cause immediate or short-term risks of system failure, reduced operating capacity, or pose a safety hazard.
- **Cadmus found 557 installation errors across all 90 systems inspected.** Many of the issues identified were classified as minor or incidental code violations, such as those involving labeling.
- **Most installation deficiencies (and the most severe) occurred at the PV array and point of interconnection.** Issues such as grounding, labeling, and wire management appeared most frequently at these two locations.
- **After receiving notice of findings, 68% of systems inspected corrected issues within 30 days.** Cadmus provided system installers with written reports of each inspection's findings, and followed up via email with installers, tracking those responding and those implementing corrections that addressed the report findings.
- **In an informal survey, 77% of customers expressed dissatisfaction with the REG program.** Customers expressed concerns related to communication and transparency with the REG program.
- **Overall, the REG program received a weighted average Quality Installation Score of 2.78 out of 5.** In comparison, the Rhode Island Renewable Energy Fund (REF) program received an average score of 3.56 out of 5. The difference may be partially due to the unusual interconnection methods required by the REG program, as well as a proportionally larger installation quality review effort applied to the REF program by the program administrator, the Rhode Island Commerce Corporation. In cases where Cadmus identified installers working in both programs, most installers had lower scores under the REG program than under the REF program.

The frequency and severity of the issues found during this study raise concerns about the readiness of the utility and local permitting authorities to successfully ensure installations are "safe, high-quality, performing as expected, and in conformance with the stated specifications."[1] To support this growing industry, Cadmus offers the following recommendations to improve overall installation quality across the REG program:

- **Provide training for local permitting and inspection authorities, installers, and utility personnel.** Though all deficiencies identified in this study are technically code requirements, aspects of relevant codes related to solar PV often can be confusing or misunderstood. Providing technical training to explain these specialized aspects could be a cost-effective way to improve installation quality across the REG program and to support long-term growth of the renewable energy industry in Rhode Island.
- **Carefully consider the role of individuals installing solar on their own homes under the REG program.** The PV system installed by a homeowner was among the worst installations inspected during this study, with a wide range of substantial installation issues. Cadmus recommends that National Grid carefully consider if, and how, such installations should continue to be allowed participation in the program.
- **Clarify program technical requirements and documentation to reduce confusion regarding, in particular, interconnection requirements.** Installers and local authorities expressed confusion regarding the program's interconnection requirements, and Cadmus noted many variations on interconnection methods. By clarifying these (and other) technical requirements, National Grid could provide more clarity and improve consistency in installation methods.
- **Consider adopting an ongoing quality assurance (QA) process for REG-supported installations.** The overall quality of installations reviewed was relatively low, with average scores well below those of the Rhode Island REF program, despite heavy overlap in geography and participating installers. National Grid should consider adding additional technical reviews to the approval process, including measures such as design reviews and post-installation inspections.

In addition to conducting 90 PV system inspections, Cadmus inspected one wind energy project as part of this study, finding found only incidental labeling issues on the 4.5 MW project. In contrast to the PV systems inspected, this very large wind project involved significant engineering resources that would prove impractical to apply to most PV systems on the residential or small commercial scales.

[1] A metric specified by the Rhode Island Office of Energy Resources in RFP 7549810, "Solar Quality Assurance Inspection Study and Report"

Introduction

This report presents the results from a study reviewing the quality of renewable energy installations funded by the Renewable Energy Growth (REG) program in Rhode Island. The Rhode Island Office of Energy Resources (OER) commissioned this study on behalf of the Rhode Island Distributed Generation Board. Study results draw upon Cadmus' on-site inspections of 91 renewable energy installations.

A 10-member Distributed Generation Board oversees the REG program (detailed further below). The Board represents different stakeholder interests and includes three non-voting members—representatives from National Grid, the Commissioner of the OER, and a representative from the Renewable Energy Fund (REF) at the Rhode Island Commerce Corporation.

About the Renewable Energy Growth Program

In 2014, the Rhode Island General Assembly voted to create the REG program. Tariffs govern participation in the REG program, which expands upon the prior Distributed Generation Contracts program. The REG program enables customers to sell renewable energy generation output under long-term tariffs at fixed prices. To facilitate this incentive structure, the REG program delineates renewable energy classes by technology type and size, and specifies an enrollment target capacity, performance-based incentive, and/or ceiling price for each class/size delineation. National Grid's website publishes annual enrollment targets and incentive levels.[2]

Two general projects categories delineate the program:

- **Small-scale solar (25 kW or less)**. Applications are accepted during continuous, open enrollment. The tariff duration lasts 15 to 20 years.
- **Solar greater than 25 kW, wind, hydroelectric, and anaerobic digester**. Applications accepted three times per year during a two-week open enrollment. The tariff duration lasts 20 years.

Renewable Energy Growth Program Minimum Technical Requirements

Cadmus worked with OER to develop Minimum Technical Requirements for this program—requirements in addition to the minimum codes and standards applicable to installations in Rhode Island. They also outlined some of the most-common, often overlooked violations. Appendix A provides a copy of the Minimum Technical Requirements document.

2 https://www9.nationalgridus.com/narragansett/business/energyeff/4_dist_gen.asp

Study Goals

This study sought to determine the quality of REG-funded renewable energy installations. The study's timeframe addressed renewable energy installations in REG tariff years 2015 and 2016 (i.e., April 2015 to April 2017).

OER intended that the study answers whether REG-funded renewable energy installations are "safe, high-quality, performing as expected, and in conformance with the stated specifications."[3] To address this, Cadmus used the following research questions to guide the team's quality assurance efforts.

Cadmus Research Questions for REG Installation Quality Study

What is the quality of renewable energy installations across technologies, system sizes, and installers?

- Based on inspection results measured on Cadmus' 1-5 quality scale
- Analyze across a sample of projects drawn from small, medium, and large installation firms, including self-installers
- Sample from installations in REG tariff years 2015-2016
- Analyze across technologies, including small solar PV, medium solar PV, and wind

What are the most common and serious installation issues identified?

- Summarize data by inspection elements such as array, interconnection, or inverter;
- by issue severity ranging from incidental to critial;
- by issue types such as lableing, grounding, or structural

Are REG Installers addressing identified violations? If yes, what is the timeline?

- Analyze the likelihood of installer response to identified violations and the likelihood for completing satisfactory correctoins
- Assess the timeline for installer responsiveness, from initial receipt of the inspection report to completion of required corrective action.

Based on the quality assurance study findings, would the REG program benefit from ongoing QA reviews to ensure long-term safety and productivity of funded renewable energy systems?

- Assessed from results of the program-wide average Quality Score
- Informed by the frequency and severity of installation issues found

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3 A metric specified by the Rhode Island Office of Energy Resources in RFP 7549810, "Solar Quality Assurance Inspection Study and Report"

Study Methodology

Study Preparation

In preparation for the study, Cadmus engaged with OER and National Grid to clarify study methods and goals. This included developing a study approach, as discussed below. The study methodology drew upon Cadmus' 10 years of experience inspecting solar energy systems, input from OER and National Grid, and REG programmatic documents.

Specifically, Cadmus referred to REG Program Tariff documents (RIPUC No. 2151-B and 2152-B),[4] which outline the REG program's rules and regulations. These documents provided Cadmus and OER with a basis for determining program rules. Cadmus used these documents to inform development of *Minimum Technical Requirements for the Renewable Energy Growth Quality Assurance Program*. (Appendix A provides a copy of these minimum requirements.)

Sampling Process

With respect to sample selection, Cadmus recommended distributing inspections across technologies, system sizes, and installers, with each technology type/size receiving two inspections per installer. Table 1 identifies the target number of inspections and installers for each technology type and size. During the study, Cadmus reallocated resources from the medium solar, large solar, and wind inspection categories to the small solar category, resulting in the same approximate total number of inspections but with a higher volume of small solar inspections than originally expected. This change was made in coordination with OER after finding that there were only two medium solar projects and one wind project completed during the study period and zero large solar projects, far fewer than originally expected.

Table 1. Proposed REG Installation Quality Study Sample Selection

Task	Projected Number of Inspections	Projected Number of Installers	Actual Number of Inspections	Actual Number of Installers
Small Solar Inspections	63	32	88	23
Medium Solar Inspections	16	8	2	1
Large Solar Inspections	10	5	0	0
Wind Inspections	4	2	1	1
Total	**93**	**47**	**91**	**25**

4 https://www9.nationalgridus.com/narragansett/non_html/Clean-RE%20Growth%20Residential%20Tariff%20Revisions%20(PUC%208-12-16).pdf and https://www9.nationalgridus.com/narragansett/non_html/Clean-RE%20Growth%20Non-Residential%20Tariff%20(PUC%208-12-16).pdf

Within each technology type and size, Cadmus and OER sought to inspect systems completed by a variety of installers. For example, OER directed Cadmus to specifically inspect a small solar system, self-installed by the owner of a residence.

For small-scale solar installations, the study selected sites using a random-proportional stratified sampling technique, based on the number of operational installations per installer. In a proportional stratified sample, the percentage of the total population in each stratum matches, as closely as possible, the proportion of individuals actually sampled in that stratum. In this case, Cadmus sought to sample installations from every small solar installer enrolled in the REG program while maintaining the sample's statistical integrity. This meant that the number of sites selected per installer matched each installer's relative percentage of total sites in the program. This allowed the study's results to be applied to the program on a broader scale. Table 2 identifies the target number of inspections for each installer type and size.

Table 2. Small Solar Statistical Sampling Methodology

Projected Sample Size per Installer Category	
Large Installer (>22 installs)	5-7
Medium Installer (15-22 installs)	3-4
Small Installer (<15 installs)	1-3

Inspection Process

Inspection Scope of Work

OER selected Cadmus as the technical consultant to support studying the quality of renewable energy installations that received incentives through the REG program. Cadmus' task included performing all study aspects, from study design specifics to data collection to data analysis and reporting. Cadmus worked closely with OER staff to solidify the study's methodology and approach. Cadmus also met with National Grid staff to present the study approach. Cadmus conducted all on-site inspections of renewable energy systems addressed in the study; these included solar PV and wind installations.

> A component of Cadmus' inspection, unique to the REG program, was reviewing each system's dedicated utility meter—separate from a premise's existing meter—as required by Section 4 of the REG Program Tariff document (RIPUC No. 2151). Specifically, Cadmus' inspection noted that no electrical connection should be on the load side of the existing utility meter.

To ensure that a robust study sample presented a level playing field for all installers, Cadmus did not conduct desktop inspections as part of this study. During on-site inspections, Cadmus collected all relevant data using a tablet-based application and provided these system-specific reports to OER on an ongoing basis. Lastly, Cadmus developed this report, which aggregates all data, provides summary findings, and offers recommendations for OER's and National Grid's next steps.

Customer Outreach and Scheduling

Cadmus scheduled and conducted all inspections with system owners. During project planning, National Grid bought an issue to Cadmus' attention: the need to remain cognizant of customers' perceptions of inspections for this utility-funded incentive. As such, Cadmus developed a standard operating procedure (SOP) for its inspectors when communicating with customers (included in Appendix B). The SOP outlined how Cadmus would conduct itself before, during, and after inspections.

Input Data Sources

To facilitate easy sharing of information required for this study, Cadmus entered into a nondisclosure agreement with OER and National Grid. All data on renewable energy systems and customers originated from National Grid's data files. OER received these data and subsequently passed them to Cadmus, so inspections could be effectively conducted. Table 3 lists data Cadmus received prior to inspections.

Table 3. Pre-Inspection Data Reviewed by Cadmus

Data Type	Description
System Owner Information	• Owner name, address, email, and phone number
System General Information	• System address • Developer and contact information
System Equipment Information	• Solar PV module manufacturer and model, number of PV modules • Inverter manufacturer and model, number of inverters • Nameplate rating • Wind energy system manuals and system specifications • Wind energy system site plans • Wind energy system one line diagrams
Tariff-Specific Details	• Date certificate of eligibility issued • Tariff year and term • Commercial operation date
Costs and Fees	• Total project cost • Electrical permit fee • Building permit fee

On-Site Data Collection

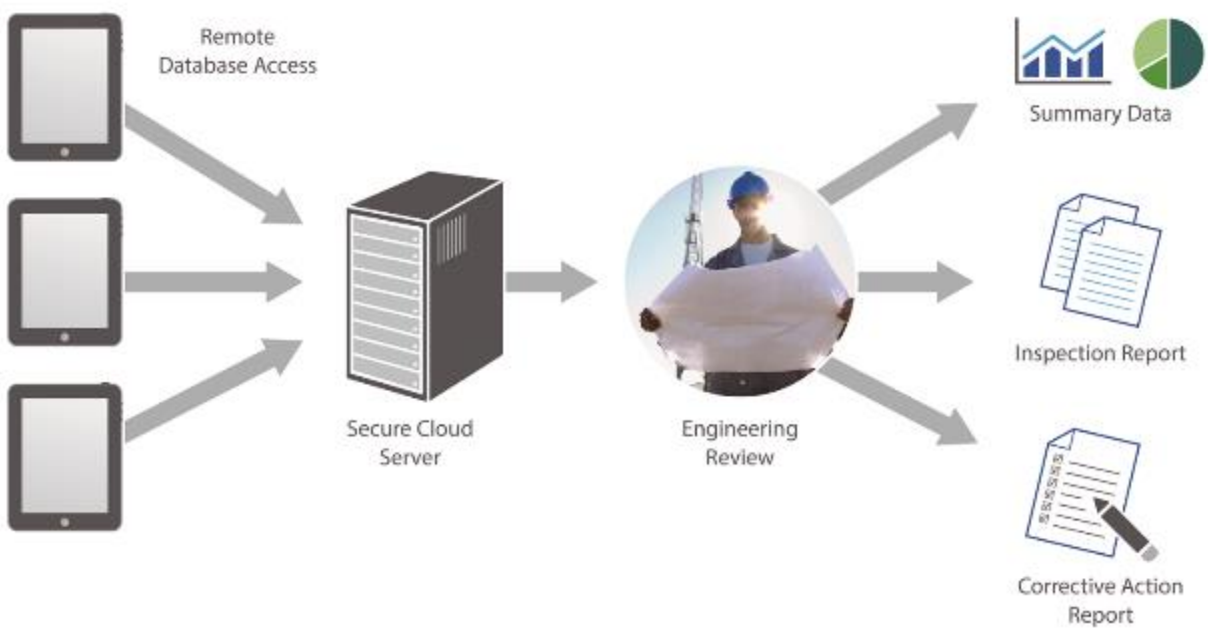
To provide timely reporting and tracking of renewable energy inspections, Cadmus used its proprietary PV Quality Evaluation and Scoring Tool (PVQUEST). A database platform, Cadmus developed PVQUEST to collect, categorize, analyze, and resolve over 800 of the most common solar PV installation issues. Drawn from data collected through thousands of PV inspections, Cadmus programmed PVQUEST with the most common and most serious installation issues.

As inspectors proceeded through inspections, PVQUEST provided a customized checklist of inspection issues, specific to each major system component (e.g., microinverters, DC disconnects, load-side connections, subpanels). Consequently, PVQUEST's highly specific inspection fields ensured, to the extent possible, that each inspector met to the same standard.

PVQUEST use on field inspections adhered to the following steps:

1. Site and system data is imported into PVQUEST
2. Field inspector completes inspection using PVQUEST running on tablet computer
3. Field inspector uploads inspection to secure cloud database
4. Engineering manager reviews inspection report and, if applicable, a Corrective Action Report and submits to installer for corrections
5. Inspection data are stored and summarized in various PVQUEST data tables

Figure 1. Overview of PVQUEST Data Flow and Outputs



Based on violations identified during on-site inspections, PVQUEST generates a quality score, which Cadmus used to determine the quality of each system inspected. Table 4 describes the defect category or severity given to each installation issue inspected by Cadmus, along with typical scores an installation that each type of issue would likely receive.

For example, a PV system with incidental issues would generally score a 4 out of 5 on the PVQUEST scoring scale. The algorithm, however, allows for some adjustments, based on quantity and a large volume of (for example) incidental issues sufficient to result in a score of 3 rather than 4. Only systems with major or critical deficiencies, however, can receive the lowest score: 1 out of 5.

All observations were based on compliance with relevant codes and standards, particularly the National Electrical Code (NEC) and manufacturer installation instructions. Cadmus did not evaluate systems against installation "best practices" or other, more subjective metrics. While useful to the industry, these metrics lack the consensus and rigor of code-making processes; hence, this study did not reference them as a basis for inspection.

For the single wind-energy system inspected as part of this study, Cadmus used a modified version of the inspection checklist that Cadmus previously developed for the Massachusetts Renewable Energy Trust Small Wind Program. This checklist includes observations related to electrical, structural, workmanship, and operational characteristics of the wind energy system.

Table 4. PVQUEST Inspection Scoring System

Defect Category	Description	Typical Score for Systems with Issues of This Type
No Issues	**No issues identified on site.**	**5**
Incidental	**Issues not expected to impact system operations or safety.** Examples: Installation debris left on site, poor wire management, missing or incomplete labels, and installed equipment not matching program records but considered equivalent.	**4**
Minor	**Issues that pose a mid- to long-term risk of system failure or safety hazards**. Examples: Bonding neutral to ground in a meter enclosure, insufficient clearance around boxes, undersized circuit protection, and improperly supported conductors.	**3**
Major	**Issues deemed likely to affect system performance or safety in the short-term, though not an immediate hazard.** Examples: Missing equipment grounding, module microfractures, missing or undersized grounding electrode conductors, improperly secured PV modules, and missing or inadequate thermal expansion joints in long conduit runs.	**2**
Critical	**Issues that pose an immediate risk of system failure and/or safety hazards. Systems often must be shut down during inspections due to safety concerns.** Examples: Exceeding current limits on busbars or conductors, exceeding inverter voltage limits, and use of non-DC rated equipment in DC circuits.	**1**

Report Delivery and Installer Follow Up

Documents Resulting from Inspections

Of particular benefit to the REG study, Cadmus' PVQUEST application automatically stored and compiled inspection data as the inspections occurred. As such, draft site-specific inspection reports could actually be generated quickly, allowing timely delivery of results—particularly when identifying hazardous violations. Along with the final inspection report (reviewed for accuracy by a senior Cadmus inspector), a template corrective action report (CAR) was included. Installers were asked to complete CARs by documenting modifications made to address identified violations, and then return CARs to Cadmus for review and processing. Appendix C provides a sample PVQUEST inspection report and a CAR. OER received all inspection reports and CARs via a secure SharePoint site.

Procedures for Follow-Up with Installers

Given that the REG program provides a production-based incentive and not an upfront grant or rebate incentive, Cadmus anticipated issues would arise with installers correcting identified violations in a timely fashion. Therefore, Cadmus limited follow-up on identified violations with installers or other points of contact for one month following an inspection's completion. Specifically, Cadmus reached out to installers/points of contact once per week for three weeks following an inspection.

To control for differences in communication styles between inspectors and installers, Cadmus made extensive use of templated emails, sent from a shared study-specific email account; so installers would not know the specific sender of any given inspection report. Consequently, they would receive, to the extent possible, exactly the same information in each case. Cadmus also templated follow-up emails, sent on each of three subsequent weeks, starting one week after delivering the inspection report.

If Cadmus did not receive indications that violations had been addressed four weeks after the inspection, the installer, system owner, and OER received the finalized inspection report, citing outstanding violations. Cadmus instructed the installer to report any subsequent corrections to OER.

Additionally, Cadmus tracked the time between receiving an inspection report and submitting acceptable evidence of corrections for each system inspected. Communication was handled through the shared email account noted above, which allowed the study team to easily track correspondence time stamps, address questions, and otherwise manage communications with system installers.

For example, many installers proved responsive to the initial report and CAR email, such as indicating through self-certification that corrections were scheduled or otherwise acknowledging receipt of Cadmus' report. For this study, Cadmus tracked both the dates of these initial responses and the dates when acceptable corrections were submitted and these results are reported separately. In some cases, the first response from an installer included the submittal of corrections, which was noted by an identical response and corrections date.

Through this process, Cadmus assessed the following responsiveness elements:

- Installer response time from the initial report and CAR delivery to acknowledgment of receipt
- Installer response time from the initial report and CAR delivery to final corrections submission
- Number of follow-up reminders required before receiving final corrections
- Number of follow-up reminders required before receiving acknowledgement of receipt
- Likelihood of final correction submissions within 30 days

Data Aggregation and Analysis

The majority of the analysis completed through this study related to calculating the frequency of identified installation deficiencies; in other words, "how often did the study team find any given installation issue?" The study team attempted to stratify the sample to represent a broad mix of installation firms and to apply these findings to the REG program's entire portfolio of small scale projects..

Key Metrics for Measuring Installation Quality

The PVQUEST score given to each project inspected served as the most frequently used metric for determining installation quality. From there, Cadmus then calculated a variety of summary statistics using the PVQUEST score, including:

- Average PVQUEST score for the study sample
- Weighted average PVQUEST score for the program population
- Average PVQUEST score by installer (and category of installer)

In addition, Cadmus tracked and reported several other relevant metrics:

- Average time (calendar days) for initial responses to inspection reports
- Average time (calendar days) for installers to successfully correct installation issues
- Fraction of inspected systems with issues remaining unaddressed after 30 days
- Feedback from customers, installers, and other stakeholders on the REG program

Most Common Installation Deficiencies

In PVQUEST, each deficiency has a unique identification code so that all 800 unique installation defects in the database can be tracked, counted, and summarized independently. This provided many analysis options and allowed the study team to derive detailed statistics about common installation issues. For this study, Cadmus defined "most common" as issues with the highest number of observations across the sites inspected. Consequently, a disconnect grounding issue identified 50 times would rank as more common than a labeling issue found 40 times among the same group of sites.

In addition to having a unique identifier, each deficiency was associated with a particular piece of equipment (e.g., PV array, DC disconnect, load side connection) and with an issue type (e.g., grounding, labeling, workmanship). This allowed Cadmus not only to categorize the most common specific deficiencies, but to identify where the majority of deficiencies occurred within the system; enabling stakeholders to target their training and internal quality assurance efforts accordingly (e.g., focus on array wire management issues).

Assessing Installer Responsiveness to Quality Issues

Cadmus recorded and tracked installer responsiveness through careful monitoring of Cadmus' shared REG inspections email account and ongoing data tracking. The study team recorded any responses from installers, or correspondence between Cadmus and an installer, ranging from brief emails confirming

receipt of reports to detailed conversations about ways to approach the corrections process. Upon receiving corrections via email, a Cadmus inspector reviewed and approved the corrections, and marked the site as “completed” in the tracking system.

Study Findings

Cadmus performed 91 inspections of renewable energy systems receiving incentives though the REG program, which included 90 solar PV systems and one wind energy system. The study also included 25 installers, of the 34 participating in the program during the study time period. Of these 91 installations, only 11%[5] met OER's criteria of being "safe, high-quality, performing as expected, and in conformance with the stated specifications."[6] This section presents the study team's key findings for sampled projects.

Overall Solar PV System Findings

Cadmus successfully completed 90 total inspections of solar PV systems installed. Specifically, we reviewed 88 small-scale solar installations and two medium-scale solar installations.

Technical Findings

The technical outcomes of the study are those findings, summarized below, related to the physical installations inspected including Cadmus' assessment of installation quality, code compliance findings, and discussion of energy yield and shading issues.

Overall Installation Quality Scores

Cadmus calculated the average quality score for projects inspected through this study. Overall, approximately 41% of systems inspected received a quality score of 1 or 2, indicating the presence of major and/or critical installation deficiencies, as shown in Table 5 and Figure 2.

Table 5. Solar Quality Score Summary

Solar Quality Score Summary		
Score		**Count**
1	System has critical and/or multiple major deficiencies	19
2	System has at least one major deficiency	18
3	System has multiple minor deficiencies	18
4	System has minor and/or incidental deficiencies	25
5	System has no, or only incidental, deficiencies	10

[5] This figure represents renewable energy systems receiving a score of 5, indicating that the systems had no, or only incidental, deficiencies.

[6] A metric specified by the Rhode Island Office of Energy Resources in RFP 7549810, "Solar Quality Assurance Inspection Study and Report"

Figure 2. Summary of Solar Quality Results

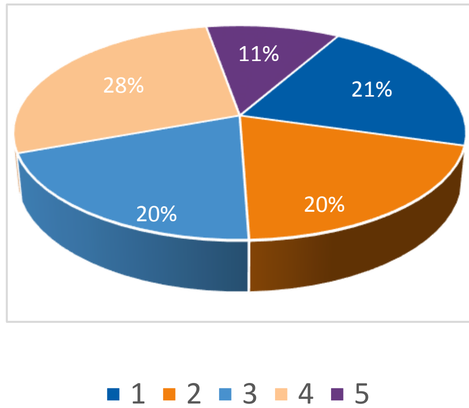


Table 6. Inspection Results During the Study Period

Inspection Month	Total Inspections	Count by Quality Score					Average Score
		1	2	3	4	5	
December 2016	36	7	7	9	11	2	2.83
January 2017	38	8	7	7	10	7	3.03
February 2017	16	4	4	3	4	1	2.63
Total	**90**	**19**	**18**	**19**	**25**	**10**	**2.88**

As Cadmus designed the sampling process to distribute limited study resources across as many installers as possible, the average score above does not represent inspection findings from the actual number of installedREG projects, only the average across the projects inspected for this study.

To convert this estimate into an estimate of program-wide installation quality, Cadmus calculated the average score per installer, and then averaged those scores using a weighting factor based on each installer's quantity of projects completed under the REG program. This program-wide weighted average placed greater emphasis on higher-volume installers, presenting a more realistic assessment of program-wide installation quality than the average calculated across the study sample. The program-wide weighted average equates to 2.78, slightly lower than the unweighted average score of 2.88.

By Installer

The average Quality Score per installer varied significantly through the course of the study, with the lowest scoring installer's average at 1.0, and the highest average at 4.14. Average scores rose slightly as installer volumes increased; small installers with one or two installations scored an average of 2.5, and the larger installers with 30 or more installations scored an average of 3.18.

Table 7. Average Quality Score by Installer Size

Solar Quality Score Summary by Installer Size		
Number of REG Installations	Inspections per Installer	Average Quality Score
Less than 3	1–2	2.50
4–30	3–7	2.74
30–100	8–10	3.18

Self-Installer and Very Low-Volume Installer PV Systems

Approximately five of the 90 inspections addressed systems installed by self-installers or very low-volume installers. These five inspections identified 67 violations, resulting in an average score of 1.2. The one self-installation completed received a score of 1 (critical) and two additional self-installers refused inspections altogether.

The overall quality of these installations was significantly worse than others inspected in the study, likely due to the installers' lack of familiarity with solar PV equipment, interconnection, and the solar specific sections of NEC and RI Building Code. The arrays' locations often included significant structural issues with the racking or module-mounting hardware. In many cases, these violations would likely result in modules in danger of falling from the support structure during the lifetime of the system. Manufacturers specify the exact hardware and installation methods to properly secure this equipment in this environment, and it is critical that all instructions be followed. Other locations contained improper equipment installed and unconventional wiring methods, in addition to the common violations observed throughout the study. The observed installation methods would make it extremely difficult for future service and often resulted in additional hazards for service personnel.

Table 8. Inspection Score for Self and Very Low Volume Installers

Cadmus ID	Inspection Score
REG0041	1
REG0065	1
REG0074	3
REG0075	2
REG0080	1

Most Common Installation Issues

In conducting the study, Cadmus found 576 installation issues, with 557 of these violating relevant codes and standards. The remaining 19 deficiencies, shown in Table 9, were Cadmus recommendations to improve installations but did not reflect violations of codes or standards.

The majority of the issues occurred at the array or the supply-side interconnection point. In addition to being the location where the majority of installation deficiencies occurred, these two inspection

elements also exhibited the majority of major and critical deficiencies. A significant number of issues also appeared at the AC combiner and inverter elements.

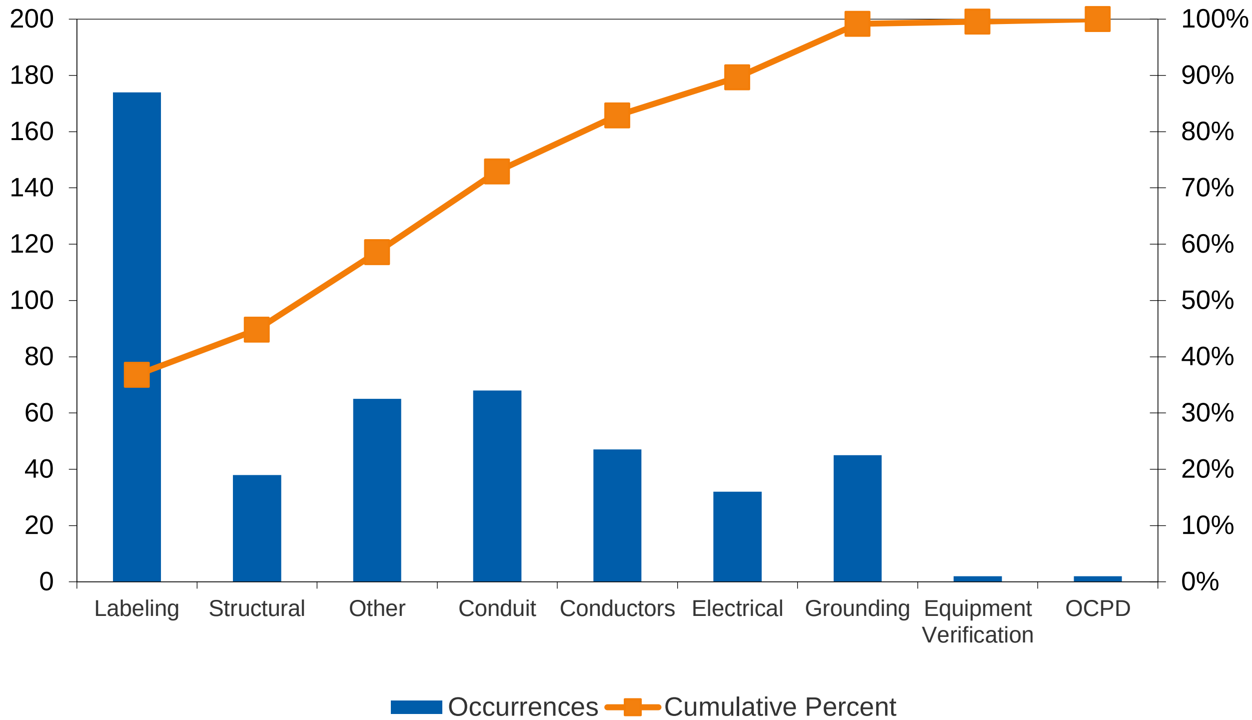
Overall, the majority of issues found were incidental or minor, with these two combined categories representing approximately 88% of all code violations found. However, Cadmus found 68 major and critical deficiencies which, per Cadmus defect category definitions, were “issues deemed likely to affect system performance or safety in the short-term, though not an immediate hazard” or “issues that pose an immediate risk of system failure and/or safety hazards. Systems often must be shut down during inspections due to safety concerns.”

Table 9. Summary of Inspection Issues Found by Defect Category and Inspection Element

Inspection Element	Recommendation	Incidental	Minor	Major	Critical	Total
AC Combiner	0	61	11	0	0	72
AC Disconnect	3	19	9	2	0	33
Array	5	18	78	43	1	145
DC Combiner	0	3	1	0	0	4
DC Disconnect	0	2	0	0	0	2
Inverter	2	58	12	0	0	72
Junction Box	0	3	10	2	0	15
Optimizer	0	0	0	1	0	1
Overall Observations	7	0	0	0	0	7
Production Meter	0	2	4	0	0	6
Subpanel	0	3	2	0	0	5
Supply Side Connection	2	121	72	16	3	214
	19	**290**	**199**	**64**	**4**	**576**

As shown in Figure 3, the most frequent deficiencies found related to system labeling, representing approximately 37% of all issues found throughout the study. Aside from labeling, the deficiencies were distributed across categories (e.g., structural, conduit, conductor installation, and grounding). Cadmus found relatively few (2) cases where equipment installed did not match program records (Equipment Verification in Figure 3). Cadmus found only two cases of improperly installed overcurrent protection devices (OCPD in Figure 3).

Figure 3. Quantity of Installation Deficiencies Found by Requirement Type



A Unique Interconnection

Unlike other residential solar PV installations in Rhode Island that are always "behind the (existing utility) meter," the REG program requires a dedicated utility meter for a system. When introduced to installers in 2015, the program intended for installers to replace existing utility meter enclosures with new enclosures, containing extra space for the new solar PV connection. At solar stakeholder meetings in July and December 2015, and at CCRI in May 2015, Cadmus presented slides and examples of this interconnection method, describing it as if a "new tenant" had occupied that building. The metering and disconnecting means were identical to those used for multifamily electrical service. During the inspection process, Cadmus identified a number of variations on this interconnection method, many of which violated National Grid's requirements[7]. Changes were made to these requirements in December 2016, that were effective January 1, 2017. Communication about the changes was unclear and only to a limited number of installers. Further, there was no communication made to the hundreds of stakeholders through OER. For overhead services, Cadmus observed the following connection methods:

- Additional (parallel) service drop, allowable by National Grid
- Junction box (splice) in existing service drop, allowed until January 2017
- Connection made in existing meter enclosure, always prohibited by National Grid

[7] https://www9.nationalgridus.com/narragansett/business/energyeff/4_interconnection-process.asp

- New multi-gang meter enclosure installed, preferred method

For underground services, Cadmus observed the following connection methods:

- Junction box (splice) in existing service lateral, unclear if ever allowed by National Grid
- Connection made in existing meter enclosure, always prohibited by National Grid
- New multi-gang meter enclosure installed, currently, the only method explicitly allowed

Figure 4. Example of New Multi-Gang Meter Enclosures Installed in (Left) Underground Service Laterals and (Right) Overhead Service Drops

Figure 5. Unlocked Enclosures Installed in (Left) Underground Service Laterals and (Right) Overhead Service Drops

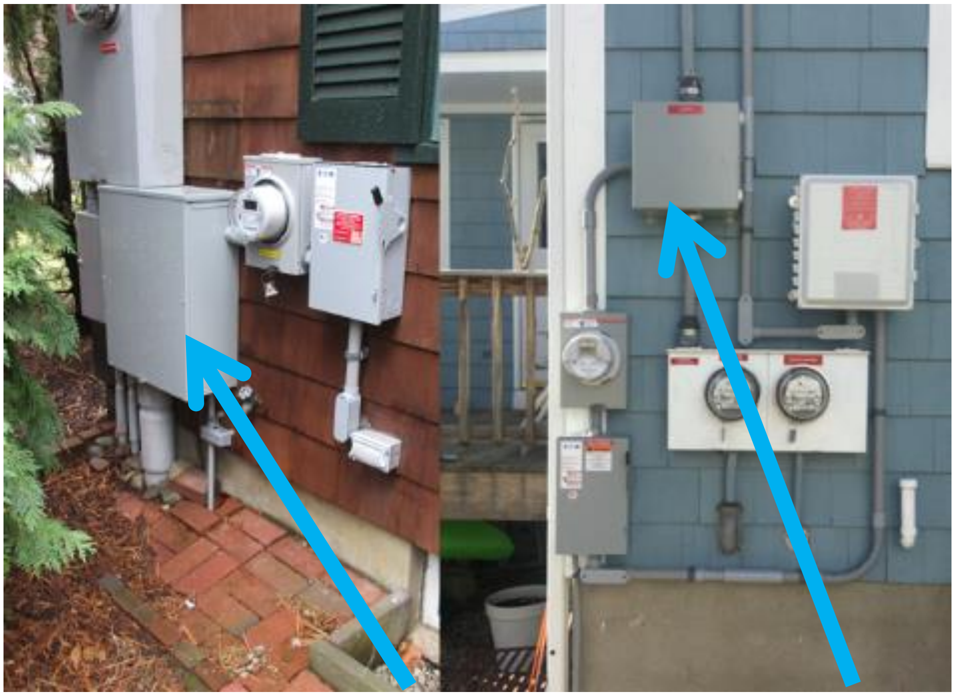
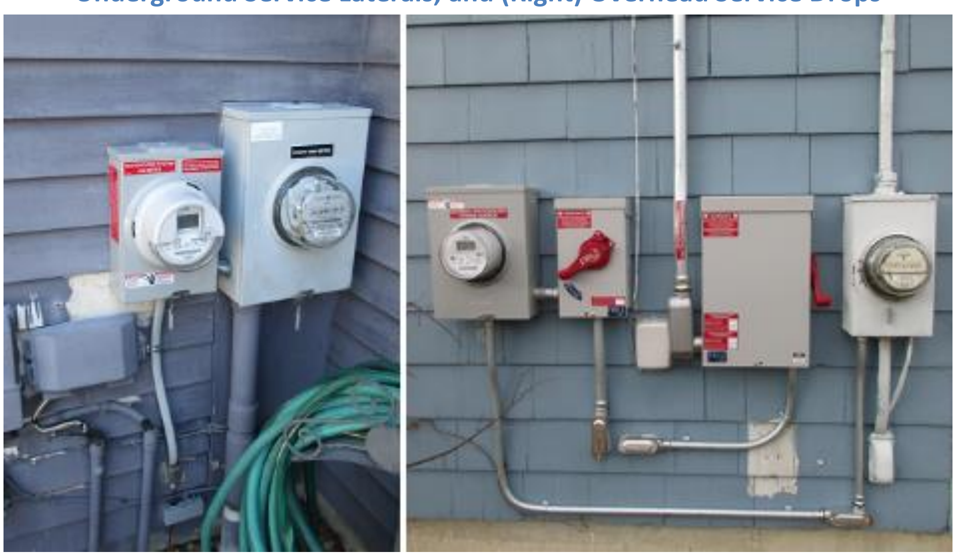


Figure 6. Connections Made In Existing Meter Enclosures on (Left) Underground Service Laterals, and (Right) Overhead Service Drops



Junction boxes installed on existing service conductors were not always locked or did not have a provision for a lock. Without a lock, the possibility of electricity theft increases as the enclosure contains unmetered conductors.

In addition, Cadmus observed many connections in existing meter enclosures. As the meters were always locked or tagged, evaluators could not inspect physical connection methods and locations. If connections were made on the customer (load) side of the existing meter, PV generation would affect existing consumption measurements, either by increasing or reducing the metered consumption, and resulting in inaccurate electric bills. Furthermore, regardless of connection locations inside meter enclosures, many electrical code violations could occur, such as terminal ratings (Article 110.3(B)) and connections of dissimilar metals (Article 110.14).

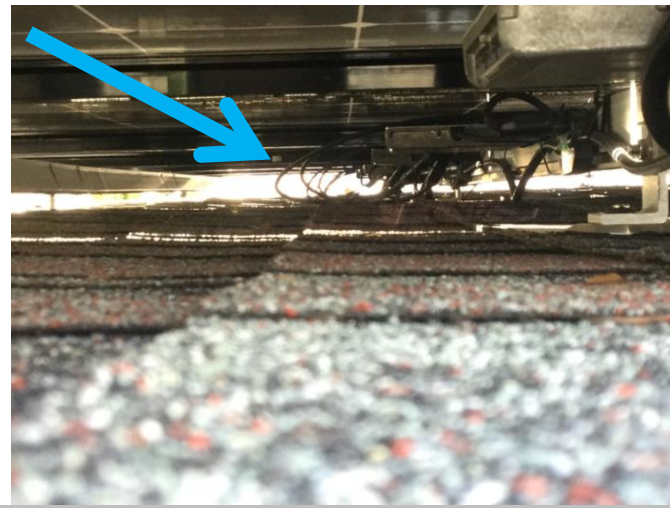
National Grid Approval of REG Meter Configuration

Cadmus also identified inconsistencies with the way that National Grid approves REG metering configurations prior to installing the new meter. Some installations with National Grid installed second meters already installed did not contain any labels or permanent placards. Other installations were delayed by a Customer Solutions/Distributed Generation Representative because not all labels (beyond those required by National Grid) were permanent placards. The requirements of Article 110.21(B) of the NEC for field-applied hazard markings only state that they shall be permanently affixed and that they are suitable for the environment. In other scenarios, Cadmus identified several locations where connections were made in the original meter enclosure, in violation of National Grid REG program requirements.

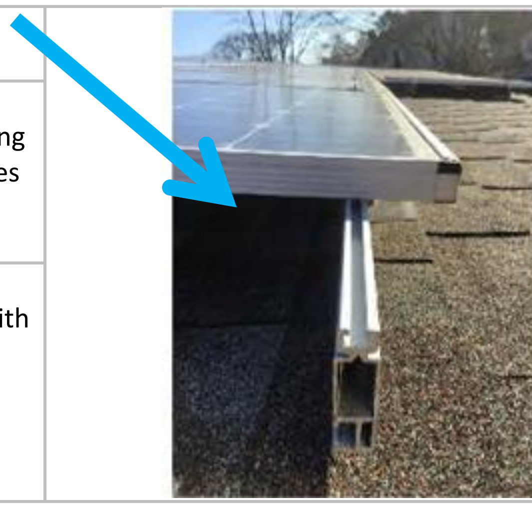
Examples of Common Installation Deficiencies

In this section, Cadmus summarizes the most common installation deficiencies found during the study.

Array Conductors Improperly Secured and Protected

Frequency 23 Observations	
Potential Impacts Conductors exposed to damage from rooftop debris, sharp edges, and abrasive surfaces may have insulation damaged and thereby increase the likelihood of a ground fault and shock hazard.	
Best Practices Conductors should be secured using durable methods, such as stainless steel clips, to protect them from damage.	

PV Modules Improperly Secured and Fastened in Place

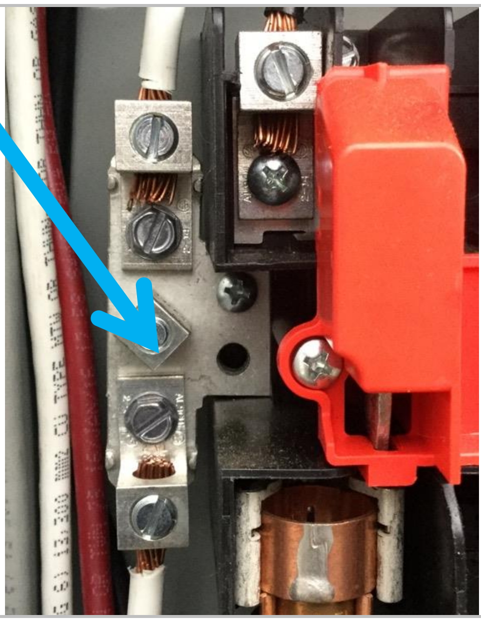
Frequency 22 Observations	
Potential Impacts Modules that are not properly-secured to racking pose a risk of falling from the array. This includes improper or missing hardware, or modules secured at improper locations.	
Best Practices Equipment should be installed in accordance with manufacturers' installation instructions.	

Grounded (Neutral) Not Bonded inside PV Service Disconnect

Frequency
13 Observations

Potential Impacts
Grounded (neutral) conductors not properly bonded to the grounding electrode conductor inside the PV service disconnect jeopardize reaction times for fuses or circuit breakers to operate in the event of a fault.

Best Practices
The National Electrical Code requires this connection for proper operation of service equipment. It can be easily achieved by adding a main bonding jumper (green screw) in the grounded conductor terminal bar.

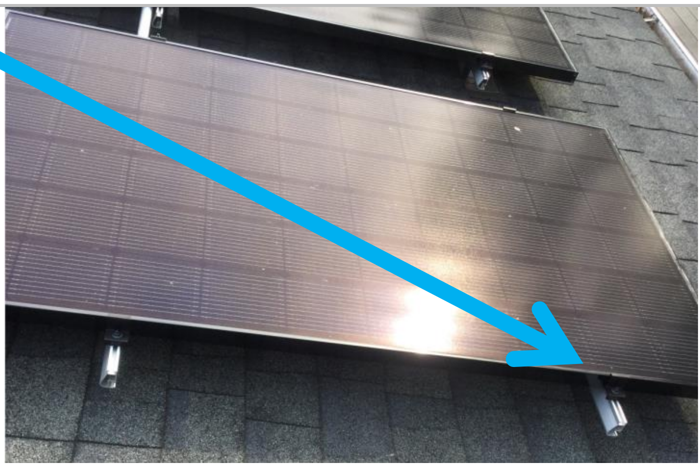


Modules Frames Not Grounded

Frequency
11 Observations

Potential Impacts
Equipment and enclosures "likely to become energized" must be grounded. If metal parts are not properly bonded to ground, they may pose a shock hazard in a fault condition.

Best Practices
Many manufacturers offer integrated bonding hardware, where the mechanical support connections also are listed to electrically ground equipment. Hardware must be properly listed for the purpose, or additional grounding may be required.



Service-Entrance Conductor Splice Not Rated for Environment

Frequency 11 Observations	
Potential Impacts Splice components not listed for outdoor use may fail prematurely, resulting in an electrical fault or fire.	
Best Practices Electrical connections serve as the most critical components to ensure proper continuity. It is important that they are suitable for the environment in which they are installed, such as sunlight and wet locations.	

Roof Penetrations Not Properly Sealed or Flashed

Frequency 7 Observations	
Potential Impacts Local building codes require all roof penetrations to contain flashing and proper sealing. Whether for conduit support or racking, improper roof penetrations pose considerable risk of water intrusion.	
Best Practices Flashing should always be utilized, regardless of the type of roof penetration. This will help ensure the roof will not leak in the long term.	

Shading and Electricity Generation

The REG program does not have a minimum shading requirement, as required by other incentive programs (e.g., REF program). Although shading and production were not the primary focus of Cadmus' inspections, we measured shading at 50 sites. The metric used was the total solar resource fraction

(TSRF), which is a ratio of available solar radiation accounting for actual tilt, orientation, and shading, compared to ideal unshaded solar exposure for a given location. Roughly speaking, the TSRF reflects how ideal a site's solar access is, with a perfectly oriented and unshaded site achieving a TSRF of 100%. It is common for a program to require a minimum TSRF of 80%. Of the 50 sites measured, Cadmus observed 13 sites below 80%, with an average TSRF of 70%, and a minimum of 59%.

Comparisons to the REF Program

The Rhode Island Commerce Corporation administers the REF program, a grant and loan incentive program. Cadmus facilitates quality assurance inspections as an entry requirement for the program, resulting in the inspection and corrective action process for all REF-funded systems. This study included system inspections for nine installers working with both the REF and REG programs. Average inspection scores per installer over this period were pulled to compare the inspection quality between the two programs. As shown in Table 10, of the nine corresponding installers, all but three scored higher on REF installations than REG installations. On average, inspection scores per installer were 46% higher for projects under the REF program compared to projects under the REG program.

Table 10. Comparison of Installer Average Quality Scores for REG and REF Programs

REG Installer	Average REG PVQUEST Score	Average REF PVQUEST Score
Installer 1	1.13	4.67
Installer 2	2.33	3.00
Installer 3	2.82	5.00
Installer 4	3.05	3.60
Installer 5	2.57	2.00
Installer 6	2.00	3.00
Installer 7	4.17	4.00
Installer 8	3.56	3.67
Installer 9	4.50	2.00
Program-wide Average	**2.78**	**3.56**

Programmatic and Process Findings

Customer Feedback

Customer feedback on the REG program and individual installers was collected anecdotally during the scheduling process, onsite at the inspections, and during the corrective action process. Responses and reactions were recorded in real-time, and were aggregated at the conclusion of the customer communications process. Twelve respondents provided usable content that was aggregated into positive, neutral, and negative impressions of both the installer and the REG program. Furthermore, the most common specific complaints were aggregated into three sub-categories (see Figure 8); some respondents had multiple comments regarding their installer or the program, in which case their responses are counted in multiple categories.

Customer Feedback on REG Program

> "There don't seem to be many resources from National Grid to help explain [the REG program] to those of us who have questions or concerns."

While some respondents were pleased with how the REG program was administered and how PBI process worked, many respondents expressed concerns about a lack of communication between National Grid and program participants. Of the 13 recorded responses about the program, six cited lack of available informational resources before entering the program (such as when to expect payment, how to navigate the application process, or what involvement to expect from National Grid), and another four cited ongoing communication complaints, such as difficulties in reaching National Grid representatives through available channels, not receiving answers to questions about billing and payments, and not observing an adequate outlet for direct complaints. The second major category of concern regarded the program's financial benefits. Five respondents did not feel their tariff payments were as significant as they initially predicted (as taxation consequences were not adequately explained at the onset of the program), and four respondents were unclear about how and when they would receive their payments. Figure 7 and Figure 8 describe the variations of responses regarding the REG program.

Figure 7. Customer Satisfaction with the REG Program

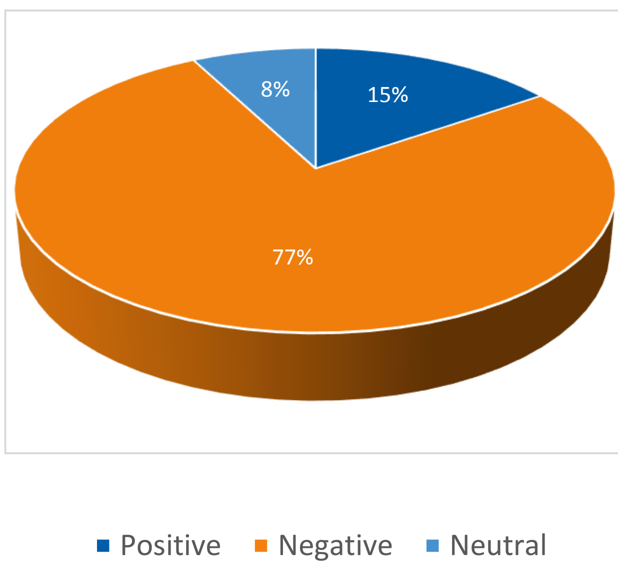
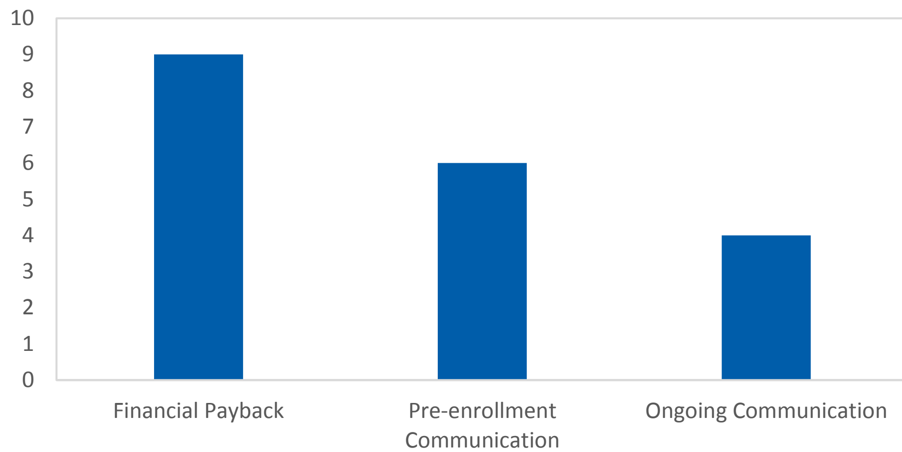


Figure 8. Most Common Negative Customer Feedback Categories for the REG Program



Customer Feedback on Installer

> "We are happy with how our system is performing and the quality of the installation. Our installer's knowledge of the REG program does leave something to be desired."

Similar to feedback about the REG program, respondent feedback about their installers largely related to communication struggles and lack of installers' prior knowledge about the REG program. Of the nine recorded responses about installers, four respondents wanted better communication with their installer, and an additional two were concerned about their installer's knowledge about the REG program and how their tariff would work post-installation. As a unique concern regarding installer feedback, two respondents reported their systems underperformed in comparison to quotes provided to the installer before the system was installed. Figure 9 and Figure 10 describe the variations of responses regarding installers.

Figure 9. Customer Satisfaction with Installers

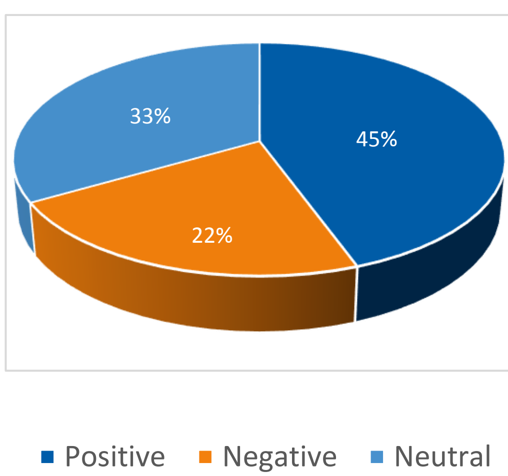
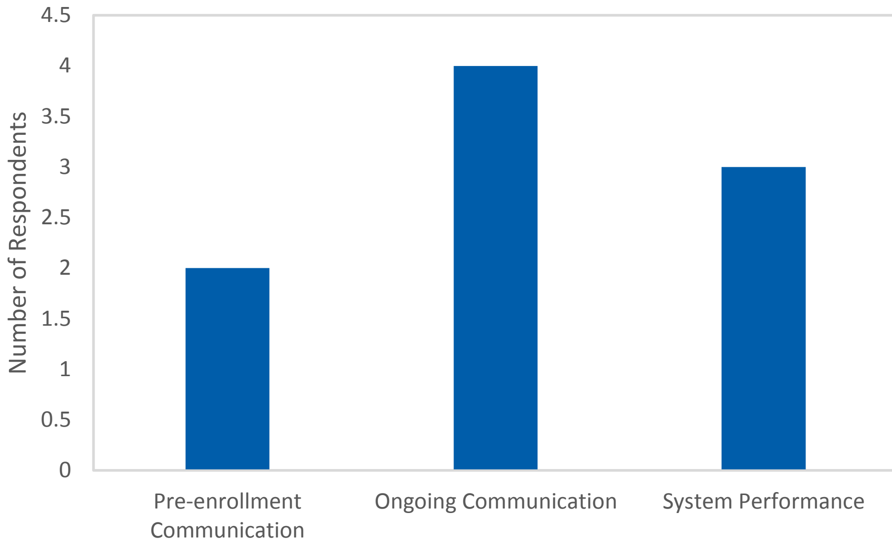


Figure 10. Most Common Negative Customer Feedback Categories for Installers



Installer and Electrical Inspector Feedback

Since the REG program was announced, Cadmus has received over 20 calls and emails from installers and electrical inspectors providing informal feedback. This feedback on the REG program was collected anecdotally during onsite inspections, during the corrective action process, and from direct outreach from installers or electrical inspectors.

Installer and Electrical Inspector Feedback on REG Program

Feedback from installers and electrical inspectors typically related to uncertainty about the REG program, including requesting additional guidance and raising concerns about misinformation or changing rules. For example, technical guidance from National Grid was unclear at times, resulting in sometimes expensive system modifications.

Various installers expressed concerns about the REG technical requirements. One installer explained to Cadmus that, “[National Grid] keep[s] changing the rules as they go along, it is difficult to keep up with their requirements.” Multiple installers also shared complaints about National Grid’s approval of the REG metering configuration. One installer is quoted as saying: “I wired the interconnection one way, they told me to wire it a different way, they then rejected it, and I had to wire it back to the original way.”

In some instances, local electrical inspectors were not approving installations because they were unfamiliar with the REG interconnection requirements. One local inspector stated that, “these solar inspections ...are becoming more difficult to understand.”

Medium Solar PV System Findings

As the program realized lower enrollment than originally predicted for solar PV systems greater than 25 kW, this study included inspections of two medium-scale solar PV projects, both completed by the same installer. These results are both included in the study's overall findings above and separated below for individual analysis.

Solar Inspection Quality Scores

Table 11. Solar Quality Scores

Program ID	Installer	Score
REG0182	Installer 23	4
REG0183	Installer 23	3
Average		**3.5**

Most Common Installation Issues

In this section, Cadmus summarizes the most common installation deficiencies for medium-scale solar PV systems found during the study.

Improper Grounding Hardware – Dissimilar Metals

Frequency
2/2 Observations

Potential Impacts
Dissimilar metals that are in direct contact with each other will corrode and eventually fail, especially those that are in a wet location. Because grounding relies on this connection, it is essential for the safe operation during its lifetime.

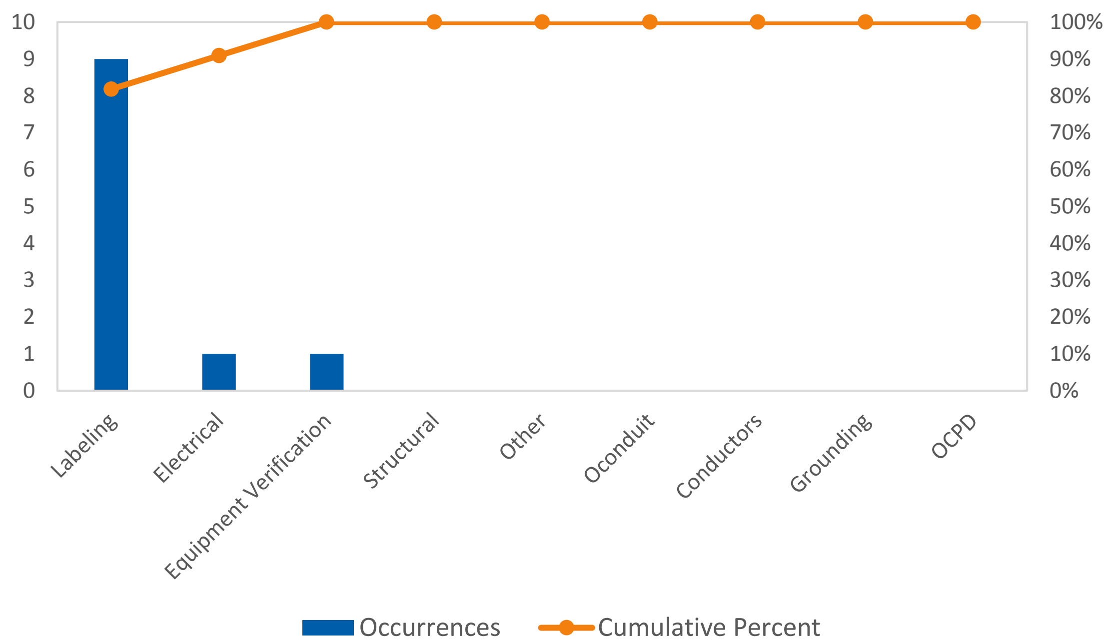
Best Practices
Hardware used outdoors is required to be listed for the environment. In addition, any metal connections shall be of similar metals.

Table 12. Summary of Inspection Issues Found by Defect Category and Inspection Element

Inspection Element	Recommendation	Incidental	Minor	Major	Critical	Total
AC Combiner	0	4	0	0	0	4
AC Disconnect	0	0	0	0	0	0
Array	0	0	3	0	0	3
DC Combiner	0	0	0	0	0	0

Inspection Element	Recommendation	Incidental	Minor	Major	Critical	Total
DC Disconnect	0	0	0	0	0	0
Inverter	0	3	0	0	0	3
Junction Box	0	0	0	0	0	0
Optimizer	0	0	0	0	0	0
Overall Observations	0	0	0	0	0	0
Production Meter	0	0	0	0	0	0
Subpanel	0	0	0	0	0	0
Supply Side Connection	0	3	0	0	0	3
	0	**10**	**3**	**0**	**0**	**13**

Figure 11. Quantity of Installation Deficiencies Found by Requirement Type



Solar Installer Responsiveness to Quality Installation Issues

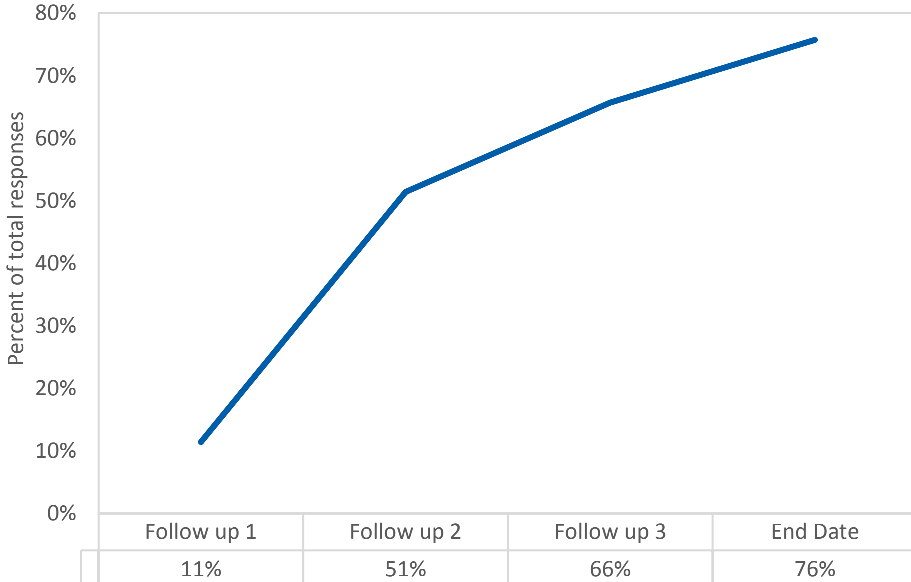
This section presents Cadmus' study findings with respect to solar installers' responsiveness to inspection reports. The study included inspections of systems completed by 24 solar installers. Of those 24 installers, Cadmus confirmed delivery of 83 inspection reports to 19 installers. Of these 83 reports, 13 systems received a score of 5 and required no corrective actions, and were excluded from our responsiveness tracking process.

Cadmus was unable to confirm delivery of seven inspection reports to five installers. Causes for this included installers no longer operating in the state of Rhode Island or contact information that was out of date or unavailable. Because we could not confirm delivery of these inspection reports, these individuals were also excluded from our responsiveness tracking process. Note, however, that the results from onsite inspections were included in our study findings in regards to installation quality.

Installer Response to Post-Inspection Communications

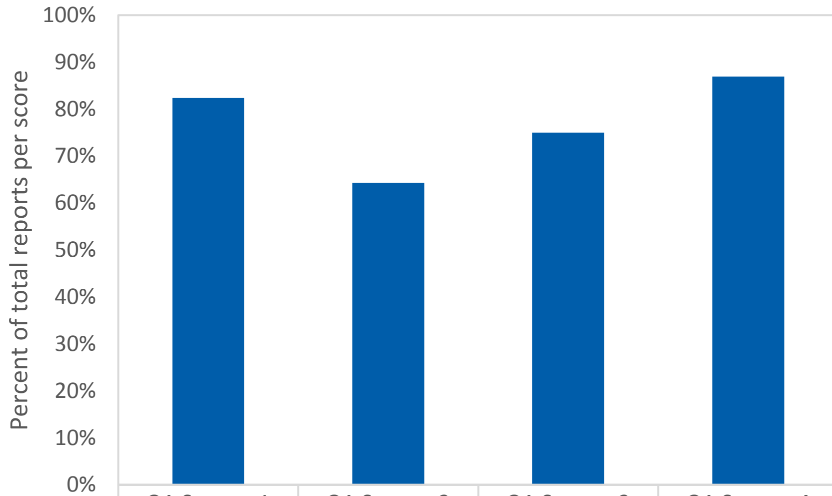
On average, installers often responded to report deliveries and reminders, generally asking questions about corrective action requirements or providing status updates for their own corrective action timelines. Initial responses overwhelmingly fell into the latter category, with installers setting dates to make corrections or stating that repairs were scheduled, but not providing specific timelines. Of installers receiving reports, 79% provided a response. These responses varied in their promptness, with most initial responses received within two or three weeks. Only 11% of installers responded after the initial report receipt and follow-up email, but over 50% responded after the second email reminder. Figure 12 shows responses received at various stages of the correspondence timeline.

Figure 12. Percentage of Responses Received at Weekly Reminder Intervals



While responsiveness by time interval followed a fairly linear progression, response rates per report score remained largely consistent. Cadmus did not observe significant differences in the number of responses received for any single score category. Responsiveness ranged from 64% to 87%, but response rates and quality scores did not exhibit statistically significant correlations. Figure 13 shows the percentage of responses received for reports sent in each score category. While the majority of reports submitted to installers elicited a response, the lowest response rate occurred among systems exhibiting major deficiencies, and, at the end of 30 days, 36% of those systems had not resulted in even a perfunctory response from the system installer. Notably, both self- or low volume installers who received reports did not provide corrections. The other three installers from the group of five identified in “Study Findings” did not have readily available contact information, and therefore did not receive inspection reports.

Figure 13. Percentage of Responses Received Out of Total Reports Sent Per Quality Score



QA Score = 1	QA Score = 2	QA Score = 3	QA Score = 4
82%	64%	75%	87%

Installer Efforts to Address Inspection Findings

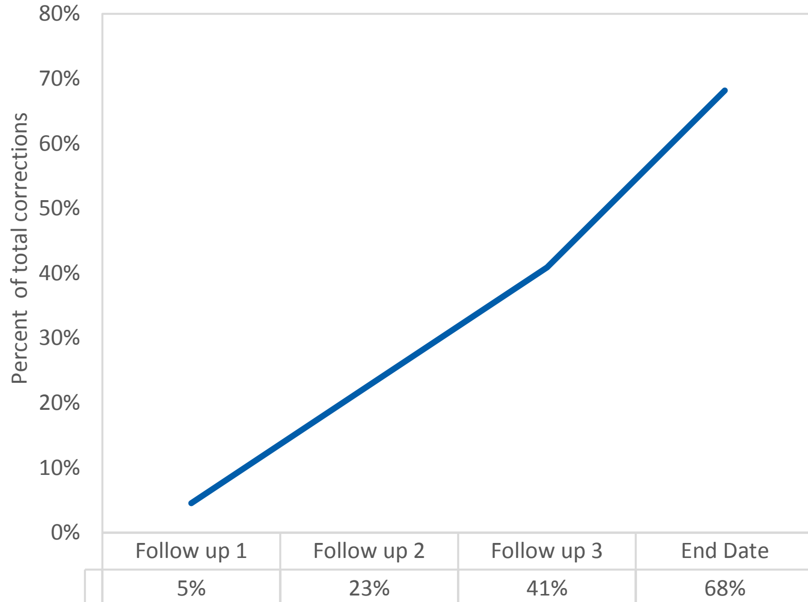
While the study team found generally high responsiveness rates, a surprisingly low number of actual corrective action items were received and approved. While 78% of sent reports received some sort of response, only 31% received tangible corrections. In other terms, 79% of systems inspected did not receive corrections within the allotted 30 days. Cadmus aimed to encourage participation in the study by explaining the scope of Cadmus' authority and the study's purpose to installers reluctant to make corrections (see text box).

Templated Email from Cadmus to Solar Installer

The score of this inspection and your respective corrective action will not affect your customer's receipt of their REG incentive from National Grid. However, we are conducting these inspections as part of a study funded by the Rhode Island Office of Energy Resources (OER) to document the quality of installations completed through the REG program. We are collecting data on installation quality, most frequently observed code violations, installer responsiveness to corrective action notices, and anecdotal feedback from customers and installers. These findings will be published in a report given to OER and National Grid, with findings presented to the Rhode Island DG Board. Presumably, the report will be available to the public. It is our intention not to name any particular customers or installers in the report, which will focus on aggregate findings, but OER and National Grid will have access to all documents associated with our findings, including inspection reports and documentation of installer actions taken in response to our findings.

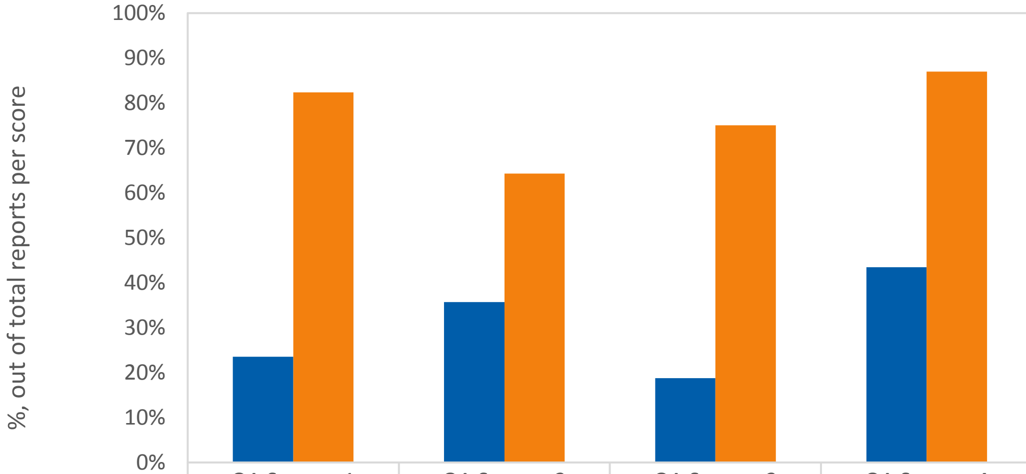
The corrections timeline followed a pattern similar to that of general responses, with most corrections submitted after the second and third reminder deadlines. Figure 14 shows corrections received at various stages of the correspondence timeline.

Figure 14. Percentage of Corrections Received at Weekly Reminder Intervals



The correction rate varied significantly across categories of report scores. While 43% of reports scored as 4 resulted in corrections, only 24% of reports scored as 1 resulted in corrections (despite over 80% of reports receiving at least some response from the installer, indicating these reports were correctly delivered to the installers). While some fluctuation occurred in corrections rates across the four score categories, leading to a somewhat nonlinear pattern, the drastic difference in corrections rates between the highest and lowest score categories proved significant. Figure 15 details the correction percentage received for reports sent in each score category, compared to total responses received.

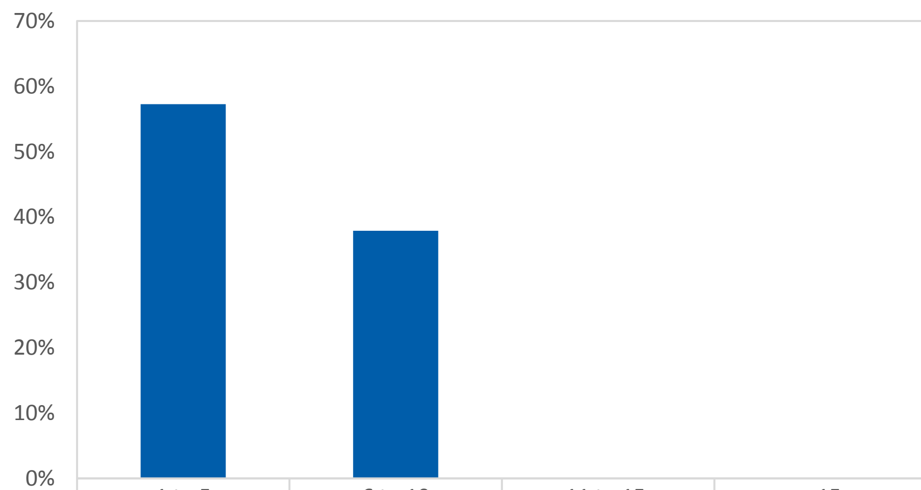
Figure 15. Percentage of Corrections Received Out of Total Reports Sent Per Quality Score



	QA Score = 1	QA Score = 2	QA Score = 3	QA Score = 4
Corrections	24%	36%	19%	43%
Responses	82%	64%	75%	87%

As quality score categories are defined by a number of metrics, including the volume and severity of issues observed, it is important to look at corrective action in terms of the raw number of corrective actions cited per report. For instance, a report containing 10 corrective action items may have a different response time than a report containing one corrective action item, depending on the severity and complications associated with making the corrections. Figure 16 shows the percentage of corrections submitted, aggregated by the number of violations cited on any given inspection report. Notably, no reports with more than 10 cited violations received corrections. The highest number of violations cited on a single report was 22.

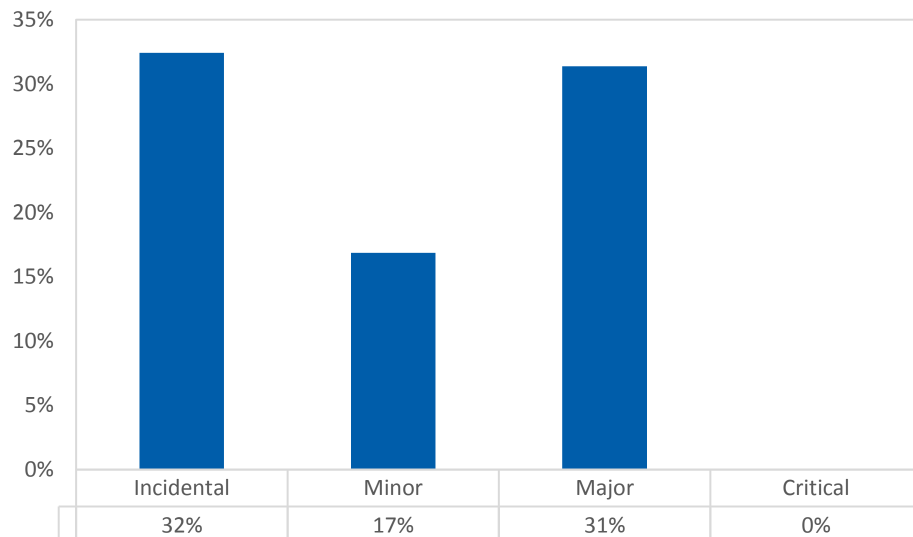
Figure 16. Percentage of Corrections Received by Volume of Violations per Report



	1 to 5	6 to 10	11 to 15	> 15
	57%	38%	0%	0%

Notably, the majority of inspection issues found were not addressed within 30 days, and no more than about one in three major or critical deficiencies were addressed as part of this study's the process. Put another way, only about half of the major and critical deficiencies successfully delivered to installers (as evidenced by their responses to Cadmus' inspection reports) were actually addressed within 30 days. Installers that did respond, however, did so on a voluntary basis. Figure 17 shows the percentage of corrections received per violation, aggregated by violation severity. Markedly, none of the critical issues noted in reports were corrected during our tracking process. As previously noted, each system inspected had already passed all relevant permitting and approval processes. Consequently, installers were under no legal obligation to address issues identified in this study.

Figure 17. Percentage of Issues Corrected by Defect Severity



Medium-Scale Solar Installer Efforts to Address Inspection Findings

The installer for both medium-scale solar PV installations was responsive to report delivery and follow up, but failed to provide finalized corrections for either installation within the allotted 30-day window. Following the first reminder email, the installer responded to both reports at the same time, indicating that the corrections were scheduled for completion.

Wind Energy System Findings

Cadmus inspected one wind energy facility as part of this study and found only incidental installation deficiencies associated with labeling and a non-functional production meter. As the production meter was not required by the program or any known code or standard, Cadmus did not deduct from the Quality Score for this deficiency, and the project received an overall quality score of 4 out of 5. The inspected wind energy facility consisted of three 1.5 MW wind turbines with approximately 80m towers, as shown in Figure 18.

Figure 18. Wind Energy System Tower Base

Conclusions and Recommendations

The REG installation quality study results and findings indicate the majority of REG-funded renewable energy installations were not “safe, high-quality, performing as expected, and in conformance with the stated specifications.”[8] In fact, only 11%[9] of 91 installations studied met these criteria.

As such, Cadmus recommends that OER and National Grid consider a range of educational and programmatic recommendations to improve installation quality in the future. In offering the recommendations that follow, Cadmus remained cognizant of the impact of solar soft costs on Rhode Island’s solar PV market, and made suggestions that would not unduly increase these costs.

Educational Recommendations

Cadmus identified a number of instances that linked installation quality issues to lack of understanding by installers, local electrical or buildings inspectors, or National Grid metering technicians. These education-based recommendations are intended to close knowledge gaps for installers, local electrical and inspectors, and National Grid staff currently engaged in the REG program, as well as installers new to the program.

Offer Training to Existing Program Participants

Renewable Energy Installers

The number of installation violations identified in this study revealed that installers did not complete code- and/or REG-compliant renewable energy systems. Installer feedback in response to inspection reports, whether as questions to Cadmus or completion of corrective actions, suggests that installers often remain unaware that installations are non-compliant. In fact, Cadmus did not find evidence of intentional or malicious poor workmanship.

As such, Cadmus recommends that training and training materials be offered to installers currently installing REG-funded renewable energy systems. The training should be specific to installation issues identified in Rhode Island and within the REG program. Further, the REG metering requirements should be presented clearly and in detail. Training and training materials should provide clear technical guidance, with photos and diagrams easy for installers to understand and to reference as needed. Cadmus recommends that a combination of in-person (e.g., during Rhode Island Solar Stakeholder meetings) and Web-based trainings to maximize training for this audience. Regarding Web-based training, Cadmus further recommends a combination of comprehensive, multi-hour trainings, and short, topical trainings to address all types of knowledge gaps.

[8] A metric specified by the Rhode Island Office of Energy Resources in RFP 7549810, “Solar Quality Assurance Inspection Study and Report”

[9] This figure represents renewable energy systems receiving a score of 5, indicating that the systems had no, or only incidental, deficiencies.

Local Electrical and Building Inspectors

Inspections Cadmus performed for this study followed approval by the local authority having jurisdiction (AHJ). Based on the number of violations Cadmus identified in these previously approved systems, local electrical and/or building inspectors often could not identify noncompliance. These inspectors' jobs do not focus on renewable energy systems. Further, learning about renewable energy systems is not a required aspect of their electrical training or certification. As such, Cadmus recommends further training for local electrical and building inspectors, particularly regarding solar PV and REG metering requirements. Training and technical support materials should provide clear guidance, including photos and diagrams, that local inspectors can easily understand and reference as needed. Cadmus recommends that these trainings be offered in person based on past experiences raining electrical and building inspectors.

National Grid Metering Technicians

Cadmus recommends that National Grid provide education to all metering technicians to reduce inconsistencies and program violations. Training and training materials should provide clear technical guidance, with photos and diagrams easy for the technicians to understand and reference as needed. Cadmus recommends that these trainings be offered in person based on past experiences training field staff for other utilities.

Require Training for New Program Participants

To proactively train new installers seeking to participate in the REG program, Cadmus recommends requiring new program participants to participate in a Web-based training prior to filing an interconnection application for the program. Web-based training could consist of a prerecorded Webinar that addresses REG program requirements, REG metering requirements, and common installation issues. The training could be available online and available for installers and their field staff to access at any time.

After completing the Web-based training, installers would need to certify that they completed the training; this certification could be collected by National Grid and/or OER, along with the interconnection application. For installers failing to complete the training, National Grid could consider suspending the processing of future interconnection applications until the installer completes the training. Cadmus recommends implementing this training requirement beginning in REG tariff years 2018–2019.

Programmatic Recommendations

Closely Manage Self-Installations

The study raised particular concerns regarding the quality of renewable energy systems by self-installers, with one self-installation receiving a score of 1 (critical) and two self-installations refusing inspections altogether. These installations represent a significant quality concern for the REG program and should be closely monitored and managed. Possible approaches that OER and National Grid could consider with respect to these installation types include:

- **Require that self-installers with an electrician's license also obtain a Rhode Island Renewable Energy Professionals (REP) license.** OER and the Department of Labor and Training maintain the REP license in Rhode Island. Although the Electrical Contractor's License already includes the work allowed by the REP limited license, Cadmus recommends that self-installers who are licensed electricians also meet one or more of the additional REP qualifications listed on OER's website.[10]

Rhode Island Renewable Energy Professional Example Qualifications

- North American Board of Certified Energy Practitioners PV Installation Professional certification
- Underwriters Laboratories (UL) PV Installer Certification Program certification
- A certificate of completion from the Department of Energy SunShot

- **Assess an additional nominal application fee for self-installations**. National Grid can use these fees, collected at the same time as the initial interconnection application fee, to support quality reviews of these specific installations. Quality measures could include third-party inspections, additional technical support from National Grid (via phone or in person), or targeted training.
- **Prohibit self-installers from participating in the REG program**. Although a homeowner can legally install a renewable energy system on his or her residence, such installations can prove problematic. Even if the homeowner is a licensed electrician, quality concerns continue as renewable energy systems are not a required aspect of electricians' training. As such, the nuances of renewable energy installations can be missed, resulting in serious safety and cost implications. OER and National Grid could consider prohibiting self-installed renewable energy systems from receiving REG incentives, regardless of whether or not the homeowner is a licensed electrician.

Enhance Program Minimum Technical Requirements

Though Cadmus developed Minimum Technical Requirements for this REG installation quality study (see Appendix A), this document should be enhanced and also adopted for use by National Grid. This document allows clearer communication of OER's and National Grid's expectations for REG-funded renewable energy installations. Further, these Minimum Technical Requirements should be updated regularly (as needed), and updates should be clearly communicated to existing program participants (e.g., installers, building/electrical inspectors, National Grid metering staff) to ensure consistency in program installations.

Modify Requirements for Overhead Service Connections

During the inspections, Cadmus observed many different service connection configurations and noted that the current requirements for overhead services lack sufficient detail to ensure safe, long-lasting operations. Specifically, the study findings determined that the majority of connectors used to make the

10 http://www.energy.ri.gov/renewable/REP/

service point connection were not rated for outdoor environments. As such, Cadmus recommends that specific and consistent requirements are set for service connection configurations. This could be accomplished by requiring all overhead services to upgrade with a multi-gang meter. Alternatively, National Grid could provide a list of approved connectors for this application and implement an interconnection-specific approval process, such as photo pre-approval or documentation verification.

Cadmus understands that, although these approaches may represent an increased cost at the time of installation, future savings will be realized from avoided upgrades and the significant reduction in the possibility of failure. Cadmus also suggests exempting existing electrical services less than 20 years old, which will help reduce unnecessary premature service upgrades.

Ongoing REG Quality Assurance Reviews

Based on the study findings, Cadmus recommends some level of ongoing quality assurance (QA) review for REG-funded renewable energy installations. Specific considerations follow for ongoing REG program QA reviews.

Sampling Rate

OER, National Grid, and the Rhode Island Public Utilities Commission (PUC) should consider the extent and frequency of QA inspections. Cadmus does not recommend inspecting 100% of systems (as the REF program requires) due to current and future high installation volumes for the REG program. Rather, Cadmus suggests applying smart or targeted sampling for higher-risk installations (e.g., low-volume or self-installers) and spot-checking high-volume installers.

In particular, Cadmus recommends implementing a systematic, high-volume installer plan, in which installers with a designated number of installations and proven track record of quality installations are subject to random sampling. A high-volume installer plan would allow OER and National Grid to focus their resources most effectively by devoting more technical resources to installers struggling to properly complete installations, rather than continuing to inspect experienced, high-performance installers.

To supplement this sampling approach, Cadmus also recommends assessing the feasibility of a photo-based inspection process for REG-funded installations. Through this process, installers submit specific photographs of completed installations for review and approval (rather than performing an in-person inspection). Such desktop inspections often can be completed at a fraction of the cost for a field inspection.

Site Access Improvements

Throughout this study, Cadmus was unable to access utility-owned meter enclosures to inspect connections, wiring methods, and other work completed as part of the PV system installation. As a result, the team was not able to fully document these installation methods and offer technical recommendations, if warranted, for improvement.

In order to allow a more thorough inspection, the study team recommends that future quality installation studies or, if adopted, ongoing QA efforts include collaboration between inspectors and utility personnel to allow access to these meter enclosures for inspection. This could be achieved through utility-provided training and meter access privileges for the inspection team, collaboration with onsite utility personnel, or similar means.

Program Feedback

Cadmus recommends an additional component to ongoing QA review: formal collection and analysis of REG program feedback from customers, installers, local electrical/building inspectors, National Grid, OER, and the PUC. Cadmus anticipates that feedback from installers and customers could be gathered through online surveys, while feedback from local electrical/building inspectors, National Grid, OER, the PUC, and other stakeholders could be gathered through phone surveys or more detailed interviews.

Feedback gathered could be used by OER and National Grid to accomplish the following:

- Improve customer experience
- Inform annual ceiling price analysis
- Identify knowledge gaps and education needs

Next Steps

Cadmus recommends that OER and National Grid convene to discuss the findings and recommendations presented in this report. Further, we strongly suggest taking timely action on recommendations to be implemented, to ensure that the quality of REG-funded renewable energy installations improves in the near future.

Appendix A: Minimum Technical Requirements for the Renewable Energy Growth Installation Quality Study

Minimum Technical Requirements for the Renewable Energy Growth Quality Assurance Program

All Rhode Island Renewable Energy Growth (REG) solar photovoltaic (PV) projects must demonstrate compliance with the Minimum Technical Requirements set forth in this document. These requirements are not intended to be all-encompassing, nor are they intended to be a substitute for engineering specifications, compliance with applicable codes, or for safety requirements. Site-specific conditions and/or local regulations may require additional requirements not contained in this document.

Metering Requirements of the REG Program

National Grid requires the PV system installation to be on a dedicated utility meter, separate from the existing premise's meter. See Section 4 of the REG Program Tariff document (RIPUC No. 2151) for more information. Specifically note that there shall be no electrical connection to the load side of the existing utility meter.

Installation Requirements of the REG Program

All installations must follow the most **current edition of all relevant codes and standards, including:**

- SBC-5: Rhode Island State Electrical Code (which incorporates the National Electrical Code [NEC], by reference)
- SBC-1: Rhode Island State Building Code (which incorporates the International Building Code, by reference)
- SBC-2: Rhode Island State One and Two Family Dwelling Code (which incorporates the International Residential Code, by reference)

In addition to the requirements of these, and other, applicable codes, participation in the REG program is contingent on compliance with the following additional requirements, as noted below. In all cases where manufacturer instructions, third-party guides/handbooks, or other materials contradict the most current edition of any local, state, or federal code, the applicable code shall take precedence over such materials.

- Twist-on wire connectors (wire nuts) shall not be used in any outdoor enclosure unless such connectors are listed to UL 486D for use in damp/wet locations. Proof of listing will be required during inspection, if applicable. (See NEC Article 110.28 for more information)
- Installations of ground- and pole-mounted solar arrays must have a disconnect switch as described in Article 690.17 exception two, located at the array, to isolate all DC current carrying conductors. This is not required where the ground- or pole-mounted array consists entirely of AC modules or microinverters.
- Areas where wiring passes through ceilings, walls, or other areas of the building must be properly restored, booted, and sealed. Thermal insulation in areas where wiring is installed must be returned to "as found or better" condition.

- Photographs must be taken of the following system components for all rooftop solar arrays: module frame grounding method, array grounding method, array wire management, module nameplate, interior of all rooftop enclosures, and exterior of all rooftop enclosures. These photos shall be kept on record with the primary installer and made available to OER, or its designees, upon request.
- An owner's manual of operating and maintenance instructions must be provided to the PV project owner and preferably also be posted on, or near, the PV project. The owner's manual should include manufacturer's specifications, serial numbers, warranty policies, emergency contact information, etc.
- Owners must be provided with, at minimum, a basic training that includes maintenance instructions, troubleshooting, meter reading, and electricity generation reporting instructions.
- Solar PV projects designed to be installed on pitched, non-flat roofs, are required to have an azimuth that is the same as the roof azimuth, in order to be eligible to receive an incentive under the REG program.

Common Installation Violations (Informational Reference)

- Supply-Side Connection/Disconnect:
  - Disconnect switches on the supply-side of the service disconnect shall be rated not less than 60A, per NEC Article 230.79(D).
  - Overcurrent protection shall be provided at the disconnect location in accordance with NEC Articles 230.90 and 230.91.
  - NEC Article 250.24(C) requires that the grounded conductor (generally, the neutral conductor) be bonded to the service disconnect enclosure added for the solar PV system. See also Article 250.28(D)(2).
  - Service-entrance conductors shall follow the wiring methods of NEC Article 230.43, and shall not be of NM cable (Romex®).
  - Consideration should be taken for available fault current at the line terminals, as required by NEC Articles 110.9 and 110.10.
  - Utility conductors shall always be connected to the LINE terminals of a disconnect switch, otherwise fuses may be energized in the open position. See NEC Article 404.6(C).
- Indoor-rated twist-on wire connectors (wire nuts) shall not be used in outdoor enclosures. NEC Article 110.28 indicates this area can be a damp or wet location, and such installation may violate the listing of the connector(s), see also Article 110.3(B).
- NM cable shall not be sleeved in outdoor raceways. NEC Article 300.9 defines the interior of such raceways as a wet location and NEC Article 338.12(B)(4) prohibits this cable to be installed in a wet location.

- NEC Article 300.7(A) requires raceways passing from the interior to the exterior of a building be filled with an approved material to prevent the circulation of warm air to a colder section of the raceway.
- NEC Article 250.24(A)(5) prohibits a grounded (neutral) conductor to be connected to ground at any location downstream of the service disconnecting means. Common violations include this connection in a customer-owned PV meter enclosure or an AC combiner panelboard.
- Terminal ratings and conductor size/limitations must be followed per NEC Article 110.3(B). Common violations include multiple conductors under a terminal listed for a single conductor (NEC 110.14), or conductors undersized for the terminals, such as inside a meter enclosure.

Appendix B: Cadmus Standard Operating Procedure for Inspector Communication with the Customer

Cadmus Standard Operating Procedure for Inspector Communication with the Customer

Prior to arriving on site, the inspector will be properly prepared and equipped to perform a prompt, thorough inspection. The inspector will act in a professional manner, clearly and concisely explaining the inspection's goals. The inspector will be well dressed, with presentable and professional attire. Boot covers, an article of waterproof cloth covering, will remain on hand to encase the inspector's footwear if weather conditions may cause dirt or mud to enter the house. Care always will be taken to treat the homeowner's home with respect.

The inspector will introduce himself/herself and explain that the onsite efforts benefit both parties—installer and customer. This process helps improve installers' best practices, ensures quality system installations for homeowners, and leads to higher-quality future installations. The inspector will engage in a friendly and courteous dialogue with the customer to provide a positive experience for the homeowner. As a common courtesy, the inspector always will ask permission before visiting any location in the house or before moving around the property.

During the initial dialogue, the inspector typically will discuss the following:

- **The inspection's purpose.** The inspector will explain to the homeowner that the site visit is intended to inspect the solar photovoltaic (PV) system and to ensure it operates in compliance with applicable National Electric Code/Building Code editions. This inspection occurs as renewable energy installations receive rebates from the state/utility, which both wish to ensure installations of high-quality, productive products that warrant incentive payments. The homeowner will not receive a copy of the final report as it is intended just for the installer, given the installation technical aspects it involves.
- **Conditions looked for.** The inspector will inform the homeowner that every system aspect will be examined to identify violations not complying with applicable electrical/building codes. As a preemptive answer, the inspector may provide examples of violations (e.g., labeling violations, bonding/grounding violations, flashing/water leakage violations).
- **Home areas requiring access for inspection.** For a complete and thorough inspection, the inspector will ask for permission to access the solar modules (typically on a home's roof), the PV

system electrical components, the main electrical panel, the route taken by conduit, and the attic (if applicable/accessible).

- **The inspection's duration.** In initial conversations with customer, the inspector will explain that the inspection lasts about one hour.

Upon completion of the initial dialogue, the inspection will commence. Photos will be taken of all PV system components, and all violations will be noted for the inspection report initial draft. Following the inspection's completion, another short conversation between the homeowner and the inspector will address the following topics:

1. **General overview of the inspection.** The inspector will inform the homeowner that the inspection has been completed. The homeowner will not be told of violations unless an immediate safety issue requires shutting down the system.

    a. **Major, minor, and incidental violations.** The homeowner will not be informed of these violations as Cadmus staff must first review the initial inspection report before violations can be included in the final report. The homeowner likely will not be familiar with PV system installations and need not be concerned with such infractions.

    b. **Critical violations.** Such violations require a system's immediate shut down. The inspector must call his/her supervisor, explaining the violation to confirm the need for a shutdown. The inspector will then contact the installer to explain why the system had to be shut down. Finally, the inspector will explain to the homeowner why the system had to be shut down and that the installer has been notified of the violation.

2. **Wrap-up.** Provided a critical violation has not been observed on site, the inspector will inform the homeowner that the inspection has been completed. A Cadmus supervisor will review the inspection report, which then can be submitted to the installer. Cadmus will instruct the installer to correct any violations found during the inspection, which Cadmus will verify through photo submittals from the installer (or in rare cases, a re-inspection). Upon the inspection's completion, the homeowner need not take further action unless the installer must schedule corrective actions required by the report and the state.

More information about Cadmus' solar quality assurance work can be found at http://www.cadmusgroup.com/our-services/energy-services/renewable-energy/.

Appendix C: Sample PVQUEST Report for the REG Installation Quality Study

PV SYSTEM INSPECTION REPORT

Application ID: REG0095			
Inspection Date:	2/20/2017 3:36:01 PM	System Inspector:	Chris Houtz
System Complete:		System Quality Assurance Score:	1

Site Information	
Customer Name:	NAME
Company:	COMPANY
Site Address:	ADDRESS
City:	CITY
State:	RI
ZIP:	ZIP

System Status
Operating Normally

System Installer Information	
Installer Name:	
Contractor:	CONTRACTOR
Phone:	
Email:	

Inspection Conducted With:	Site Owner

PV Installation Photograph (Curb View)

The following QA inspection report identifies all non-conformances found during the post-installation field inspection. This report, to the extent possible, attempts to ascertain the system's compliance with OER's Minimum Technical Requirements for the Renewable Energy Growth.

Disclaimer: The inspection is completed in good faith based on submitted documentation, onsite observations/measurements, and other information received from OER, the system installer, and/or other sources. The reviewer makes no warranty for the design and installation of the system under review and assumes no liability for the reviewed system's operation and/or performance.

Equipment Verification / Array

	Program Records	Observed
Array Module Quantity	23	20
Array Module Manufacturer	Sun Power	Verified
Array Azimuth (degree)		180
Array Tilt (degree)		34
Array Module Model Number	SPR-X19-320	Verified

Equipment Verification / Inverter

	Program Records	Observed
Inverter Quantity	1	Verified
Inverter Manufacturer	Solar Edge	Verified
Inverter Model Number	SE7600A-US	SE6000A-US

System Verification / Overall Observations

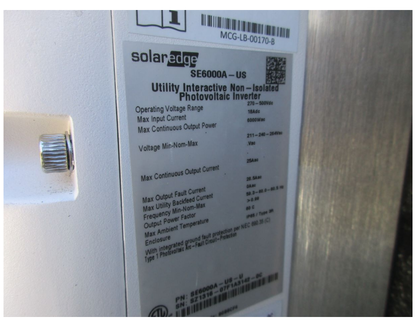
	Program Records	Observed
System Capacity	7.36	6.4
TSRF		

Administrative Program Compliance / *Array : Best Practice*

ID#	Defect Category	Deficiency Description	Inspector Comments
A_EV013	Incidental	Module quantity observed does not match program records. The system installer must submit a revised project completion form reflecting the system, as installed, including any changes to the total project cost and provide copies of the new specifications and equipment warranty information to the OER.	

Administrative Program Compliance / *Inverter : Best Practice*

ID#	Defect Category	Deficiency Description	Inspector Comments
SI_EV032	Incidental	Inverter model number does not match program records. The system installer must submit a revised project completion form reflecting the system, as installed, including any changes to the total project cost and provide copies of the new specifications and equipment warranty information to the OER.	



Administrative Program Compliance / *Overall Observations : Best Practice*

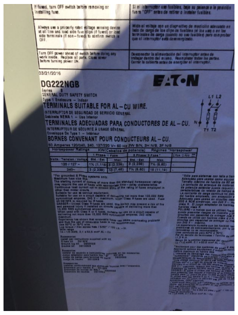
ID#	Defect Category	Deficiency Description	Inspector Comments
OO_SC21	Major	System capacity (nameplate kWdc) does not match program records and may be resulting in overpayment of incentive.	20 modules X 320W = 6.4kWDC

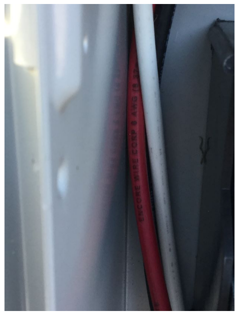
Program and Code Compliance / *Array : Corrective Action Required*

ID#	Defect Category	Deficiency Description	Inspector Comments
A_EL27	Minor	No electrical bonding means (e.g., bonding jumpers) observed between rail sections, as required by NEC Articles 690.43 and 110.3(B).	No bond has been made to the cross beams.

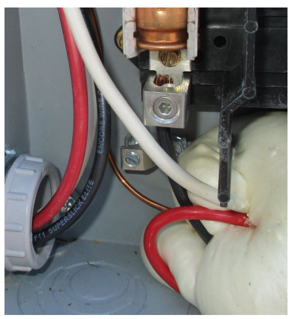
Program and Code Compliance / *Supply Side Connection : Corrective Action Required*

ID#	Defect Category	Deficiency Description	Inspector Comments
SSC_EL01	Major	Disconnect is incorrectly rated for service entrance use and/or does not have a minimum current rating of 60A, in violation of 230.79(D).	Service conductors are not sized to the enclosure's rating, in violation of NEC 240.43.

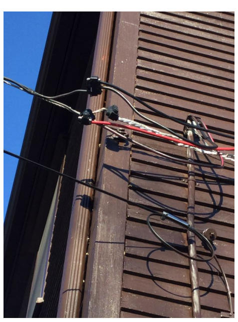




ID#	Defect Category	Deficiency Description	Inspector Comments
SSC_G06	Major	Grounding electrode conductor is missing or undersized, in violation of NEC Articles 690.47(C), 250.66, 250.122, and 250.166.	This section of the GEC appears to be #10 AWG which is undersized.



ID#	Defect Category	Deficiency Description	Inspector Comments
SSC_C01	Minor	Service Entrance conductor splice is not installed in accordance with its listing, in violation of NEC Article 110.3(B) and 110.14.	The piercing connectors do not appear to be listed for outdoor use.



SSC_L01	Incidental	Permanent plaque or directory denoting location of all power sources and location of disconnects on premise at each service equipment location is missing, incomplete, or unsuitable for the environment, in violation of NEC Articles 705.10, 690.56 and/or 110.21.	Missing label denoting "Service Disconnect x of 2".