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

FINAL REPORT

November 5, 2018

Prepared for:

Rhode Island Office of Energy Resources

315 Iron Horse Way, Suite 101

Providence, RI 02908

Prepared by:
Danielle Burns
Tyler Orcutt
Matt Piantedosi
Shawn Shaw, P.E.

CADMUS

Table of Contents

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

Cadmus, working under contract to the Rhode Island Office of Energy Resources (OER), performed an independent study of installation quality 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.

As of October 2018, Cadmus completed inspections on 86 small-scale solar, eight medium-scale, and six large-scale solar photovoltaic (PV) systems installed through the REG program, the results of which this report presents. Cadmus performed inspections 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. All inspections conducted as part of this study were completed after each project received approval from the relevant authorities and permitting agencies in order to provide the most accurate information possible on completed installations within the program.

This report includes the following key study findings:

- **Forty-seven percent of small-scale solar PV systems inspected exhibited major or critical installation deficiencies.** Major and critical deficiencies can be considered those expected to cause immediate or short-term risks of system failure, reduced operating capacity, or systems that pose a safety hazard.
- **Most installation deficiencies occurred at the PV array and point of interconnection.** Issues such as grounding, labeling, and wire management appeared most frequently at these locations.
- **Quality scores under this study were, on average, 0.34 points lower than scores under the 2017 quality study.** Using Cadmus' scoring system, a code-compliant system scores a 5, while systems with multiple major and/or critical issues would score a 1.
- **Installers who participated in both the 2017 and 2018 studies improved in overall quality scores.** Of installers who were inspected under both study rounds, quality scores were 0.47 points higher in this study than in the 2017 quality study.
- **Installers that previously participated in the REF program had an average quality score of 3.11, while non-REF participating installers had an average quality score of 2.54.** Installers participating in the REF program are exposed to mandatory quality measurements through physical inspections, installation photo reviews, and/or more stringent technical requirements.

Based on these findings, Cadmus recommends the following high-priority improvements be made to support improved installation quality in the REG Program. Cadmus considered recommendations high priority if they had higher anticipated impacts and shorter implementation timelines (less than six months).

- **Offer training to renewable energy installers**
- **Collect and report additional data related to installation quality**, specifically license information and production estimate/Total Solar Resource Fraction
- **Offer training to local electrical and building inspectors**
- **Closely manage self-installations**
- **Require training for new program participants**, through a web-based training
- **Add disclaimer language to REG tariff documents** regarding potential inspections

Introduction

This report presents the final 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. Results draw upon Cadmus' on-site inspections of 86 small-scale, eight medium-scale, and six large-scale solar photovoltaic (PV) installations. Cadmus completed a similar study of installation quality in 2017, the results of which were published by the Rhode Island Public Utilities Commission (PUC).[1]

A 10-member Distributed Generation Board (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 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 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 and size delineation. National Grid's publishes annual enrollment targets and incentive levels.[2]

Two general projects categories delineate the program:

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

---

1 The Cadmus Group, LLC. *Study of Renewable Energy Installation Quality in the Renewable Energy Growth Program.* 2017. Available online: http://www.ripuc.org/eventsactions/docket/4604-OER-Cadmus-Study-InstallationQuality(11-14-17).PDF

2 National Grid. "Rhode Island Renewable Energy Growth Program." Date accessed May 2018. Available online: 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 year 2017.

OER requested that the study determine 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 (QA) efforts.

Table 1. REG Study Goals

Cadmus Research Questions for REG Installation Quality Study
What is the quality of renewable energy installations across technologies, system sizes, and installers?
• Base on inspection results measured on Cadmus' 1 to 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 year 2017 • 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; and 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?
• Assess from results of the program-wide average quality score • Inform by the frequency and severity of installation issues found

[3] A metric specified by the OER in RFP 7549810, "Solar Quality Assurance Inspection Study and Report." 2015.

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.

Sampling Process

With respect to sample selection, Cadmus recommended distributing inspections across technologies, system sizes, and installers, with each technology type and size receiving two inspections per installer. Table 2 list the target number of inspections and installers for each technology type and size. During the study, Cadmus reallocated various resources from the small, medium, and large solar inspection categories in coordination with OER, based on the number of projects completed and available for inspection during the study period.

Table 2. 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	85	22	86	17
Medium Solar Inspections	7	2	8	6
Large Solar Inspections	3	2	6	4
Total	**95**	**26**	**100**	**27**

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 small solar systems, self-installed by the owner of a residence.

4 The Narragansett Electric Company. *Renewable Energy Growth Program for Residential Customers.* 2016. Available online: https://www9.nationalgridus.com/narragansett/non_html/Clean-RE%20Growth%20Residential%20Tariff%20Revisions%20(PUC%208-12-16).pdf

The Narragansett Electric Company. *Renewable Energy Growth Program for Non-Residential Customers.* 2016. Available online: https://www9.nationalgridus.com/narragansett/non_html/Clean-RE%20Growth%20Non-Residential%20Tariff%20(PUC%208-12-16).pdf

For small-scale solar installations, the study team 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 Cadmus' team to apply the study's results to the program on a broader scale. Table 3 shows the target number of inspections for each installer type and size.

Installers sometimes use subcontractors to perform onsite electrical work. The data provided for this study did not include information on subcontractors, but Cadmus was able to track the performance of certain subcontractor companies based on electrical permit information and/or anecdotal feedback from installers.

Table 3. Small Solar Statistical Sampling Methodology

Installer Category	Projected Sample Size
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. This role 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, and the team 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.

A component of Cadmus' inspection, unique to the REG program, was reviewing each system's dedicated utility meter—in parallel with 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' inspectors 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 preliminary 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 our 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 staff 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 the team could effectively conduct inspections. Table 4 lists data Cadmus received prior to inspections.

Table 4. 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, model, and number of PV modules • Inverter manufacturer, model, and 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. This used data collected through thousands of PV inspections to program PVQUEST with the most common and most serious installation issues.

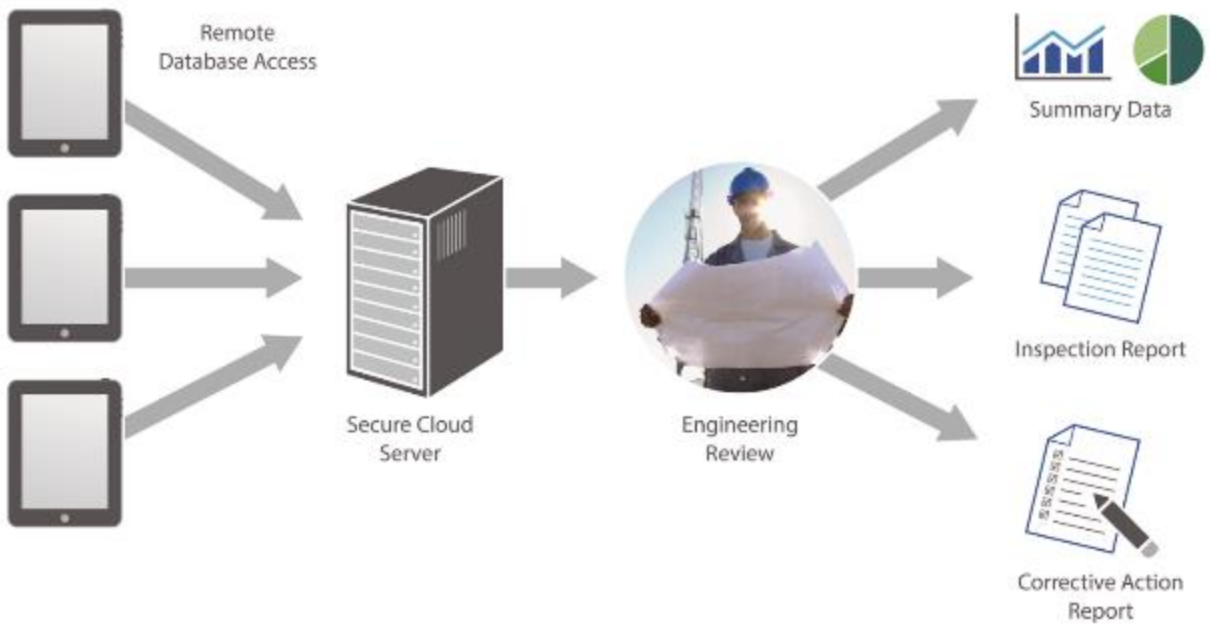
For the REG study, as inspectors proceeded through inspections, PVQUEST provided a customized checklist of inspection issues, specific to each major system component (e.g., microinverters, alternating current [AC] disconnects, supply-side connections, and subpanels). Consequently, PVQUEST's highly specific inspection fields ensured, to the extent possible, that each inspector met to the same standard.

Inspectors adhered to the following steps when using PVQUEST on field inspections:

- Imported site and system data into PVQUEST
- Completed inspection using PVQUEST running on tablet computer
- Uploaded inspection report to secure cloud database

Once uploaded to a secure database, an engineering manager reviewed the inspection report and approved it or, if applicable, submitted a Corrective Action Report (CAR) to the installer for corrections. The tool stores and summarizes the inspection data in various PVQUEST data tables for future reference.

Figure 1. Overview of PVQUEST Data Flow and Outputs



Based on violations identified during on-site inspections, PVQUEST generated a quality score, which Cadmus used to determine the quality of each system inspected. Table 5 lists the defect category or severity given to each inspected installation issue, along with typical scores for each type of installation issue.

Table 5. 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	**3**

Defect Category	Description	Typical Score for Systems with Issues of This Type
	around boxes, undersized circuit protection, and improperly supported conductors.	
Major	**Issues deemed likely to affect system performance or safety in the short-term, though not an immediate hazard.** Examples: Missing equipment grounding, module damage, 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**

For example, a PV system with at least three 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. Additionally, a PV system with one or two incidental (often labeling) issues would result in a score of a 5. Only systems with major or critical deficiencies can receive the lowest score: 1 out of 5.

Inspectors based all of their observations 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 lacked the consensus and rigor of code-making processes; hence, for this study, the team did not reference them as a basis for inspection.

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, our team could generate draft site-specific inspection reports quickly, allowing timely delivery of results to installers—particularly when identifying hazardous violations. Along with the final inspection report, the team included a template CAR (described above) to installers. Cadmus asked installers to complete the CAR by documenting the modifications they made to address identified violations and then return the completed CAR 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, the team 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 and/or points of contact once a week for three weeks following an inspection.

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

If Cadmus did not receive notice that the appropriate parties had addressed the violations four weeks after the inspection, it sent the installer, system owner, and OER the finalized inspection report, citing outstanding violations. Cadmus instructed the installer to report any subsequent corrections to OER.

Additionally, the team tracked the time between receiving an inspection report and submitting acceptable evidence of corrections for each system inspected. Cadmus handled communications 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 were responsive to the initial report and CAR email, such as indicating through self-certification that they had scheduled the corrections or otherwise acknowledged receipt of Cadmus' report. For this study, Cadmus tracked both the dates of these initial responses and the dates when installers submitted acceptable corrections and reported these results separately. In some cases, the first response from an installer included the submittal of corrections, noted by an identical response and corrections date.

Through this process, Cadmus assessed the following elements of responsiveness:

- 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?" Cadmus 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 calculated a variety of summary statistics using the PVQUEST score, including these:

- 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 users can track, count, and summarize all 800 unique installation defects in the database independently. This provided many analysis options and allowed the 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, Cadmus associated each deficiency with a particular component (e.g., PV array, alternating current (AC) disconnect, and supply-side connection) and with an issue type (e.g., grounding, labeling, and workmanship). This allowed the team to not only categorize the most common specific deficiencies, but to identify where the majority of deficiencies occurred within the system. This allowed stakeholders to target their training and internal QA efforts accordingly (e.g., focus on array wire management issues).

Assessment of Installer Responsiveness to Quality Issues

Cadmus records and tracks installer responsiveness through careful monitoring of its shared REG inspections email account and ongoing data tracking. This records any responses from installers or correspondence between Cadmus and an installer, which can range 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 reviews and approves the corrections, and marks the site as “completed” in the tracking system.

Study Findings

From January 1, 2018, to September 24, 2018, Cadmus successfully completed 100 total solar PV system inspections. Table 6 shows the number of small and medium/large inspections by REG tariff year, and the overall percentage of installations that were inspected as part of this study.

Table 6. REG QA Study 2018 Inspections by REG Tariff Year

Inspections by REG Tariff Year				
Inspection Type	REG Tariff Year	Total Number of REG Installations	Number of Inspections Performed	Percentage of REG Installations Inspected
Small Solar	2016	1,351	1	0.1%
	2017	1,832	85	5%
	2018	774	0	0%
Medium/Large Solar	2016	52	0	0%
	2017	55	14	25%
	2018[a]	27	0	0%

The findings summarized below present the study's technical outcomes related to physical installations inspected. These include Cadmus' assessments of installation quality, code compliance findings, and discussions of energy yield and shading issues.

Small Solar PV System Findings

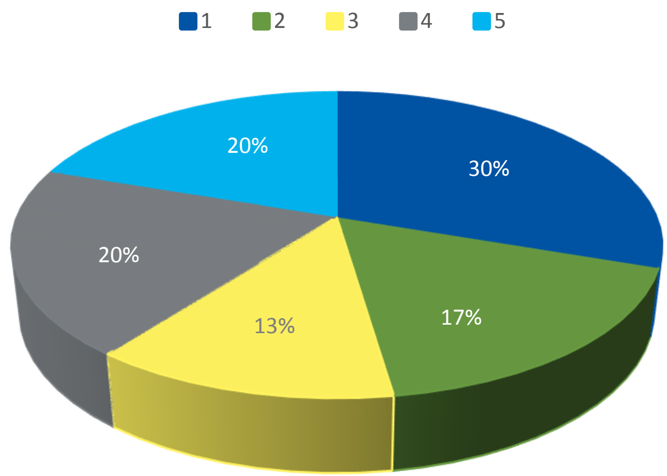
Overall Installation Quality Scores

Cadmus calculated the average quality score for projects inspected through this study. Overall, approximately 48% of systems examined received a quality score of 1 or 2, indicating the presence of major and/or critical installation deficiencies, as shown in Table 7 and Figure 2.

Table 7. Solar Quality Score Summary (Small-Scale)

Solar Quality Score Summary		
Score	Inspection Criteria	Count
1	System has critical and/or multiple major deficiencies	26
2	System has at least one major deficiency	15
3	System has multiple minor deficiencies	11
4	System has minor and/or incidental deficiencies	17
5	System as no or only incidental deficiencies	17

Figure 2. Summary of Small PV Solar Quality Results by 5-point Inspection Score (5 = highest)



As Cadmus designed the sampling process to distribute limited study resources across as many installers as possible, the average score shown above does not truly represent the actual population of REG projects, only the average across projects inspected for this study.

> The program-wide weighted average presents a more realistic assessment of the program-wide installation quality than the average calculated across the study sample

To convert this estimate into a program-wide installation quality estimate, Cadmus calculated the average score per installer, and 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 a greater emphasis on higher-volume installers, presenting a more realistic assessment of the program-wide installation quality than the average calculated across the study sample. The program-wide weighted average equaled 2.44, as shown in Table 8—slightly lower than the unweighted average score of 2.81.

Table 8. Small-Scale Inspection Results During the Study Period

Inspection Month	Total Inspections	Count by Quality Score					Average Score
		1	2	3	4	5	
January 2018	6	2	0	0	1	3	3.50
February 2018	12	4	2	0	3	3	2.92
March 2018	6	1	2	3	0	0	2.33
April 2018	26	8	4	6	4	4	2.69
May 2018	19	6	4	2	4	3	2.68
June 2018	11	3	2	0	3	3	3.09
July 2018	5	1	1	0	2	1	3.20
August 2018	1	1	0	0	0	0	1.00
Totals	**86**	**26**	**15**	**11**	**17**	**17**	**2.44**

One installer with 10 inspections accounted for a significant portion of low-scoring inspections. Of these installer's 10 inspections, 9 inspections received a score of 1, indicating critical issues with quality. If inspections from this installer are excluded as outliers, the program-wide average quality score is 3.01.

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-scoring installer's average at 4.80.

Self-Installer and Low-Volume Installer PV Systems

Approximately 44 of the 86 small-scale inspections addressed systems installed by very low-volume installers. Cadmus defined very low-volume installers as those with fewer than eight operational REG projects during tariff year 2017. Installations from very low-volume installers totaled 191 operational projects out of 475 operational projects at the initiation. These 44 inspections identified 310 violations, resulting in an average score of 2.52. The only self-installer contacted during the study refused inspection altogether.

> 12 of the 17 installers inspected through the course of the study were defined as low-volume installers (70%). The average score for these low-volume installers was **2.52**, compared to a **3.04** average score for high-volume installers**.**

These installations had a lower overall quality level than others inspected in the study, likely due to the installers' lack of familiarity with solar PV-specific codes, standards, and installation best practices in Rhode Island.

Table 9. Inspection Scores for Low-Volume Installers

Installer ID	Number of Inspections	Average Score
1003	5	3.80
1018	5	4.80
1020	5	3.20
1021	1	3.00
1027	7	1.00
1030	5	2.40
1031	1	1.00
1032	1	1.00
1037	4	1.50
1038	3	1.67
1039	2	3.50
1041	5	3.40

Most Common Installation Issues

In the 86 inspections completed, Cadmus found 509 installation issues, with 506 of these violating relevant codes and standards.

The majority of the issues occurred at the array or the supply-side interconnection point. Not only did the majority of installation deficiencies occur at these two locations, but these two inspection elements exhibited the majority of *major and critical deficiencies*. Cadmus also found a significant number of issues at the inverter and AC combiner elements.

Table 10. Summary of Inspection Issues Found by Defect Category and Inspection Element (Small-Scale)

Inspection Element	Recommendation	Incidental	Minor	Major	Critical	Total
AC Combiner	0	14	13	4	0	31
AC Disconnect	0	3	2	0	0	5
Array	0	27	93	67	3	190
Inverter	0	42	35	4	0	81
Junction Box	0	1	5	0	0	6
Optimizer	0	0	2	2	0	4
Overall Observations	3	0	0	0	0	3
Production Meter	0	0	2	0	0	2
Supply-Side Connection	0	110	68	9	0	187
	3	**197**	**220**	**86**	**3**	**509**

Examples of Common Installation Deficiencies

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

Racking System Mechanical Connections Incorrectly Made

Frequency
25 Observations

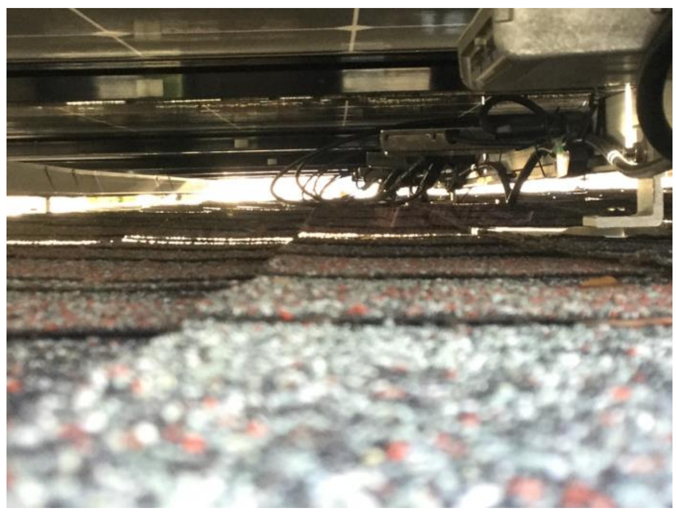
Potential Impacts
Racking components are designed and evaluated to be installed in accordance with their installation instructions. Variations from the instructions may result in premature failure or damage to modules. A common example is a rail extending beyond its limit, creating a cantilever effect.

Best Practices
Equipment should be installed in accordance with manufacturers' instructions. Hardware should not be used beyond its limitation.

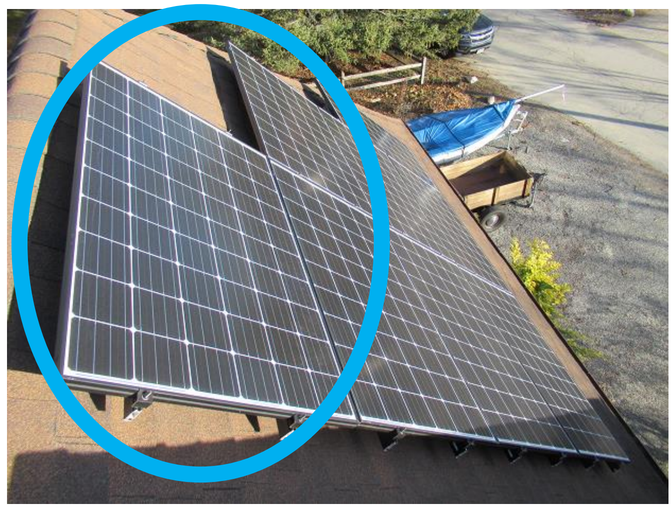
PV Modules Improperly Secured and Fastened in Place

Frequency 28 Observations	
Potential Impacts Modules not properly secured to racking pose risks 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.	

Array Conductors Improperly Secured and Protected

Frequency 19 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.	

No Means of Grounding Module Frames

Frequency 10 Observations	
Potential Impacts Modules not properly bonded might not facilitate the inverter's ground-fault protection in the event of an electrical fault.	
Best Practices Several methods exist to properly bond modules through electrical terminations and mechanical hardware listed to UL 1703.	

A Unique Interconnection

Unlike a traditional grid connection, which typically occurs on the customer's side of the meter (commonly known as "behind the meter"), the connection method for this program is exclusively on the utility side of the existing meter. A new utility meter is installed for the PV system, acting similarly to a "new tenant" meter on the premises creating a parallel metered connection. National Grid outlines specific requirements[5] for this new connection. If the existing electrical service is underground, the only permissible connection method is to replace the existing meter enclosure with a multi-gang enclosure (as shown in Figure 3).

For overhead services, the two permissible methods include replacing the existing meter enclosure (shown in Figure 4), akin to the underground service option, and adding parallel service conductors (also shown in Figure 4). For this option, Cadmus often observed issues regarding with electrical connections or support methods, as noted below. Under REG Round 1, Cadmus observed 214 total inspection deficiencies related to interconnection methods; these ranged in severity from Recommendations to Critical Issues, accounting for approximately 37% of total deficiencies observed. During this round, we observed a total of 187 deficiencies at this location, accounting for approximately 37% of total deficiencies observed.

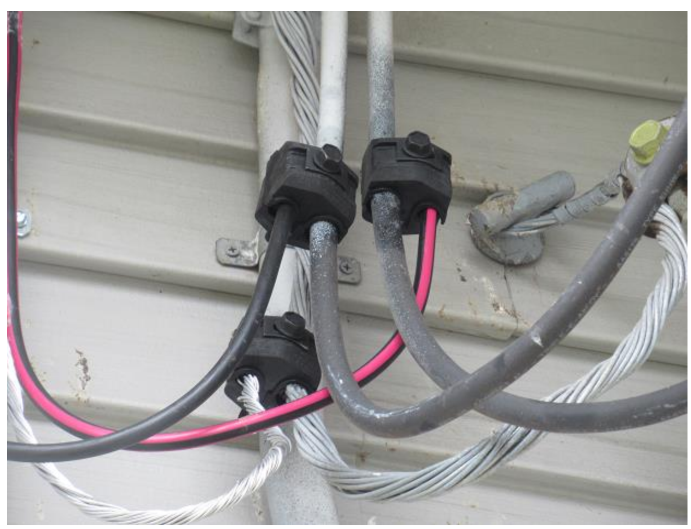
---

5 National Grid. "Interconnection Process." Accessed May 11, 2018. Available online: https://www9.nationalgridus.com/narragansett/business/energyeff/4_interconnection-process.asp

Figure 3. Example of Multi-Gang Meter Enclosure on Underground Electrical Service

Figure 4. Example of Parallel Service Cables (Left) and a Single Service Cable with a Multi-Gang Meter (Right)

Service Entrance Conductor Splice Incorrectly Installed

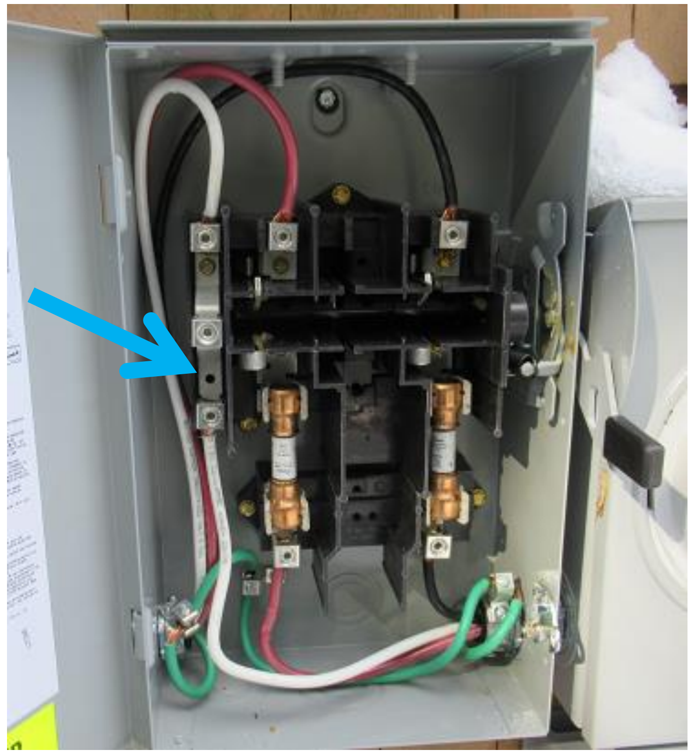
Frequency 23 Observations	
Potential Impacts Connectors are evaluated for specific conductors and specific environments. This particular connection almost always occurs in free air, exposed in outdoor locations. If connectors are installed in a location or with conductors they have not been evaluated for, there will be a higher probability of failure.	
Best Practices Consideration should be given to the conductor size, type, and quantity, as well as to the environment in which they are installed.	

Grounded Conductor Incorrectly Bonded to PV Service Disconnect Enclosure

Frequency
16 Observations

Potential Impacts
When a grounded conductor is not bonded in the PV service disconnect enclosure, it may not have an effective reference in the event of a fault. The main bonding jump is used to help limit the voltage imposed on the system by lightning or other fault sources.

Best Practices
The most common type of connection is by a screw provided by the disconnect manufacturer. The screw should be installed to bond the grounded conductor to the equipment and grounding electrode system.



Service-Entrance Cable Unsupported

Frequency
17 Observations

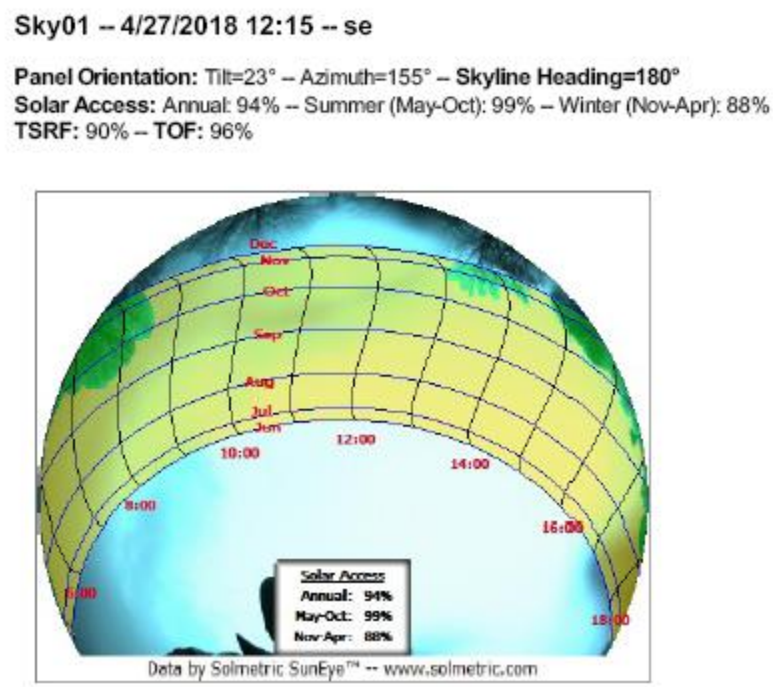
Potential Impacts
Service-entrance cables that are not supported at proper minimum intervals risk an increased probability of degradation, as well as a negative esthetic appearance.

Best Practices
NEC contains minimum support intervals for various cable or raceway wiring methods. Shorter intervals may be required to better affix the wiring method to the surface.

Shading and Electricity Generation

As part of the inspection protocol under both the REG and REF programs, Cadmus generated shading reports at sites using Solmetric SunEye technology. These reports assessed the solar access and shading obstructions of a particular site to produce a metric known as the total solar resource fraction (TSRF). TSRF values range from 0% to 100%, and solar PV incentive programs can use them as eligibility requirements. The REF program has an 80% minimum TSRF requirement. Although homeowners may not know the actual TSRF value for their site, they can be confident that the production estimate provided by the installer will incorporate a TSRF at 80% or higher. Figure 5 shows an example of skyline analysis from a small-scale solar REG inspection.

Figure 5. Example Skyline Generation from REG SunEye Report



Unlike the REF program, the REG Program does not have a minimum shading or TSRF requirement. Overall, of the 70 small-scale TSRF measurements performed, 24 systems had a TSRF less than 80%. No particular installers were responsible for a larger proportion of low-TSRF sites, although approximately 65% of the sites listed in Table 11 were installed by low-volume installers. In one instance, Cadmus identified a system (REG1024) that contained an array installed on the north side of a home, paired with significant shading to the south for other arrays. As a result, the system had a TSRF of 45.6%. Another system (REG1526) had a TSRF of 62% due to significant shading on the system. PV systems oriented to the north and/or containing significant amounts of shading are generally a poor investment for homeowners.

Table 11. Low TSRF Values for Small-Scale REG Inspections

Cadmus ID	TSRF
REG1002	76%
REG1014	78%
REG1024	44%
REG1056	74%
REG1104	75%
REG1132	79%
REG1133	72%
REG1147	76%
REG1159	77%
REG1205	76%
REG1244	71%
REG1299	79%
REG1319	71%
REG1357	78%
REG1381	70%
REG1391	73%
REG1458	71%
REG1459	78%
REG1526	62%
REG1608	76%
REG1842	68%
REG2012	77%
REG2085	77%
REG2126	74%

Comparisons to 2017 REG Study

In 2017, Cadmus performed a study of renewable energy installation quality in the REG program, assessing REG systems installed under tariff years 2015 and 2016 (2017 study). The Rhode Island PUC published the study results in April 2017.[6]

The 2017 study produced a small-scale weighted score[7] average equating to 2.78, in comparison to the 2018 study's weighted average of 2.44. Although the 2018 weighted average was lower than 2017, individual scores by installers improved in 2018. Low- or very low-volume installers installed approximately 50% of the sites inspected in 2018. While individual scores were higher than in 2017, their impacts on the overall program weighted average was minimal. Though this trend shows an improvement from installers previously participating in both study years, larger-volume installers or new entrance installers produced lower scores.

Under this iteration of the REG quality study (2018 study), inspections that resulted in a quality score of 1 or 2 made up a higher percentage of total inspection scores.

Figure 6. 2017 Score Summary

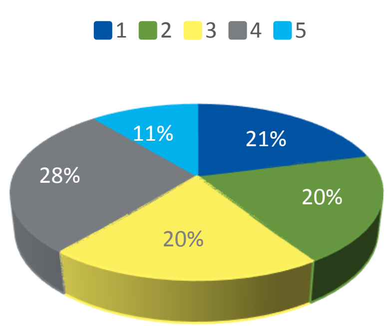
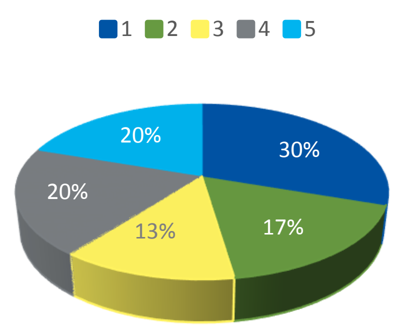


Figure 7. 2018 Score Summary



For each inspection defect category, Cadmus observed a percentage of total citations in 2018 similar to that of the 2017 study, as shown in Table 12.

---

6 The Cadmus Group, LLC. *Study of Renewable Energy Installation Quality in the Renewable Energy Growth Program.* 2017. Available online: http://www.ripuc.org/eventsactions/docket/4604-OER-Cadmus-Study-InstallationQuality(11-14-17).PDF

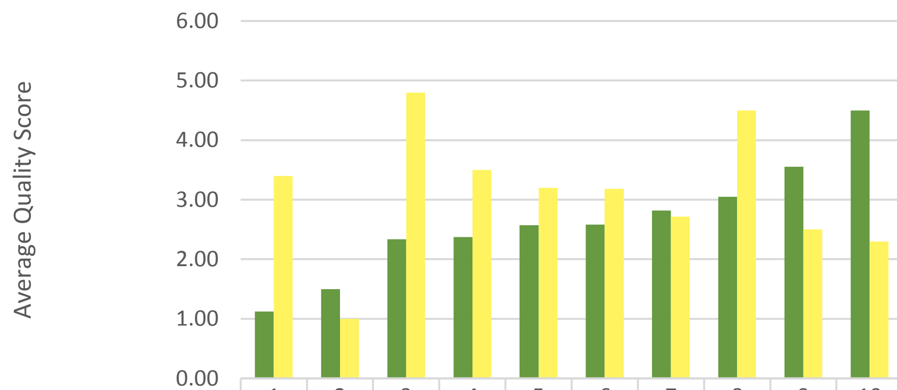
7 Cadmus calculated weighted average by using a weighting factor based on each installer's quantity of projects completed under the REG program.

Table 12. Defect Categories as Percentage of Total Citations

Defect Category	2017 Study	2018 Study
Recommendation	3%	1%
Incidental	50%	39%
Minor	35%	43%
Major	11%	17%
Critical	1%	0.6%

For installers inspected as part of the 2017 and 2018 REG installation quality studies, Cadmus found 2018 scores improved over 2017 scores. On average, inspection scores for these installation companies were 75% higher for projects inspected under the 2018 study.

Figure 8. Average Score Comparison under 2017 and 2018 REG Quality Studies for Selected Installers



	1	2	3	4	5	6	7	8	9	10
2017 REG QA Score	1.13	1.50	2.33	2.38	2.57	2.58	2.82	3.05	3.56	4.50
2018 REG QA Score	3.40	1.00	4.80	3.50	3.20	3.18	2.71	4.50	2.50	2.30

Table 13. Average Scores per Installer under 2017 and 2018 REG Quality Studies

Installer ID	2017 REG QA Score	2018 REG QA Score
1041	1.13	3.40
1032	1.50	1.00
1018	2.33	4.80
1039	2.38	3.50
1020	2.57	3.20
1043	2.58	3.18
1023	2.82	2.71
1029	3.05	4.50
1025	3.56	2.50
1005	4.50	2.30
1027	Uninspected	1.00
1030	Uninspected	2.40
1003	Uninspected	3.80
1037	Uninspected	1.50
1038	Uninspected	1.67
1021	Uninspected	3.00

Comparisons to the REF Program

The Rhode Island Commerce Corporation administers the REF program—a grant and loan incentive program. Cadmus facilitates QA inspections as a program entry requirement, including inspection and implementation of the corrective action process, if warranted, for all REF-funded systems.

Sites inspected under the REF program during a timeframe similar to that of REG sites inspected under this study reflected an overall quality score of 3.26. The 2018 REG study observed an overall, weighted quality score of 2.44.

This study included system inspections for seven installers unique to the REG program, therefore not having participated in the QA inspections process through REF. Notably, non-REF participating installers had an average quality score of 2.54 (as shown in Table 14), while installers that previously participated in the REF program had an average quality score of 3.11.[8] This score discrepancy may reflect a larger breadth of code and best-practice knowledge in REF participating installers, acquired through direct involvement with the program's rigorous QA process.

8 This average reflects all installers participating in the REF program, including those inspected outside of tariff year 2017's REG installation period.

Table 14. Installer Average Quality Scores for Non-REF Program Participants

Installer ID	2018 REG QA Score
1027[a]	1.00
1037	1.67
1038[a]	1.67
1030	2.40
1043	3.29
1039	3.50
1003	4.25

[a]Installers 1027 and 1038 use the same subcontractor for electrical installation.

This study also included system inspections for seven installers working with both the REF and REG programs. Over this period, Cadmus assessed average inspection scores per installer to compare the inspection quality between the two programs. As shown in Table 15, of seven corresponding installers, two scored higher on REF installations than REG installations. On average, inspection scores per installer were 30% higher for projects under the REG program than projects under the REF program.

Table 15. Comparison of Installer Average Quality Scores for REF and REG Programs

Installer ID	Average REG QA Score	Average REF QA Score
1005	2.57	2.15
1020	3.20	1.25
1023	2.71	3.21
1025	2.50	1.92
1029	4.67	3.68
1032	1.00	3.50
1041	3.75	2.62

Medium Solar PV System Findings

Technical Findings

The study's technical outcomes are findings related to physical installations inspected, as summarized below. These include Cadmus' assessment of installation quality, code compliance findings, and discussions of energy yield and shading issues.

Overall Installation Quality Scores

Cadmus calculated the average quality score for medium-scale projects inspected through this study. Overall, approximately 63% of systems inspected received a quality score of 5, indicating no major, minor, or critical deficiencies, as shown in Table 16.

Table 16. Solar Quality Score Summary (Medium-Scale)

Solar Quality Score Summary		
Score	Inspection Criteria	Count
1	System has critical and/or multiple major deficiencies	0
2	System has at least one major deficiency	0
3	System has multiple minor deficiencies	1
4	System has minor and/or incidental deficiencies	2
5	System as no or only incidental deficiencies	5

As Cadmus designed the sampling process to distribute limited study resources across as many installers as possible, the average score presented does not fully represent the actual population of REG projects; rather, it represents the average across projects inspected for this study. While Cadmus received an estimate of the total number of active, medium-scale, solar projects, responsible installers for each installation were not easily identified from the information provided. Therefore, Cadmus could not calculate a reliable weighted average for the medium-scale category.

By Installer

The average quality score per installer varied throughout the course of the study, with the lowest scoring installer's average at 3.0, and the highest average at 4.5, as shown in Table 17.

Table 17. Medium-Scale Inspection Scores by Installer

Installer	Number of Inspections	Average Score
1048	2	4.5
1049	2	5.0
1050	1	4.0
1051	1	5.0
1052	1	3.0
1053	1	5.0

Most Common Installation Issues

For the eight medium-scale inspections completed for this study, Cadmus found 34 installation issues, with 11 of these violating relevant codes and standards. The majority of the issues occurred at the array or the AC combiner, in addition to a significant number of issues occurring at the inverter and supply-side connection elements, as shown in Table 18.

Table 18. Summary of Inspection Issues Found by Defect Category and Inspection Element (Medium-Scale)

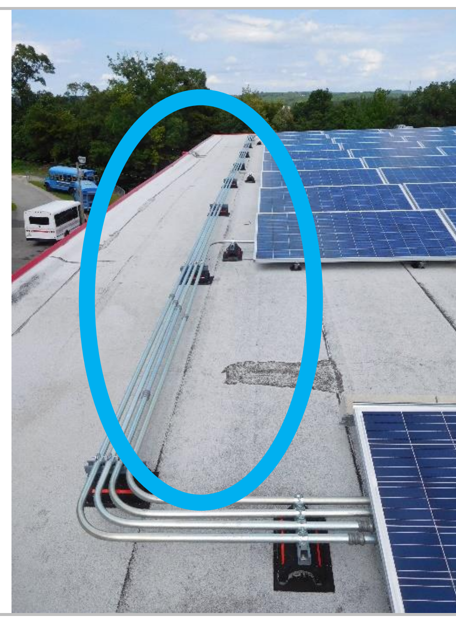
Inspection Element	Recommendation	Incidental	Minor	Major	Critical	Total
AC Combiner	0	9	0	0	0	9
AC Disconnect	0	0	0	0	0	0
Array	1	4	6	0	0	11
Inverter	0	6	2	0	0	8
Junction Box	0	0	0	0	0	0
Optimizer	0	0	0	0	0	0
Overall Observations	1	0	0	0	0	1
Production Meter	0	0	0	0	0	0
Supply Side Connection	0	2	3	0	0	5
Total	**2**	**21**	**11**	**0**	**0**	**34**

Four of the eight medium-scale inspections completed were ground-mounted arrays. Of the four roof-mounted arrays inspected, one inspection (REG2156) accounted for 14 of the 34 inspection issues found. Without this outlier, the average QA score for medium-scale inspections is 4.71.

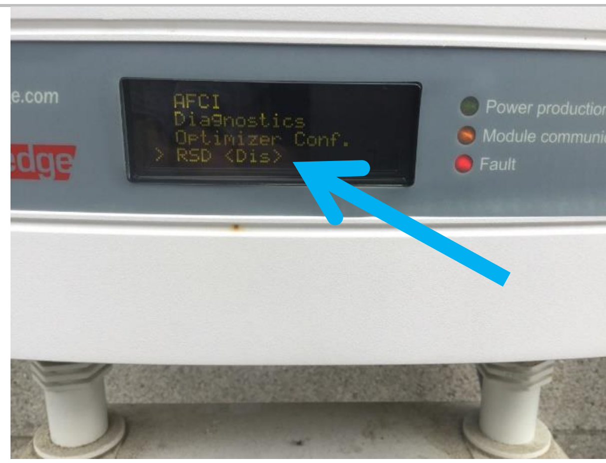
Examples of Common Installation Deficiencies

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

Missing or Deficient Labeling of System Components

Frequency 19 Observations	
Potential Impacts Labeling is important for the safety of workers, firefighters, and others in the immediate vicinity of the PV system. When PV is installed on a building, raceways that contain DC wiring require specific labeling. These labels warn firefighters that the raceways contain PV conductors and imply that extra care be taken around them.	
Best Practices DC raceways on or in buildings require labels every 10 feet with the wording: “WARNING: PHOTOVOLTAIC POWER SOURCE.” The label shall be red, with a minimum of 3/8” white capital letters and be reflective.	

Missing or Deficient Rapid Shutdown Function

Frequency Two Observations	
Potential Impacts When the rapid shutdown function is not functional or provided, DC wiring may be energized up to 1,000V during daylight hours. This may hinder the ability to safely mitigate issues such as a building fire.	
Best Practices Rapid shutdown is required on PV systems installed on buildings. A properly working rapid shutdown device limits DC conductor voltage outside of the array area to 30V in 30 seconds.	

Large Solar PV System Findings

Technical Findings

The study's technical outcomes are findings (summarized below) related to physical installations inspected. These include Cadmus' assessments of installation quality, code compliance findings, and discussions of energy yield and shading issues.

Overall Installation Quality Scores

Cadmus calculated the average quality score for large-scale projects inspected through this study. Overall, as shown in Table 19, approximately 67% of systems inspected received a quality score of 1 or 2, indicating the presence of major and/or critical installation deficiencies.

Table 19. Solar Quality Score Summary (Large-Scale)

Solar Quality Score Summary		
Score	**Inspection Criteria**	**Count**
1	System has critical and/or multiple major deficiencies	3
2	System has at least one major deficiency	1
3	System has multiple minor deficiencies	0
4	System has minor and/or incidental deficiencies	0
5	System as no or only incidental deficiencies	2

As Cadmus designed the sampling process to distribute limited study resources across as many installers as possible, the average score above does not fully represent the actual population of REG projects, only the average across projects inspected for this study. While Cadmus received an estimate of the total number of active large-scale solar projects, responsible installers for each installation were not easily identifiable from the informtion provided. Therefore, a reliable weighted average could not be calculated for the large-scale category.

By Installer

Though the average quality score per installer varied throughout the course of the study, the lowest scoring installer's average was 1.0 and the highest average was 3.7, as shown in Table 20.

Table 20. Large-Scale Inspection Scores by Installer

Installer ID	Number of Inspections	Average Score
1048	3	3.7
1054	1	1.0
1055	1	2.0
1056	1	1.0

Most Common Installation Issues

For the six large-scale inspections completed for this study, Cadmus found 26 installation issues, with 19 of these violating relevant codes and standards. The majority of the issues occurred at the array. Cadmus also found a significant number of issues at the AC disconnect and AC combiner elements.

Table 21. Summary of Inspection Issues Found by Defect Category and Inspection Element (Large Scale)

Inspection Element	Recommendation	Incidental	Minor	Major	Critical	Total
AC Combiner	0	5	0	1	0	6
AC Disconnect	0	0	4	0	0	4
Array	0	2	5	6	1	14
Inverter	0	0	1	1	0	2
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
Supply Side Connection	0	0	0	0	0	0
	0	**7**	**10**	**8**	**1**	**26**

Four of the six large-scale inspections completed were ground-mounted arrays. Of the two roof-mounted arrays inspected, one inspection (REG2161) accounted for 19 of the 26 inspection issues found. Without this outlier, the average QA score for large-scale inspections is 3.25.

Examples of Common Installation Deficiencies

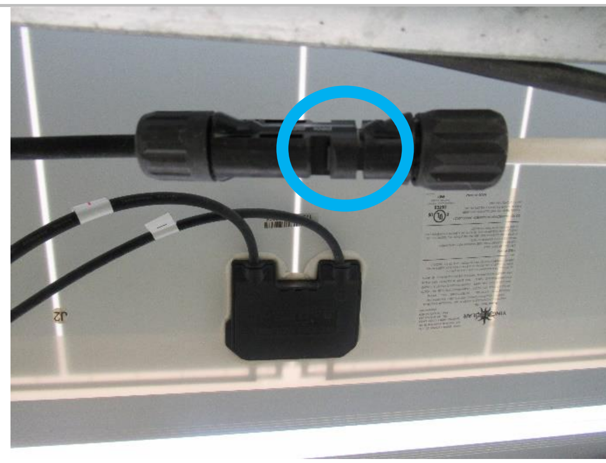
In this section, Cadmus summarizes the most common installation deficiencies found through the study.

Missing or Deficient Labeling of System Components

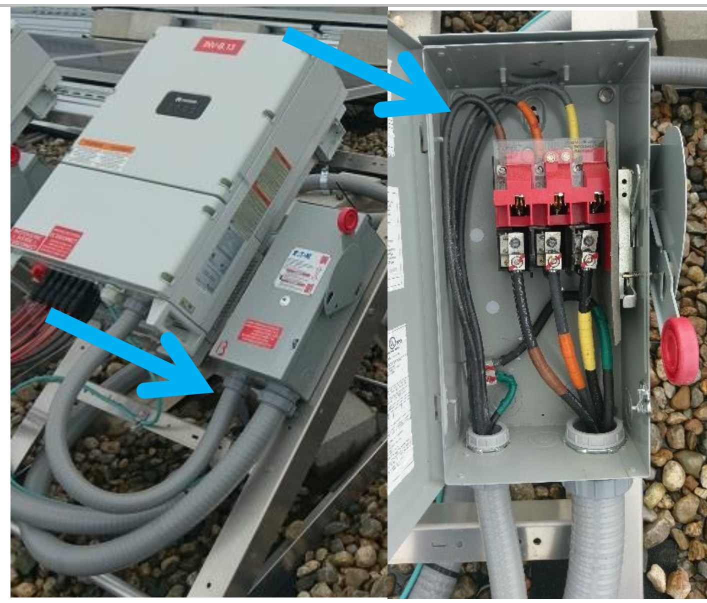
Frequency 4 Observations	
Potential Impacts Properly labeling system components is important for the safety of those working on the system. Personnel must know the details and	

dangers of working on the equipment for safe servicing and maintenance.	
Best Practices Enclosures containing circuit breakers should be identified to allow the safe isolation of equipment during maintenance. All equipment should include the required hazard markings, as outlined in the code.	

Array Conductors Improperly Connected

Frequency Two Observations	
Potential Impacts Hazards exist when DC connectors are not properly installed. Due to this DC current's physical nature, poor electrical connections can cause heat, arcing, or a thermal event.	
Best Practices Use extreme care when making field connections to DC conductors. Ensure connectors are tight and conductors cannot pull out of connectors. Only connectors of the same brand and product line should be plugged together.	

AC Disconnect Wired Backwards

Frequency One Observation	
Potential Impacts Electricians servicing AC disconnects are subject to electric shock or electrocution when disconnects have been wired backwards and unprotected terminals are energized.	
Best Practices Although a PV inverter produces power, it is essential to locate these conductors on the bottom or “load” terminals. When a disconnect is opened (in the off position), the inverter stops producing power due to the UL 1741 standard, and inverter conductors will be de-energized. Conductors from the interconnection, however, will remain energized and must be located on the line terminals, which often contain additional protection.	

Solar Installer Responsiveness to Quality Installation Issues

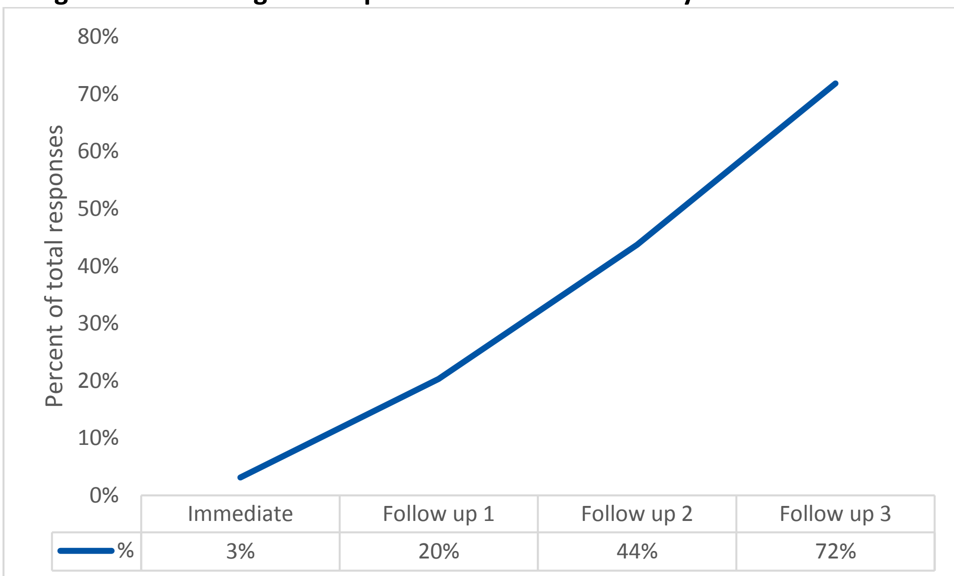
This section presents Cadmus’ study findings with respect to solar installers’ responsiveness to inspection reports. The study inspected systems completed by 26 solar installers. Of these installers, Cadmus confirmed delivery of 87 inspection reports to 20 installers. Of the 87 reports, 24 systems received a score of 5, required no corrective actions, and were excluded from the responsiveness-tracking process.

Cadmus could not confirm delivery of 13 inspection reports to four installers. Causes for this included: installers no longer operating in the state of Rhode Island or out-of-date or unavailable contact information. As Cadmus could not confirm delivery of these inspection reports, the responsiveness-tracking process excluded these individuals. The study findings, however, include results from on-site inspections regarding installation quality.

Installer Responses 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, 72% responded, though the timeliness of these responses varied, with most initial responses received after three weeks. Only 20% of installers responded after the initial report receipt and follow-up email, but over 40% responded after the second email reminder. Figure 9 shows responses received at various stages of the correspondence timeline.

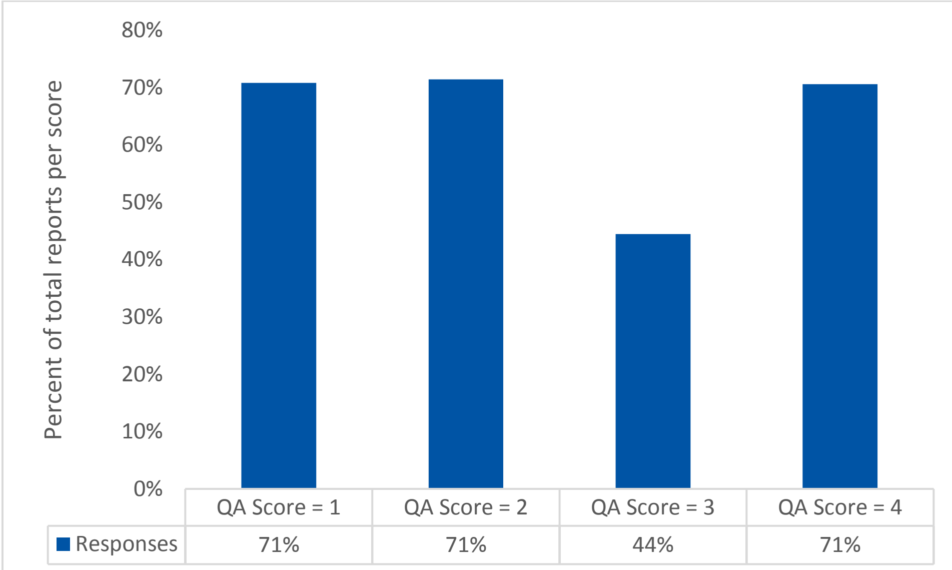
Figure 9. Percentage of Responses Received at Weekly Reminder Intervals



While responsiveness by time intervals followed a 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 44% to 71%, but response rates and quality scores did not exhibit statistically significant correlations. One installer with 10 inspections was particularly unresponsive to Cadmus' requests for quality improvements. Of these installer's 10 inspections, 9 inspections received a score of 1, indicating critical issues with quality.

Figure 10 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 (an inspection score of 3). At the end of 30 days, 89% of those systems had not produced even a perfunctory response from the system installers.

Figure 10. Percentage of Responses Received Out of Total Reports Sent Per Quality Score



Installer Efforts to Address Inspection Findings

Following receipt of corrections and subsequent approval by a Cadmus inspector, Cadmus recorded corrective action items as "completed." Four sites providing corrective action were rejected, and Cadmus did not receive subsequent responses from the responsible installer. Notably, all four sites with rejected corrections were installed by the same company.

While the study team found generally high responsiveness rates, a surprisingly low number of actual corrective action items were received and approved. While 72% of sent reports received some response, only 33% received tangible corrections. In other terms, 67% of systems inspected did not receive corrections within the allotted 30 days. Cadmus even sought to encourage study participation by explaining the scope of Cadmus' authority and the study's purpose (shown in the 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.

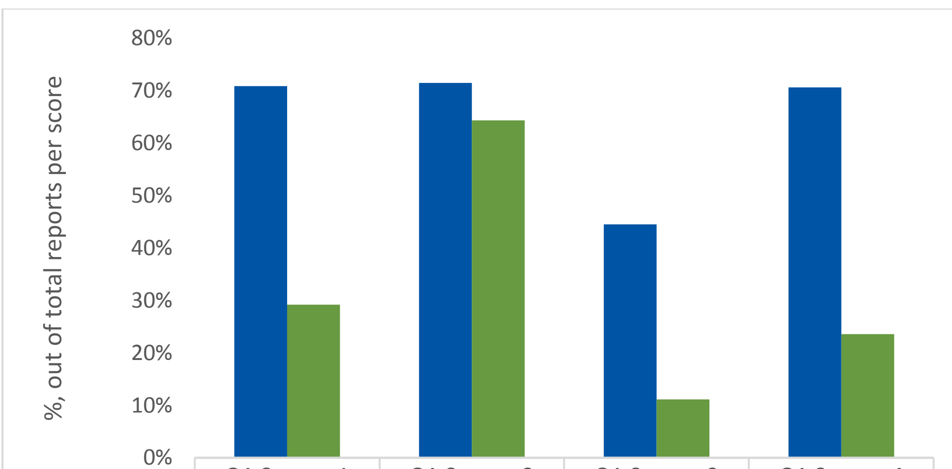
The corrections timeline fell heavier on the second and third reminder timeline, indicating installers uncommonly provided corrections through their first response. For example, an installer providing corrections most likely did so through their second or third response (rather than responding immediately with corrections). Figure 11 shows corrections received at various stages of the correspondence timeline.

Figure 11. Percentage of Corrections Received at Weekly Reminder Intervals

	Immediate	Follow up 1	Follow up 2	Follow up 3
%	0%	0%	6%	33%

The correction rate varied across categories of report scores. While 64% of reports scored as 2 resulted in corrections, only 11% of reports scored as 3 produced corrections. Figure 12 details the correction percentage received for reports sent in each score category, in comparison to total responses received.

Figure 12. Percentage of Corrections Received Out of Total Reports Sent Per Quality Score

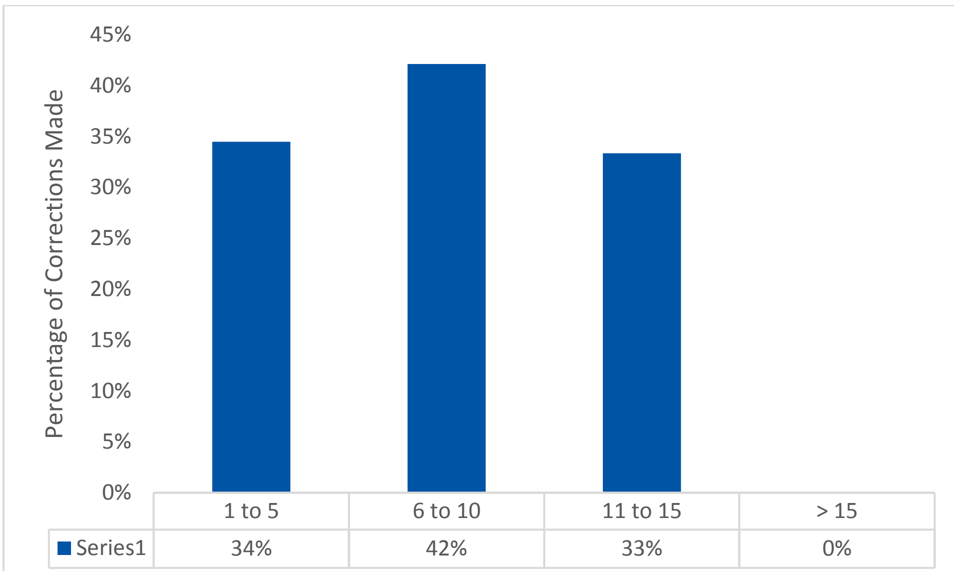


	QA Score = 1	QA Score = 2	QA Score = 3	QA Score = 4
Responses	71%	71%	44%	71%
Corrections	29%	64%	11%	24%

As quality score categories are defined by multiple metrics, including the volume and severity of issues observed, it is important to examine corrective action in terms of the raw number of corrective actions cited per report. For example, a report containing 10 corrective action items may produce a different response time than a report containing one corrective action item, depending on the severity and complications associated with making the corrections.

Figure 13 shows the percentage of corrections submitted, aggregated by the number of violations cited on any given inspection report. Notably, no reports with more than 15 cited violations received corrections. The highest number of violations cited on a single report was 20.

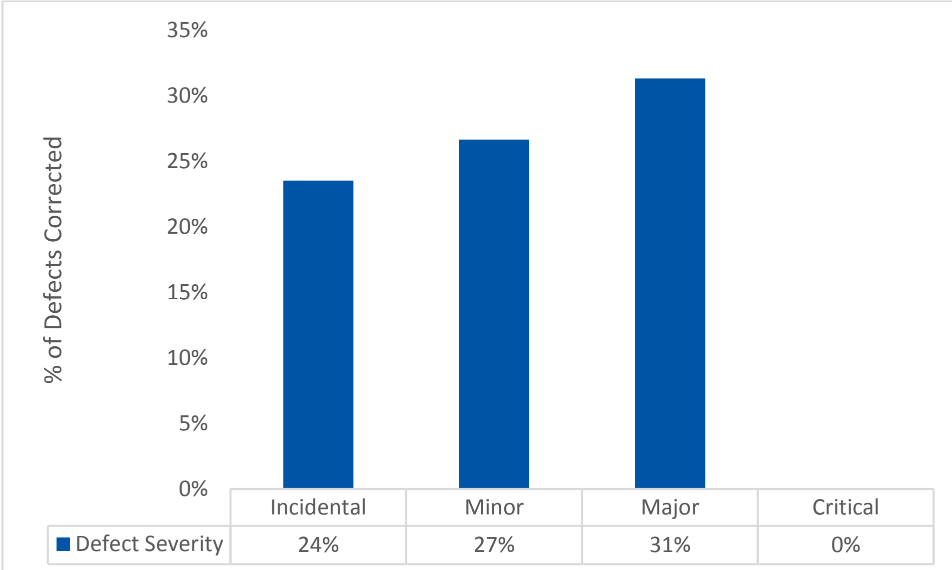
Figure 13. Percentage of Corrections Received by Volume of Violations per Report



Notably, the majority of inspection issues found were not addressed within 30 days, and less than one in three major or critical deficiencies was addressed as part of this study's the process. This means only about one-third of major and critical deficiencies successfully delivered to installers were actually addressed within 30 days. Installers responding, however, did so on a voluntary basis.

Figure 14 shows the percentage of corrections received per violation, aggregated by violation severity. Markedly, none of the critical issues noted in reports were corrected during the tracking process. As previously discussed, each inspected system already passed all relevant permitting and approval processes. Consequently, installers were under no legal obligation to address issues identified through this study.

Figure 14. Percentage of Issues Corrected by Defect Severity



Customer Survey

To augment findings from on-site inspections, Cadmus conducted an online survey of REG customers in the small solar category. Conducted in parallel with the on-site inspections, the survey targeted all 505 REG participants with systems interconnected under the REG program from November 1, 2017, to March 31, 2018. The survey addressed questions such as the following:

- How satisfied are REG customers with their installer's customer service and installation quality?
- How satisfied are REG customers with National Grid's role in the REG program?
- How educated are REG customers regarding the REG program?
- What types of quality concerns are customers experiencing with their REG-supported installation?

To incentivize responses, Cadmus awarded a $100 gift card to one randomly selected survey participant. The survey prompted 132 complete responses to Cadmus, with the results aggregated in this section. Of these responses, 43% (58 responses) were received within one day of the survey release. Other response rates ranged from 2 to 14 days, with an average response rate of seven days.

Customer Feedback on Installer

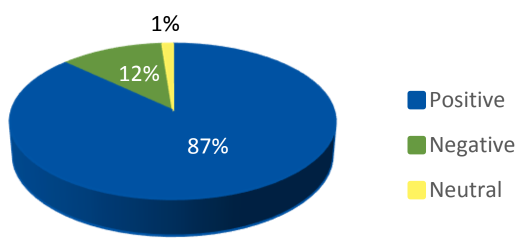
Survey respondents were asked to rate their satisfaction with their system installer, particularly regarding the installer's performance in conducting physical installations and their customer service performance. Respondents were asked to rate their installers on a scale from "very satisfied" to "not satisfied at all" for the following two questions:

1. How would you rate your satisfaction with your installer's performance in installing your system?

2. How would you rate your satisfaction with your installer's customer service (e.g., responsiveness to questions and concerns, clarity and timeliness of communication)?

Cadmus used responses to both questions as indicators of overall satisfaction with installer's performance. The 246 unique responses to these two questions indicated largely positive customer satisfaction levels with installers across the REG program, with answers falling in the "satisfied" to "very satisfied" categories (shown in Figure 15). Participants responding "not sure" were marked as having neutral impressions. In comparison to similar statistics from the 2017 study,[9] REG participants exhibited significantly more favorable impressions of installers' performance. The 2017 study collected anecdotal information from a small sample of customers, with 45% reporting a positive impression of their installer's quality and performance.

Figure 15. 2018 Satisfaction with Installer

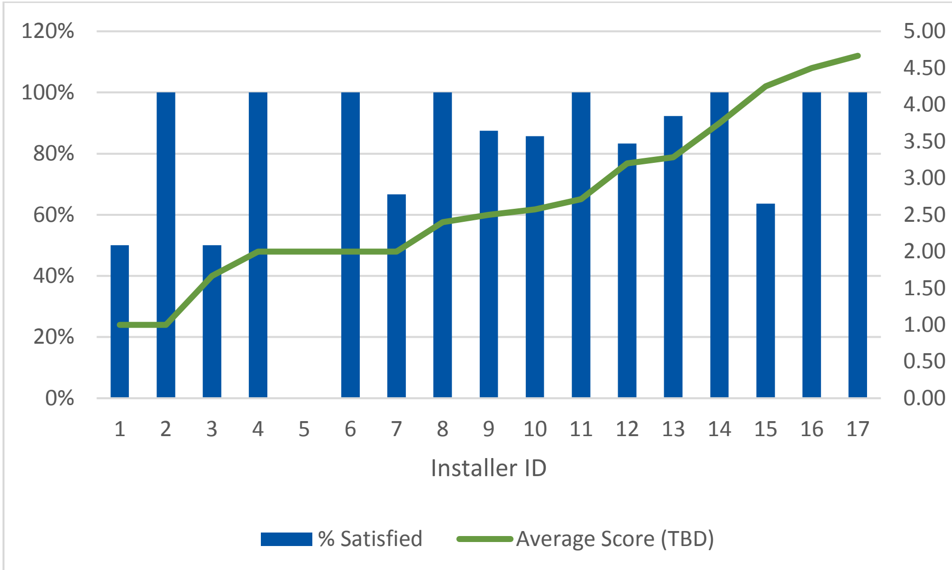


Using results from the two survey questions discussed above, installers were assigned a "satisfaction score" that reflected the percentage of survey respondents reporting positive impressions of their installers out of the total number of respondents per each installer. For instance, if a particular installer was responsible for installing 10 survey respondents, the survey would provide 20 data points of satisfaction for that installer (10 responses to question 1, and 10 responses to question 2). If 10 of these 20 responses reported positive satisfaction, the installer would receive a satisfaction score of 50%. These satisfaction scores were compared to each installers' average quality score from Cadmus' on-site inspections to determine whether installers consistently installing low-quality systems had unsatisfied customers (and vice versa).

Although some individual respondents with installers exhibiting low average QA scores expressed dissatisfaction with their installer's performance, overall customer satisfaction with installers did not strongly correlate with installer performance on QA inspections (as shown in Figure 16).

[9] Feedback from the 2017 study was largely anecdotal, as no standardized survey was sent to program participants. Since the 2018 survey was significantly more detailed than the 2017 responses, comparisons were made between the two study years' aggregate 2018 results as much as possible to provide comparable statistics.

Figure 16. Customer Satisfaction and QA Scores per Installer



Under a few specific instances, customers expressed slight dissatisfaction with their installer's performance in installing their system (question 1), but they expressed strong satisfaction with the installer's customer service and follow-up in addressing complaints from the system installation (question 2), resulting in an overall positive impression of the installer. This trend indicated the strongest drivers of satisfaction included installers' customer service, communication, and post-installation follow up, rather than their perceived installation quality.

Performance and Benefit Expectations

Some negative survey responses related to systems with unmet system performance expectations, REG payment expectations, or both. Cadmus asked respondents to rate their system's output and payments on the scale shown in Table 22, addressed by the following two questions:

1. To respondents who said their REG payments were inconsistent with their expectations: How different are the Renewable Energy Growth payments generated by your system compared to what you anticipated?
2. How does the system's production/energy output compare with what you expected?

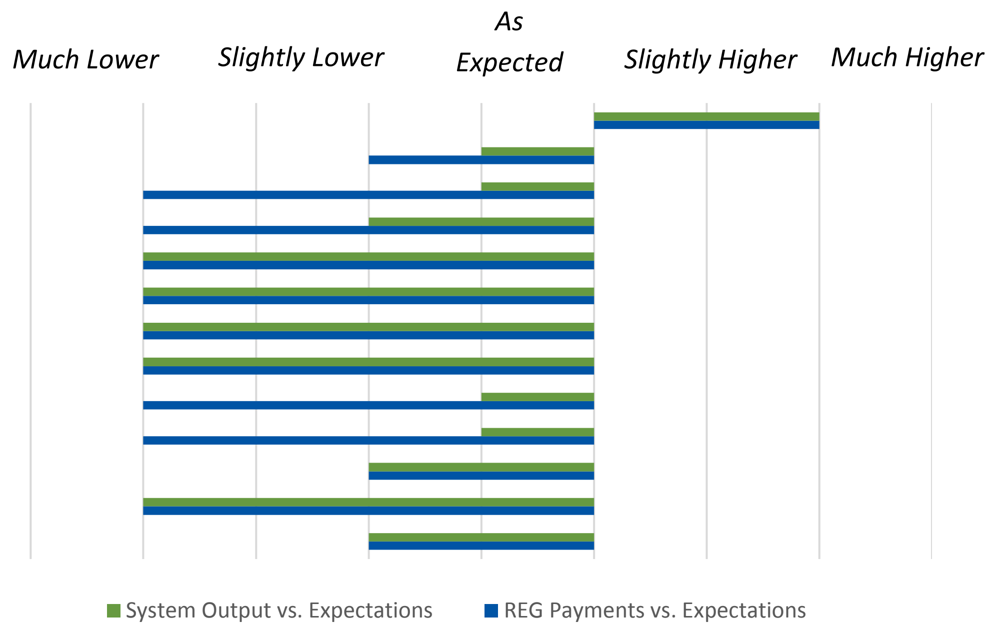
Table 22. System Payment and Output Scale of Responses

System Payment and Output Scale
Slightly Lower than Expected
Much Lower than Expected
As Expected
Slightly Higher than Expected
Much Higher than Expected

In total, 34 of the 130 respondents said payments generated by their system were lower than they expected, with 55% of those respondents receiving payments much lower than expected. Furthermore, 31 respondents stated that their system's production or energy output was lower than their expectations, with 11 systems producing energy at much lower rates than expected.

As REG payments depended on energy production, a system producing less energy than expected resulted in lower-than-expected payments, leading to overlaps in these two statistics. Of respondents stating that their payments were lower than expected, 73% also indicated lower-than-expected production. Low production served as the largest cause of dissatisfaction, with 92% of respondents indicating any dissatisfaction levels also reporting low system output. Figure 17 shows system output and payment expectations, reported from 13 individual respondents answering both questions discussed above.

Figure 17. Correlation between System Output and REG Payments

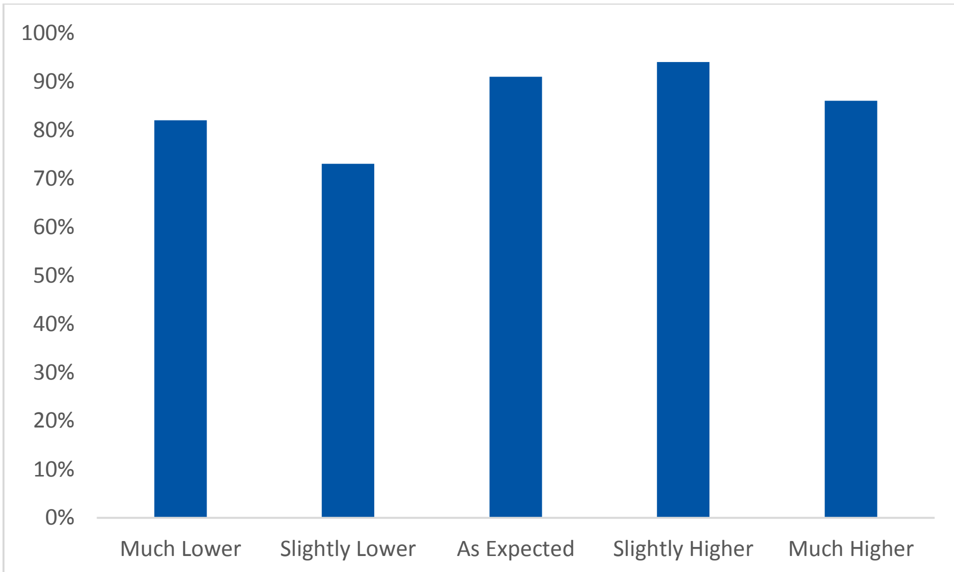


Based on corresponding survey answers, the largest source of unmet payment expectations was a distinct misunderstanding of how REG payments worked. When asked to provide feedback to National Grid on how to improve the REG program, many responses reflected this in various ways:

- Not informed of the tax implications of cash payments generated by the system.
- Not informed that monthly payments are dependent on actual energy produced. Monthly payments were presented as fixed, based on expected production.
- No receipt of pre-enrollment information regarding how payments would be monetized (i.e., utility bill credits or cash deposit).
- Significant delays (one to three months) between when the system started producing energy and when credits appeared on the utility bill.

The survey revealed a noteworthy correlation between low system production and dissatisfaction across various program aspects. This could indicate a disconnect between customers' initial expectations about their systems' performance and payback versus the systems' actual generation. Customers with systems performing as expected from initiation of the process were more satisfied with installers, payments, and the REG program as a whole, as shown in Figure 18.

Figure 18. Customer Satisfaction by System Performance Category



Programmatic Timelines

Following unmet performance and payment expectations, dissatisfaction with meter installations and interconnection timelines produced the second-highest dissatisfaction source from survey participants. Specifically, over one-third of survey respondents expressed dissatisfaction with the timing of the interconnection process, particularly identifying net meter installations and issuance of Permission to Operate from National Grid as causes of lengthened timelines.[10] Survey respondents also reported additional communication issues with National Grid:

- Lack of communication from National Grid on project status updates
- Difficult to find contact information or confusing outreach channels
- Delayed or no responses from National Grid regarding customer outreach

When the survey requested feedback to National Grid, survey respondents provided responses similar to those gathered in the 2017 study. Notably, pre-enrollment communications and ongoing communications from National Grid were cited as the most common requests in 2017, and they accounted for a significant portion of requests in 2018. Figure 19 and Figure 20 display the results.

[10] Statistics represented in this section were determined by survey respondents' impressions of timelines, rather than regulatory- or utility-mandated timelines.

Figure 19. Common Requests—2017 Feedback

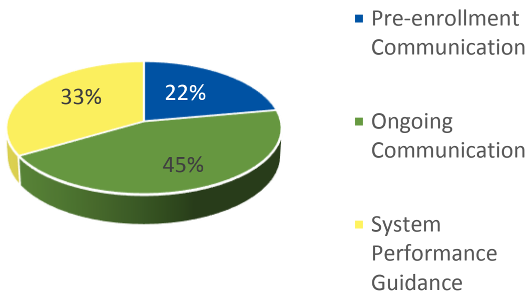
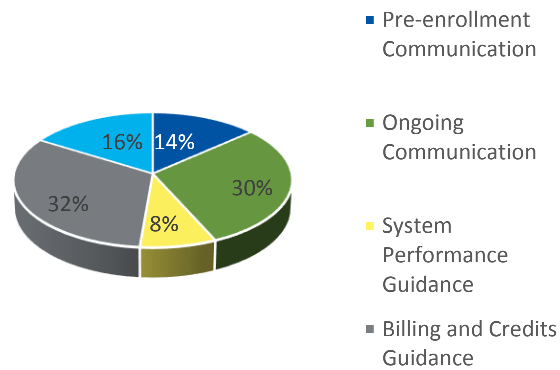


Figure 20. Common Requests—2018 Survey



Survey responses indicated a combination of dissatisfaction with interconnection timelines and a lack of understanding regarding appropriate contact points for timeline-related concerns. Customers reporting dissatisfaction and longer-than-expected timelines exhibited a significant overlap with those reporting they wanted more information from National Grid prior to enrolling in the REG program. Therefore, issuance of clear communication channels could significantly alleviate customer complaints regarding National Grid's role in interconnection.

Roof Age

The National Roofing Contractors Association (NRCA) recommends that PV systems should only be installed on roofs with an expected service life at least as long as that of solar components.[11] Solar PV installations on a roof with a shorter life expectancy can pose safety and warranty concerns, including roof leaks or collapses, or costly system removal and reinstallation to accommodate roof replacements. A rooftop solar PV installation has a useful life of 20 to 25 years, with a typical warranty of 10 years. As asphalt shingle roofs have a 20-year life expectancy on average,[12] best practice dictates solar PV should not be installed on homes with roofs older than approximately five to eight years. Though installing on a new roof is ideal, this is not always possible. The older the roof, however, the greater the chance for a potential roof failure or a PV system requiring removal to facilitate a roof replacement (and ultimately reinstallation). The purchase price of PV systems rarely include removal and reinstallation costs.

Survey results revealed a relatively significant number of REG program participants that installed solar PV systems on older roofs. Specifically, 33% of survey respondents had solar PV systems installed when

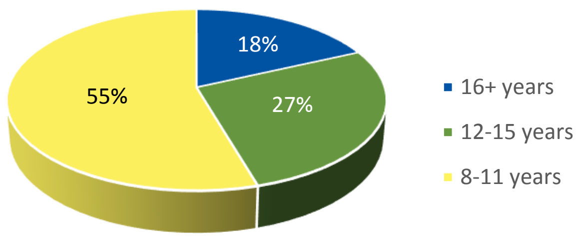
---

[11] National Roofing Contractors Association. *NRCA Guidelines for Rooftop-mounted Photovoltaic Systems, Second Edition*. 2018. https://www.nrca.net/store/detail/nrca-guidelines-for-rooftop-mounted-photovoltaic-systems-second-edition/1745

[12] National Association of Home Builders/Bank of America Home Equity. *Study of Life Expectancy of Home Components*. February 2017. https://www.interstatebrick.com/sites/default/files/library/nahb20study20of20life20expectancy20of20home20components.pdf

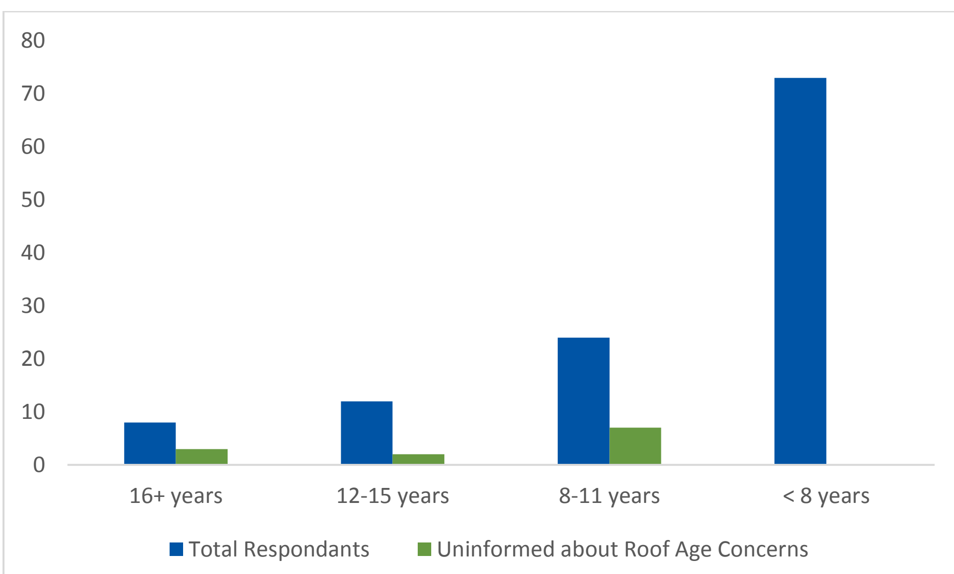
their roof was over eight years old, with some respondents' roofs over 16 years old at the time of installation. Figure 21 shows the percentage of these respondents with roof ages of 8 to 11 years, 12 to 15 years, and 16+ years.

Figure 21. Respondents per Roof Age Category



In some cases, customers may decide to move forward with solar PV installations on older roofs after weighing the installation's costs and benefits and its corresponding warranty and safety implications. If roof replacements may occur during the working life of the solar panels, the cost of removing and reinstalling panels may be specified in the solar PV installation contract. Still, some survey respondents with older roofs did not receive guidance from their installers regarding possible system removal during the contract term. Figure 22 shows the number of respondents in each roof age category that did not receive guidance regarding system removal. Respondents with a roof age less than eight years were not prompted to indicate whether they received guidance about the roof age.

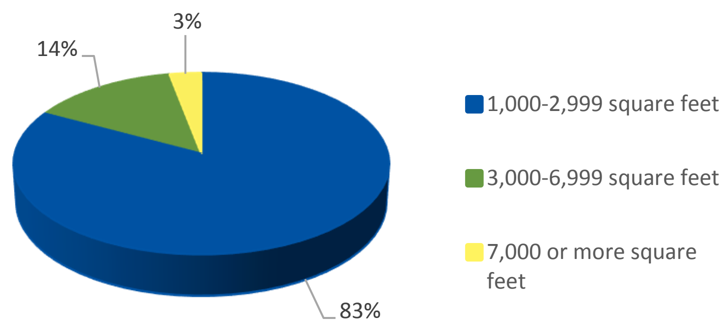
Figure 22. Uninformed Respondents per Roof Age Category



Response Demographics

Solar PV systems installed for survey participants were largely installed on single-family homes, with only two respondents indicating that their installations were on “other” types of building. Figure 23 displays the square footage breakdown of 130 single-family homes reported through the survey.

Figure 23. Square Footage of REG Participating Single-Family Homes Reported by Survey Respondents (n=130)



Recommendations

The REG installation quality study results and findings indicate that the majority of REG-funded renewable energy installations were not "safe, high-quality, performing as expected, and in conformance with the stated specifications."[13] In fact, only 24%[14] of 100 inspected installations met these criteria.

In addition to direct quality concerns, there is a potential risk of future consumer protection issues. Specifically, 92% of participants surveyed expressing some level of dissatisfaction with their REG payments. Whether this is tied to confusion over tariff payments, lower than expected production, or other factors, this is a high level of dissatisfaction that may instigate consumer pushback in the future. Further consumer concerns could potentially arise from the relatively significant number of REG program participants that installed solar PV systems on older roofs (33% of survey respondents had solar PV systems installed on a roof greater than eight years old).

Considering the quality and consumer concerns identified by the study, Cadmus recommends that OER, National Grid, and the PUC consider a range of educational and programmatic recommendations to improve installation quality in the future. Cadmus organized recommendations by priority (low, medium, or high), determining these levels based on anticipated impacts and timelines to complete the recommendation, as shown in Table 23. In prioritizing the following recommendations, Cadmus remained cognizant of solar soft costs' impacts on Rhode Island's solar PV market.

Table 23. Prioritization of Recommendations by Anticipated Impact and Timeline

Impact ↑	High Priority	Medium Priority
	Medium Priority	Low Priority
	Timeline →	

High-Priority Recommendations

Cadmus considered recommendations high priority if they had higher impacts and shorter implementation timelines (less than six months).

Offer Training to 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

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

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

reports, whether as questions to Cadmus or completion of corrective actions, suggests installers often remained unaware that installations did not comply.

As such, Cadmus recommends that National Grid and/or OER offer training and training materials to installers currently installing renewable energy systems through the REG program. The training should be specific to installation issues identified in Rhode Island and within the REG program. Further, trainers should present the REG interconnection requirements clearly and in detail. Training and training materials should provide clear technical guidance, with photos and diagrams that installers can understand and reference as needed. Cadmus recommends offering 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. To maximize impact, we suggest the training timeline be consistent with Rhode Island's adoption of the 2017 edition of the NEC (adoption date yet to be determined).

Responsible Party(ies): National Grid and OER

Collect and Report Additional Data Related to Installation Quality

On the REG interconnection application, National Grid collects a number of data points, primarily related to customer information and system details. This application process can be leveraged to gather data points related to system quality. Specifically, Cadmus recommends the following two additions:

- **License information**. Per Rhode Island General Law §5-65-1, a registered contractor or firm with a contractor's registration must perform the work associated with installation of solar energy systems or equipment (e.g., racking systems, in-ground mounting or anchoring). To ensure installations by licensed individuals, including additional license information on the interconnection application would be beneficial. Specifically, Cadmus recommends firms holding a Rhode Island General Contractors registration provide their license numbers on interconnection applications. The licensee number could be used to assess installation quality on a contractor or firm-wide basis.
- **Production Estimate and Total Solar Resource Fraction (TSRF)**. Shading analysis or a minimum TSRF is not an REG program requirement. However, quality systems are those that are installed well, but also optimally designed (including having a high TSRF). By gathering TSRF and estimated production values, future quality evaluations can provide advance notice of potential consumer protection issues by comparing actual and expected generation. Anecdotally, some customers included in this study noted lower than expected benefits but without being able to objectively compare pre-installation estimates/expectations with actual performance; therefore, it is not possible to determine the cause for this dissatisfaction. With this information, National Grid can make informed decisions about specifying minimum design standards or other consumer protection measures for future program years.

These additional data points should be reported to OER on a monthly basis, along with other interconnection details.

Responsible Party: National Grid with support from OER

Offer Training to Local Electrical and Building Inspectors

Inspections Cadmus performed for this study followed approval by the local authority having jurisdiction. 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. Additionally, learning about renewable energy systems is not a required aspect of their electrical training or certification.

As such, Cadmus recommends annual 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 offering these trainings in person, based on past experiences with training electrical and building inspectors.

Responsible Parties: National Grid and/or OER (in coordination with the Rhode Island Building Code Commission Office)

Closely Manage Self-Installations

The study raised particular concerns regarding the quality of renewable energy systems placed by self-installers, with all self-installers from this round's study refusing inspection altogether. These installations represented a significant quality concern for the 2017 REG program and should be closely monitored and managed. OER and National Grid could consider the following approaches with respect to these installation types:

- **Require that all self-installed systems undergo a third-party inspection**. Due to historically low inspection quality scores by self-installers, Cadmus recommends subjecting these systems to a mandatory third-party inspection to ensure safety and compliance of the system.
- **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.
- **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 work

Rhode Island Renewable Energy Professional Example Qualifications

- North American Board of Certified Energy Practitioners PV Installation Professional certification
- Underwriters Laboratories PV Installer Certification Program certification
- Associate's degree or higher in a renewable energy technology or solar PV installation from an accredited school

allowed by the REP limited license, Cadmus recommends self-installers licensed as electricians also meet one or more additional REP qualifications listed on OER's website.[15]

- **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, self-installers can miss the nuances of renewable energy installations, which may result in serious safety and cost implications. Cadmus recommends that OER and National Grid consider prohibiting self-installed renewable energy systems from receiving REG incentives, regardless of the homeowner's status as a licensed electrician.

Responsible Parties: National Grid and/or OER

Require Training for New Program Participants

To proactively train new installers seeking to participate in the REG program (including self-installers), Cadmus recommends requiring new program participants to undertake 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 on National Grid's website for installers and their field staff to access at any time.

After completing the web-based training, Cadmus recommends requiring installers to certify that they completed the training; National Grid could collect this certification along with the final 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 the upcoming REG tariff year.

Responsible Parties: National Grid, with support from OER

Add Inspection Disclaimer Language to REG Tariff Documents

Currently, inspections of systems installed under the REG program are not mandatory for program participation. As a result, challenges can arise in scheduling inspections, such as for this study, as no language in the REG program tariff states that inspections may be required if participating in the program. Cadmus recommends that OER's and National Grid's respective legal teams review and determine if disclaimer language can be added to the applicable REG tariff documents and National Grid's website. The disclaimer language should clarify that any applicant seeking to participate in the

[15] Rhode Island Office of Energy Resources. "Renewable Energy Professional (REP)." Accessed May 11, 2018. Available online: http://www.energy.ri.gov/policies-programs/for-vendors/renewable-energy-professional.php

REG program may have their system subject to inspection by a third-party, solar quality inspector contracted by OER or National Grid.

Responsible Parties: National Grid and OER

Medium-Priority Recommendations

Cadmus considered recommendations medium priorities if they had a lower impact and a shorter implementation timeline (less than six months), *or* a higher impact and a longer implementation time (greater than six months).

Conduct Ongoing REG Quality Assurance Reviews

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

Sampling Rate

OER, National Grid, and the Rhode Island 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 program. Rather, Cadmus suggests applying targeted sampling for higher-risk installations (e.g., new, 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 only become 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 the work of experienced, high-performance installers.

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

Program Feedback

Cadmus recommends adopting an additional component for 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 we can efficiently gather feedback from installers and customers through online surveys, while collecting feedback from local electrical/building inspectors, National Grid, OER, the PUC, and other stakeholders through phone surveys or more detailed interviews.

OER and National Grid can use this feedback to accomplish the following:

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

Responsible Parties: National Grid and OER

Implement Performance Metric for Verification of Dual-Meter Accuracy

National Grid receives compensation from the REG Program based on the value of performance-based incentives, paid out in a given timeframe. Receipt of this compensation is tied to proposed performance metrics (see RIPUC Docket 4774). For example, National Grid performance metrics currently include deadlines for REG meter installations and initial customer billing. To support REG Program installation quality, Cadmus recommends that National Grid consider an additional performance metric of verification of dual-meter accuracy.

National Grid must visit each installation to install the REG meter. As part of this process, Cadmus recommends that National Grid meter technicians review and verify the accuracy of supply-side connections. Actions could include completing a checklist and notifying installers of any concerns. Any issues identified would be the responsibility of the installer or homeowner to remedy.

Responsible Party: National Grid

Low-Priority Recommendations

Recommendations considered low priority are those that Cadmus anticipates will have lower impacts and longer implementation timelines (greater than six months).

Enhance Program Technical Requirements

Though Cadmus developed solar technical requirements for the prior REG installation quality study (see Appendix A), this document could be enhanced to ensure National Grid adopts it. For example, Cadmus recommends including electrical diagrams of interconnection types and arrangements that National Grid permits for small-scale solar installations. This document would allow clearer communication of OER's and National Grid's expectations for REG-funded renewable energy installations (including potential third-party inspections). Further, Cadmus recommends updating these technical requirements regularly (as needed), and clearly communicating these updates to existing program participants (e.g., installers, building/electrical inspectors, and National Grid staff) to ensure consistency in program installations.

Responsible Parties: OER, with support from National Grid

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 ensure 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

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

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