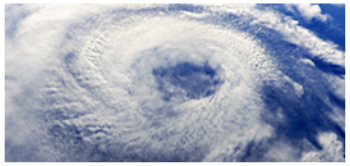
CADMUS



Study of Renewable Energy Installation Quality in Rhode Island

Renewable Energy Growth Program

January 10, 2018

Presented by:
Shawn Shaw, P.E.

Presentation Outline

- Introduction
- Study Methodology
- Interconnection Methods
- Results from Onsite Inspections
- Installer/Inspector Feedback
- Results from Installer Responsiveness Tracking
- Conclusions & Recommendations

About The Cadmus Group

Technical Due Diligence

- Inspections
- Design Reviews
- Feasibility Studies

Policy and Financial Analysis

- Power purchase agreements
- Net Metering
- Program Design & Evaluation

Training

- Code Officials
- Installers
- First Responders

EnergyTrust of Oregon

NY-Sun Solar Powering New York ny-sun.ny.gov

MASSACHUSETTS CLEAN ENERGY CENTER

CLEAN ENERGY FINANCE AND INVESTMENT AUTHORITY

REF Commerce RI Renewable Energy Fund

3

Our Solar Inspection Expertise

10 Years of Solar Inspections

- 5,000+ inspections completed
- 150+ MW inspected
- In RI, MA, NY, NJ, CT, CA, TX, WI

By Highly Qualified Inspectors

- NABCEP Certified PV Installation Professionals
- Journeyman and Master Electricians
- Professional Engineers

Today's Presenter: Shawn Shaw, P.E.

Principal Investigator

- Cadmus Renewable and Distributed Energy Practice Lead
- Registered electrical engineer (NY)
- Conducted and reviewed thousands of solar inspection reports
- Evaluated renewables programs in NY, MA, CT, OR, PA, IN, WI, NJ
- Authored and contributed to industry papers on solar quality (IPMVP, SAPC)

REG QA Study Purpose

- Study commissioned by OER, on behalf of the DG Board
  - Cadmus selected via competitive procurement
- Determine whether REG-funded renewable energy installations are "*safe, high quality, performing as expected, and in conformance with the stated specifications*"

Study Preparation

Engagement with National Grid

- Study methods and goals
- Customer engagement
- Data sharing

Minimum Technical Requirements

- Installation guidelines
- Code compliance-focused

Research Plan

- Research questions
- Sampling protocol
- Cadmus follow-up with installers on outstanding violations

Research Questions and Methods

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

- Inspection results measured on Cadmus 1-5 QA scale (also used for REF program inspections)
- Across a sample of projects drawn from small, medium, and large installation firms (including self installations)
- Installations in REG tariff years 2015-2016 (04/2015-04/2017)
- Solar and wind included

Research Questions and Methods

What are the most common and serious installation issues identified?

- Results compiled and analyzed in Cadmus PVQUEST database
- Data summarized by
  - Inspection element (array, interconnection, etc.)
  - Issue severity (minor, critical, etc.)
  - Issue type (grounding, labeling, etc.)

Research Questions and Methods

Are Rhode Island installers addressing identified violations? If yes, what is the timeline?

- Templated process for delivery and follow up on inspection reports
  - Delivered to installer via email
  - 3 follow-up emails on weekly schedule
  - 30 days given to respond/address issues
- Metrics tracked
  - Timeline for first response to inspection report
  - Timeline for completing satisfactory corrections

Research Questions and Methods

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

- Program-wide average QA score
- Frequency and severity of installation issues found

Site Visit Sampling Targets

Task	Projected Sample Size per Installer Category		Projected Number of Inspections
Small Solar Inspections	Large Installer (>22 installs)	5-7	90
	Medium Installer (15-22 installs)	3-4	
	Small Installer (<15 installs)	1-3	
Medium Solar Inspections	2		2
Wind Inspections	1		1
Total	**93**		**93**

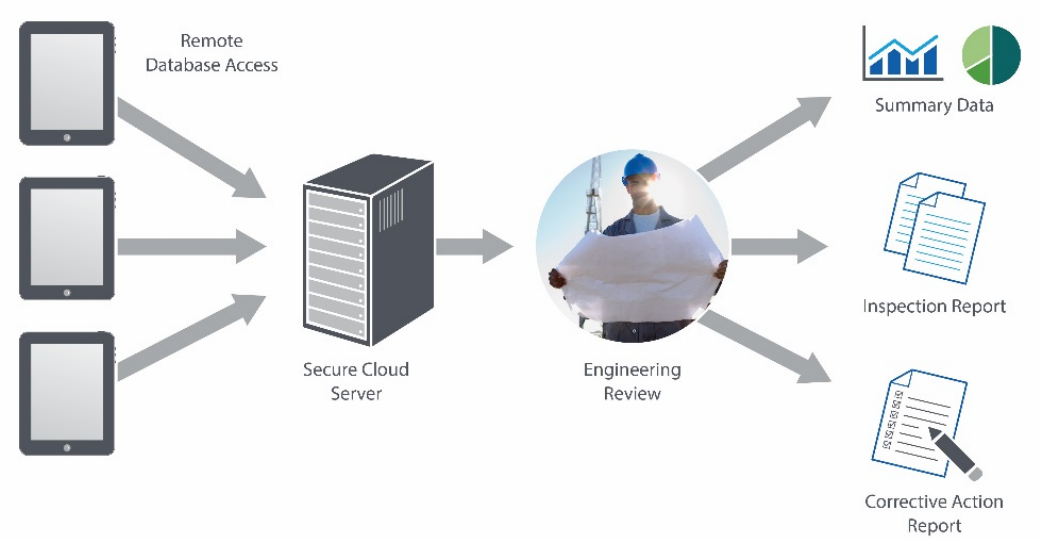
Cadmus Inspection Process

Inspection Process

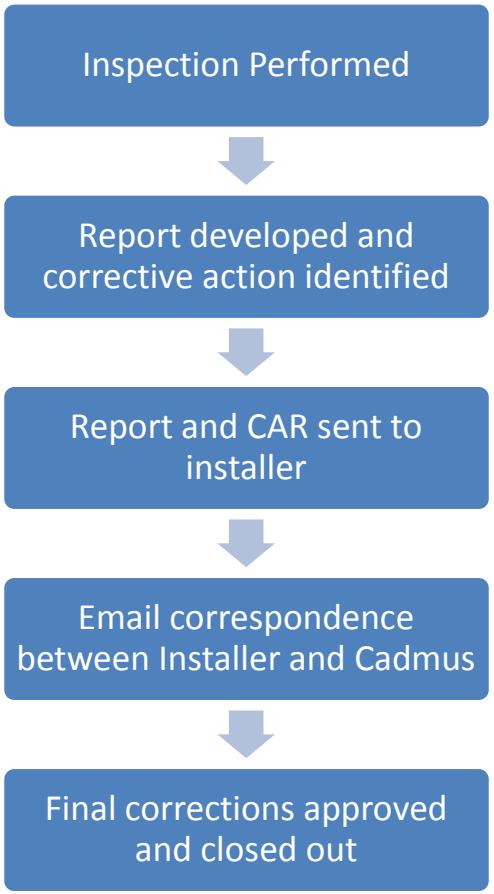
- Group of potential sites selected based on sampling criteria
- Inspections scheduled and conducted with the system owner
- Comprehensive, on-site evaluations of each system selected for inspection
  - System evaluated for safety, reliability, productivity, and compliance with REG program requirements

Cadmus' PV Quality Evaluation and Scoring Tool (PVQUEST)

- Links real-time field inspections with a variety of reporting and analytic functions
- Programmed with 800+ of the most common installation issues
- Each inspection results in an Inspection Report and Corrective Action Report



Report Delivery and Follow Up



- Inspection Report and Corrective Action Report (CAR) generated for each inspection
- Installers given 30 days to provide corrections after receiving Report and CAR
  - Email notifications weekly until responses received
- Final corrections reviewed and approved by Cadmus inspector

Data Aggregation and Analysis

Scheduling

- Customer responsiveness
- Customer feedback on installers
- Customer feedback on REG Program

Inspections

- Average QA score by installer
- Most common technical violations
- Violations specific to REG metering

Report Delivery

- Installer responsiveness to communications
- Corrective action response time
- Likelihood of corrective action

Data Aggregation and Analysis

PVQUEST Inspection Report Violations

Score	Classification	Description
5	No Issues	**No issues identified on site.**
4	Incidental	**Issues not expected to impact system operation or safety.** Examples: Installation debris left onsite, poor wire management, missing or incomplete labels, and installed equipment not matching program records but considered equivalent.
3	Minor	**Issues that pose a mid-to long-term risk of system failure or safety hazard**. Examples: Bonding neutral to ground in a meter enclosure, insufficient clearance around boxes, undersized circuit protection, and improperly supported conductors.
2	Major	**Issues deemed likely to impact system performance or safety in the short-term, though not an immediate hazard.** Examples: Missing equipment grounding, module microfractures, missing or undersized grounding electrode conductor, improperly secured PV modules, and missing or inadequate thermal expansion joints in long conduit runs.
1	Critical	**Issues that pose an immediate risk of system failure and/or safety hazard. Systems are often shut down during the inspection 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.

Results from Onsite Inspections

Preliminary Results

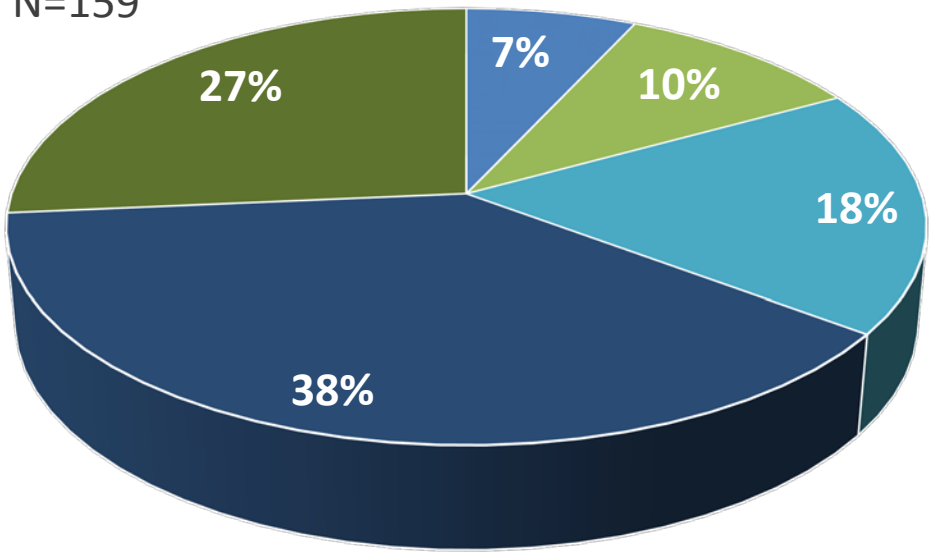
- 89 inspection results
- Average score: 2.94
- Total of 534 violations observed
  - 11 Critical
  - 46 Major
  - 200 Minor
  - 277 Incidental

Preliminary Inspection Results Comparison

Systems by Severity of Issues Found

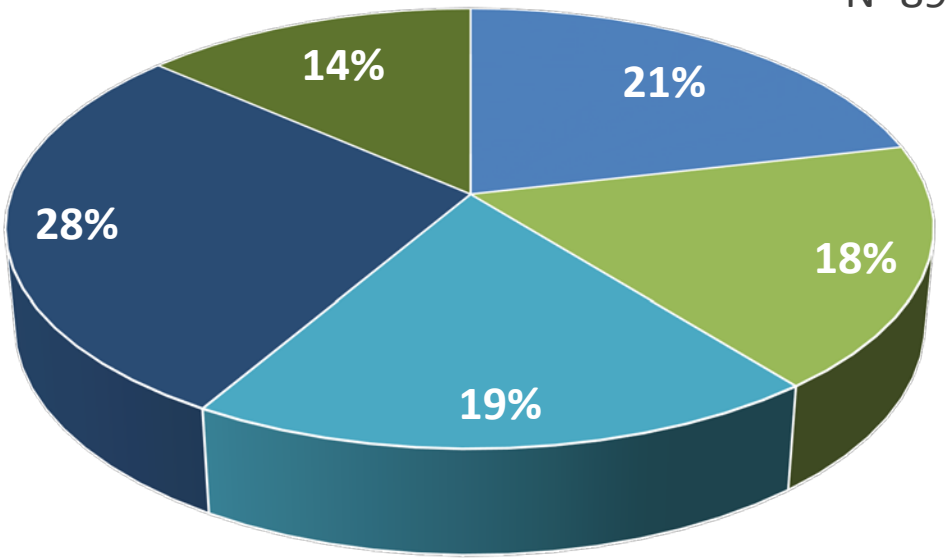
Renewable Energy Fund
Inspection Violations as of 12/1/15

N=159



Renewable Energy Growth
Inspection Violations as of 3/7/17

N=89



- Critical
- Major
- Minor
- Incidental
- No Issues

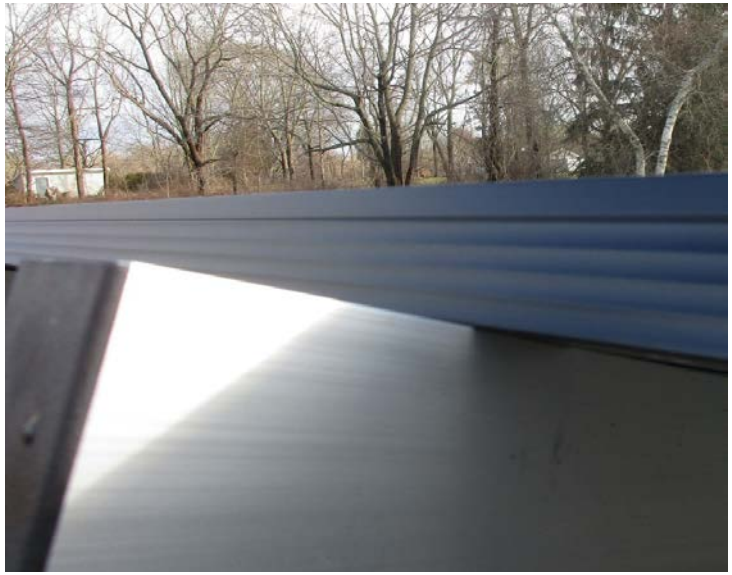
- Critical
- Major
- Minor
- Incidental
- No Issues

Preliminary Results by Element

- **Array**
  - *89 occurrences*
  - 22% contained **minor** conductor protection issues
  - 10% contained **critical** issues (poor workmanship)

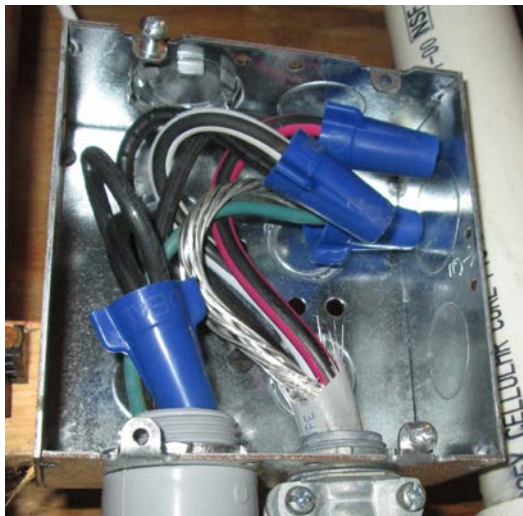
Preliminary Results by Element

- **Racking**
  - *89 occurrences*
  - 20% contained **major** structural/module issues
    - Physical racking not installed properly (too short)
    - Modules not properly secured (missing or improperly-sized clamps)



Preliminary Results by Element

- **Junction Box**
  - *10 occurrences*
  - 4 contained improper splice methods (**minor-major**)
  - 4 contained other **minor** issues
  - 3 were not properly-secured (**minor**)
  - 1 was not grounded



Preliminary Results by Element

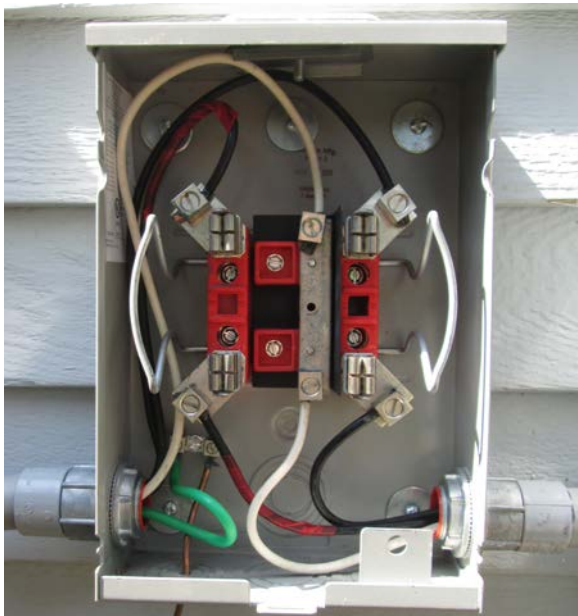
- **String Inverter**
  - *54 occurrences*
  - 71% contained labeling/other **incidental** issues
  - 21% contained **minor** issues
    - Conduit fittings
    - Disconnect grouping
    - Grounding

Preliminary Results by Element

- **AC Combiner**
  - *35 occurrences*
  - 69% contained **incidental** labeling issues
  - 31% contained other **minor** issues

Preliminary Results by Element

- **Production Meter (customer-owned)**
  - *34 occurrences*
  - Minimal issues observed, single occurrence:
    - Grounding
    - Terminal rating
    - Conduit fittings
    - Conduit support



Preliminary Results by Element

- **AC Disconnect**
  - *23 occurrences*
  - 56% contained **incidental** labeling issues
  - 43% contained other **minor** issues
  - 1 contained a **major** issue

Preliminary Results by Element

- **Supply-Side Connection**
  - *89 occurrences*
  - 60% contained **incidental** labeling issues
  - 43% missing **incidental** directory/power source identification
  - 21% contained **major/critical** issues
    - Improper/missing grounding
    - Disconnect not rated for application
    - No fuses
    - Undersized conductors
  - 30% contained other **minor** issues
  - 26% contained **minor** grounding issues
  - 20% contained **minor** splice or conductor insulation issues

Self/Small Installers

- Cadmus inspected approximately 5 systems classified as either:
  - Self-installation
    - By electrician on their own home
  - Small installer
    - Low-volume electrical contractor, typically new to solar

Self/Small Installers

- Average score: 1.2
- Total of 67 violations identified
- 11 Major/Critical issues identified
  - Main disconnect not rated for service application
  - Main disconnect not properly grounded
  - Modules not properly secured to racking

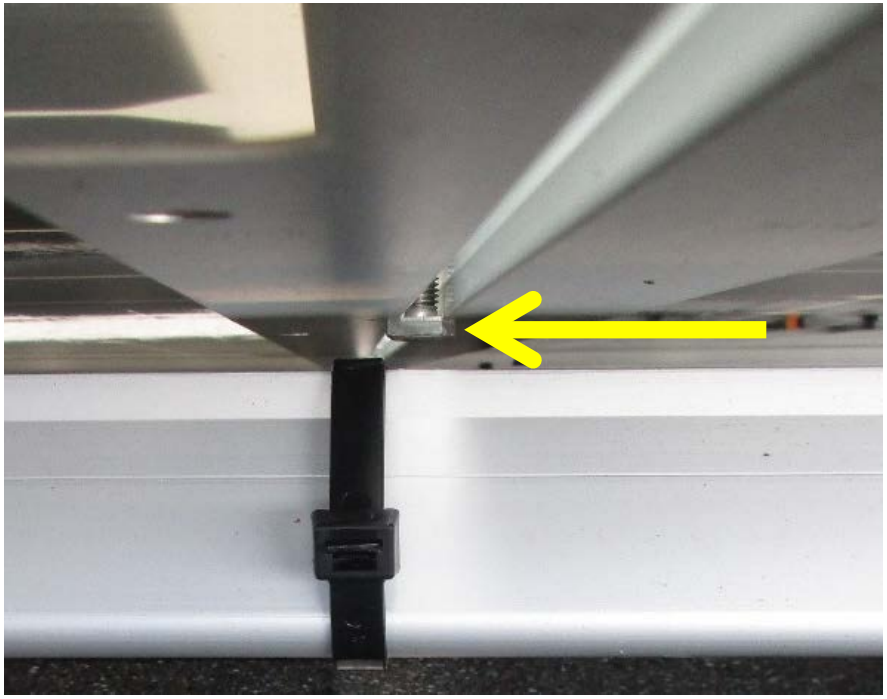
Cadmus ID	Inspection Score
REG0041	1
REG0065	1
REG0074	3
REG0075	2
REG0080	1

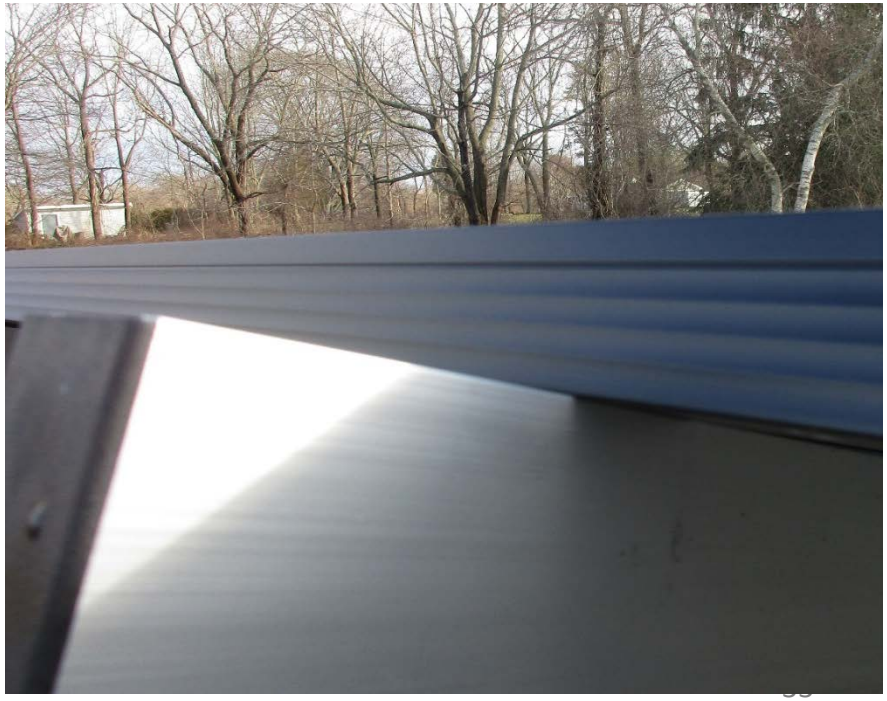
Self/Small Installers

- Main disconnect not listed as service-equipment

Self/Small Installers

- Modules not properly secured to racking

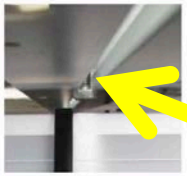
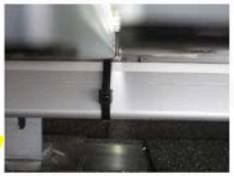







Example Array Issues

ID#	Defect Category	Deficiency Description	Inspector Comments
A_002	Major	Other issue observed. See inspector photos/comments for further details.	Ground lugs are almost touching the module back sheet, in violation of NEC 110.3.
A_S04	Major	Racking system mechanical connections not made correctly and/or racking not installed per manufacturer instructions, in violation of NEC Article 110.3(B).	Mid clamp is not engaged in the rail and is not properly securing the module.
A_S06	Major	Module is not properly secured to the racking system, per manufacturer instructions and NEC Article 110.3(B).	There is not enough rail after the end of the end clamp as required by the manufacturer's instructions.
A_EL04	Minor	Conduit fittings and connectors are missing or not designed and listed for this use, in violation of NEC Articles 110.3(B), 300.15 and (PVC-352.6, LFNC-356.6, LFMC-350.6, EMT-358.6). See inspector comments/photos for further details.	Missing connector in violation of NEC Article 300.15(C).
A_EL12	Minor	Circuit conductors are sagging and/or not supported and secured at least every 4.5' and within 12" of every outlet box, junction box, cabinet, or fitting, in violation of NEC Articles 338.10(B)(4) and 334.30.	





Example Array Issues

ID#	Defect Category	Deficiency Description	Inspector Comments
A_S06	Major	Module is not properly secured to the racking system, per manufacturer instructions and NEC Article 110.3(B).	End clamps are installed too close to the end of the rail and missing in some places.
A_EL01	Minor	Outdoor wire ties/clips are not UV and/or outdoor rated, in violation of NEC Article 110.3(B).	
A_EL05	Minor	Thermal expansion fitting not present on raceways to compensate for expansion and contraction in violation of NEC Articles 352.44, 300.7(B) and tables 352.44 and 355.44.	
A_EL09	Minor	DC PV source circuit conduit or raceway lacks adequate support, in violation of NEC Article (LFMC 350.30, EMT 358.30, Metal Trough 376.30).	
A_EL12	Minor	Circuit conductors are sagging and/or not supported and secured at least every 4.5' and within 12" of every outlet box, junction box, cabinet, or fitting, in violation of NEC Articles 338.10(B)(4) and 334.30.	
A_EL29	Minor	The array contained components that were not listed for an outdoor environment, in violation of NEC Articles 300.6 and 110.3(B). See inspector comments/photos for further details.	Corrosion and rust observed.
A_S011	Minor	Roof penetrations are not properly sealed and flashed to prevent moisture ingress.	
MI_S01	Minor	Microinverter is not mounted/ installed in accordance with its listing and manufacturer instructions, in violation of NEC Article 110.3(B).	Mounting hardware is almost in contact of module back sheet.




Example Array Issues

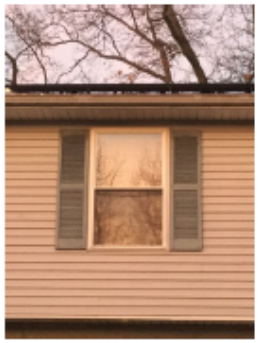
ID#	Defect Category	Deficiency Description
A_EL12	Minor	Circuit conductors are sagging and/or not supported and secured at least every 4.5' and within 12" of every outlet box, junction box, cabinet, or fitting, in violation of NEC Articles 338.10(B)(4) and 334.30.





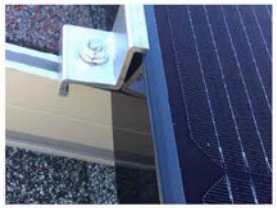
Example Array Issues

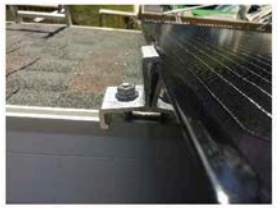
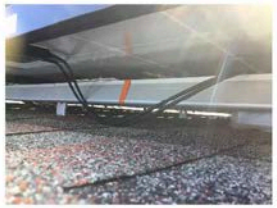
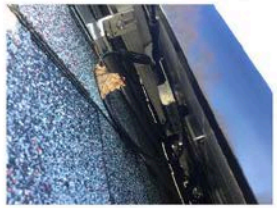
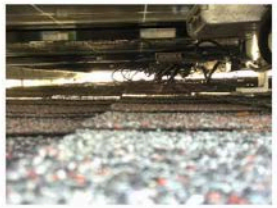
ID#	Defect Category	Deficiency Description
A_EL12	Minor	Circuit conductors are sagging and/or not supported and secured at least every 4.5' and within 12" of every outlet box, junction box, cabinet, or fitting, in violation of NEC Articles 338.10(B)(4) and 334.30.




Example Array Issues

ID#	Defect Category	Deficiency Description	Inspector Comments
A_S06	Major	Module is not properly secured to the racking system, per manufacturer instructions and NEC Article 110.3(B).	All end clamps appear to be the wrong size for these modules.
A_EL12	Minor	Circuit conductors are sagging and/or not supported and secured at least every 4.5' and within 12" of every outlet box, junction box, cabinet, or fitting, in violation of NEC Articles 338.10(B)(4) and 334.30.	PV wires were not supported anywhere under the array and were in direct contact of the roof.
A_EL26	Minor	Exposed equipment grounding conductor is smaller than #6AWG and is not protected from physical damage, in violation of NEC Articles 690.46 and 250.120(C).	




A Unique Interconnection…




REG-Specific Interconnection

- Section 4 of the RE Growth Program Tariff document (RIPUC No. 2151) outlines a metering configuration
- Solar PV installation shall be on a new utility meter
- Absolutely no connection to load side of existing utility meter
- ***Intended for the installer to replace existing utility meter enclosure with multi-gang enclosure*** (i.e. replace existing 1-gang with new 2-gang)
  - Existing meter is utilized for existing service/loads
  - New PV system/meter is a new “tenant” in the building
- Consideration should be taken for new disconnect/fuse location and marking…

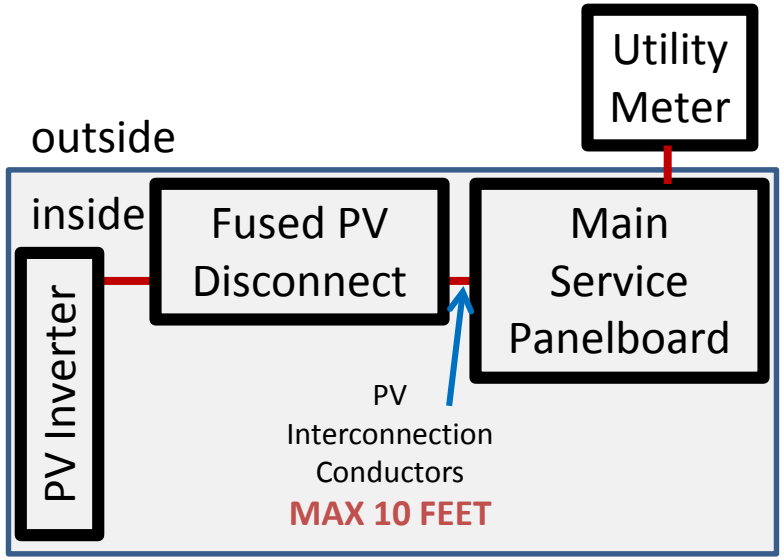
Two-Gang Meters

Underground Example

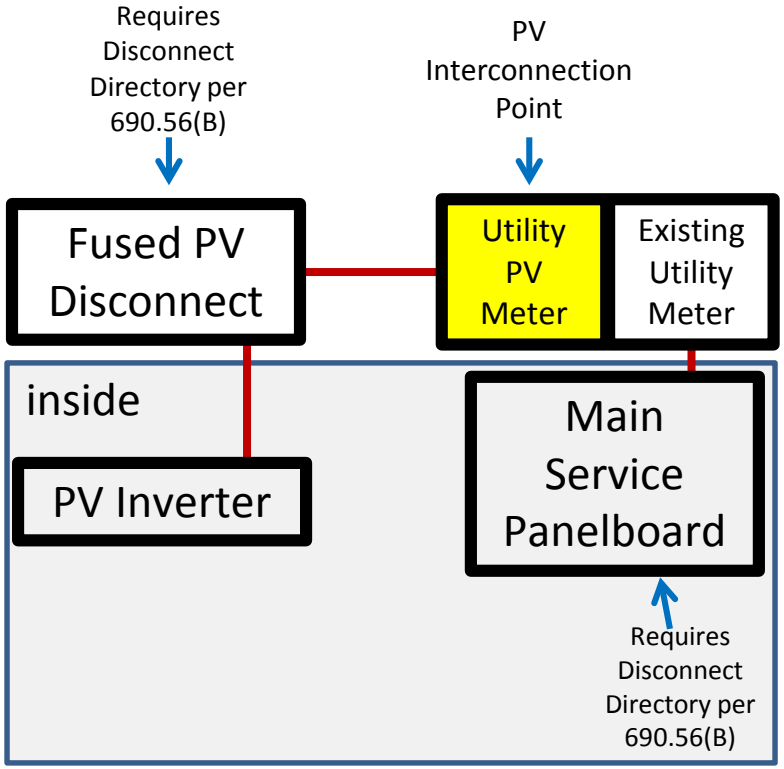
Overhead Example

REG-Specific Interconnection

- **Traditional Method** Example
  - Supply-side interconnection
  - "behind the meter"



- **New Method** Example

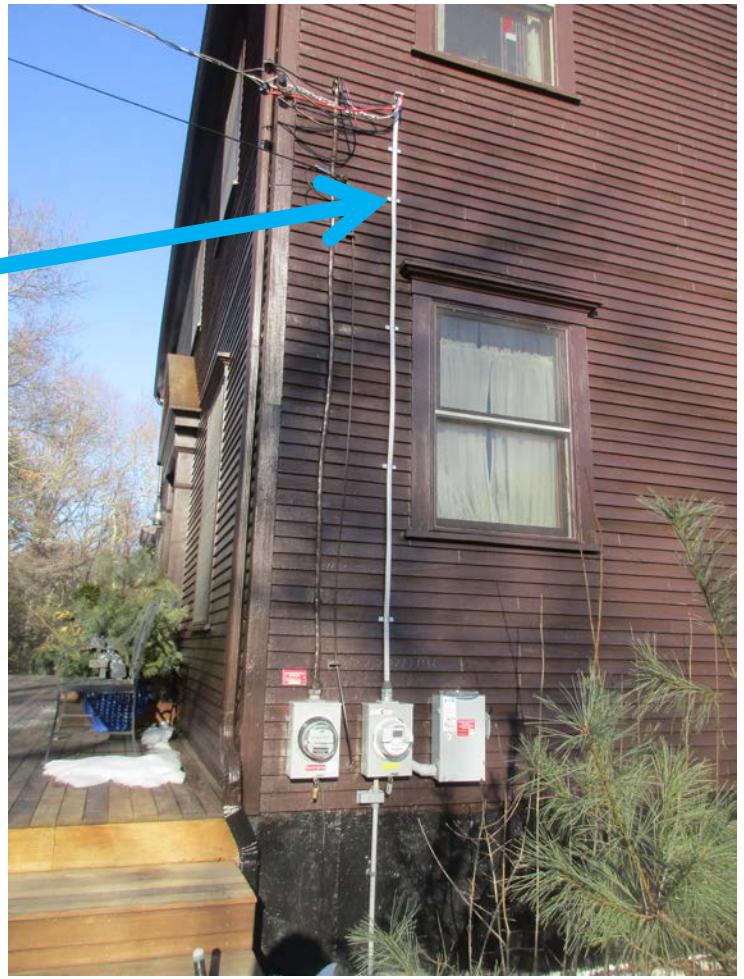


REG-Specific Interconnection

- Interconnection method is unique to program
- All other wiring is common across all programs
- Beyond the intent of replacing existing meter, ***many other connection methods observed…***

Connection at Service Point

- A new service drop dedicated for PV connection



Connection at Service Point

- Connection method typically not listed for outdoor use
- Unclear if National Grid or installer responsible

Connection at Service Point

Connection at Service Point

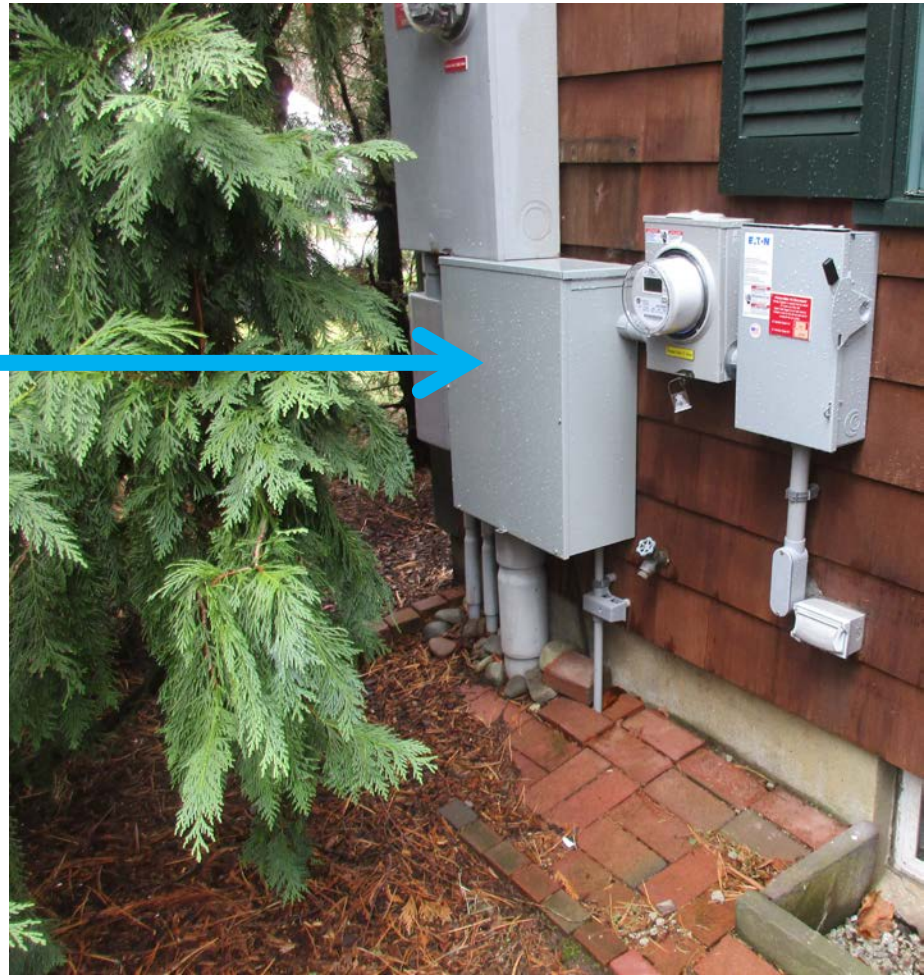
- Concerns:
  - Esthetics
  - Impairs existing service repair/upgrade
    - Available space
    - Connection method for three conductors

Tap Box in Overhead Service

- Existing overhead service drop contains tap enclosure

Tap Box in Underground Service

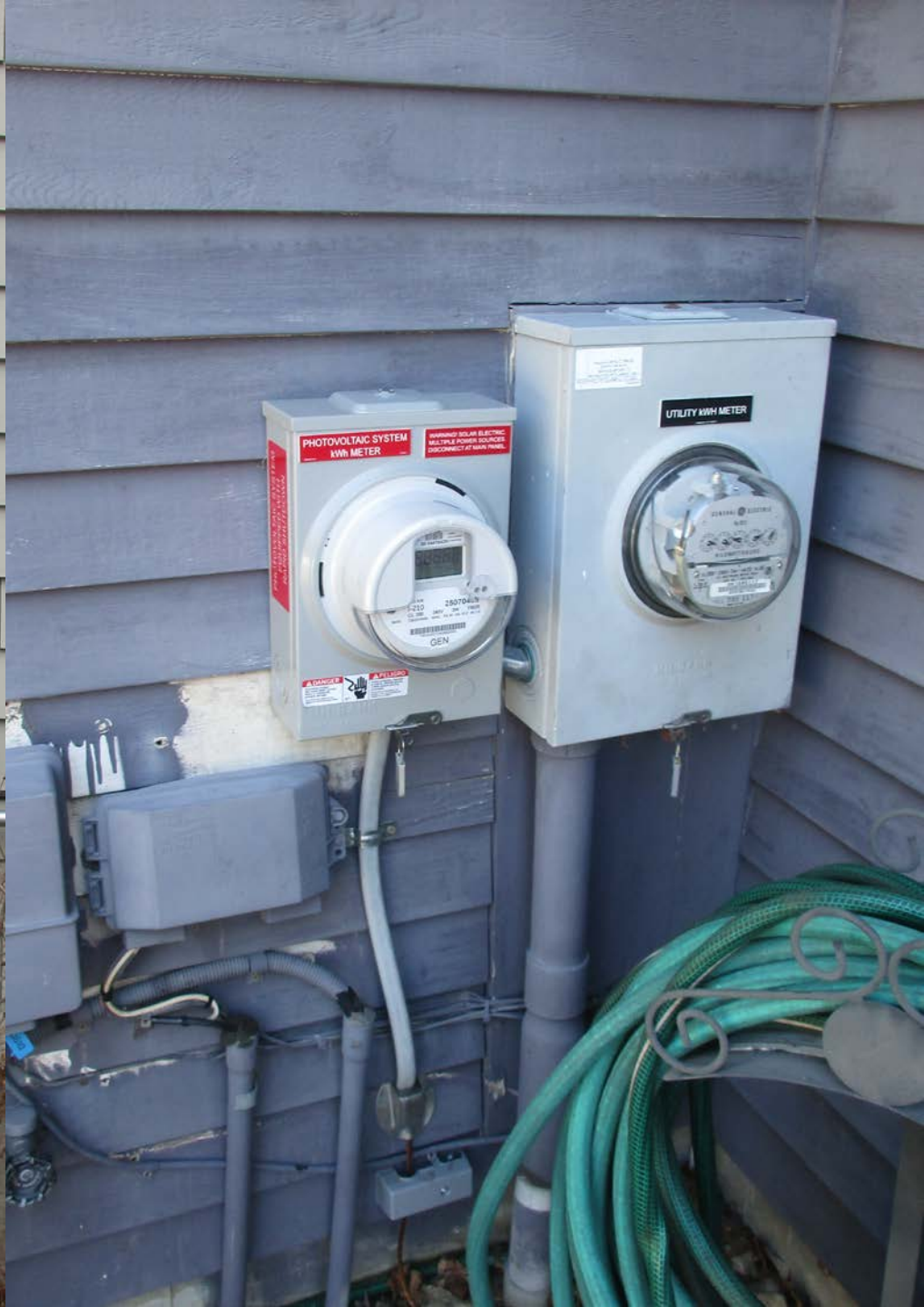
- Existing underground service lateral contains tap enclosure



Connection in Existing Meter Enclosure

- Existing locked utility meter enclosure contains a connection
  - Cadmus unable to verify:
    - Line vs. load terminals
    - Code-compliant method


E·T·N


PHOTOVOLTAIC SYSTEM
kWh METER
UTILITY kWH METER


NATIONAL GRID METER

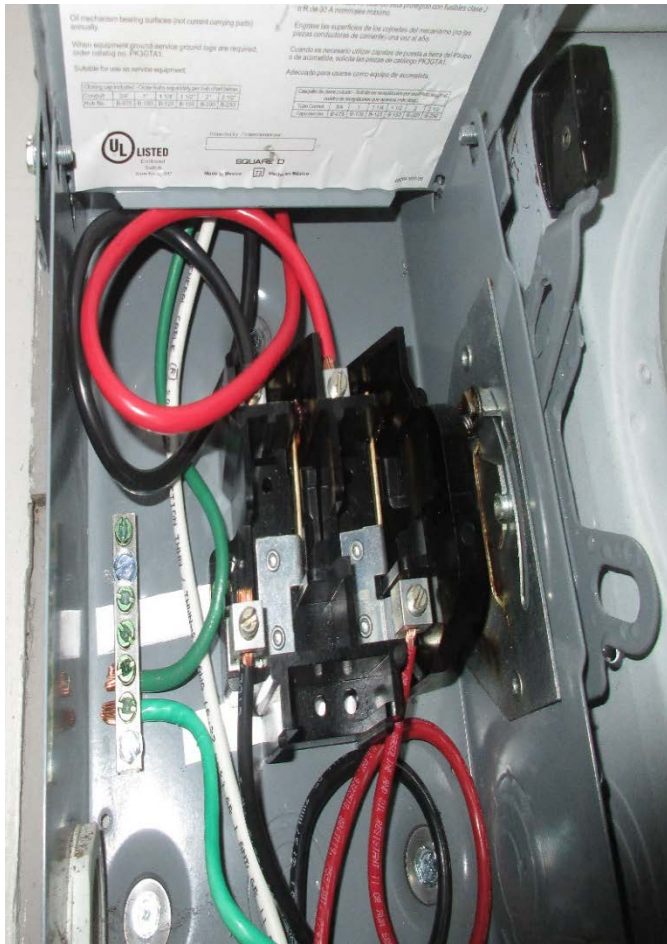
Overhead Enclosure for Service Lateral

- Wrong type of meter enclosure used for underground service

Common Violations Observed

REG-Specific Issues

- Unprotected interconnections
  - No fuse or circuit breaker



REG-Specific Issues

- Undersized service-entrance conductors
  - NEC requires minimum #6 AWG wire
  - Cadmus observed conductors as small as #10 AWG

REG-Specific Issues

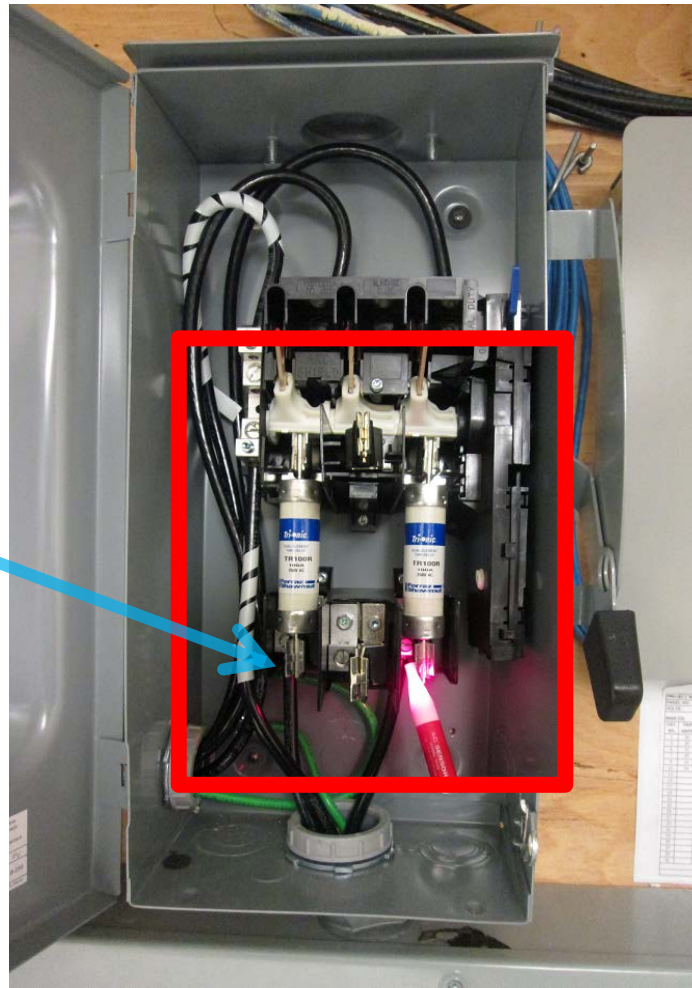
- Undersized Service Disconnect
  - NEC requires minimum 60A
  - Cadmus observed many 30A

REG-Specific Issues

- Equipment installed without sufficient working clearance

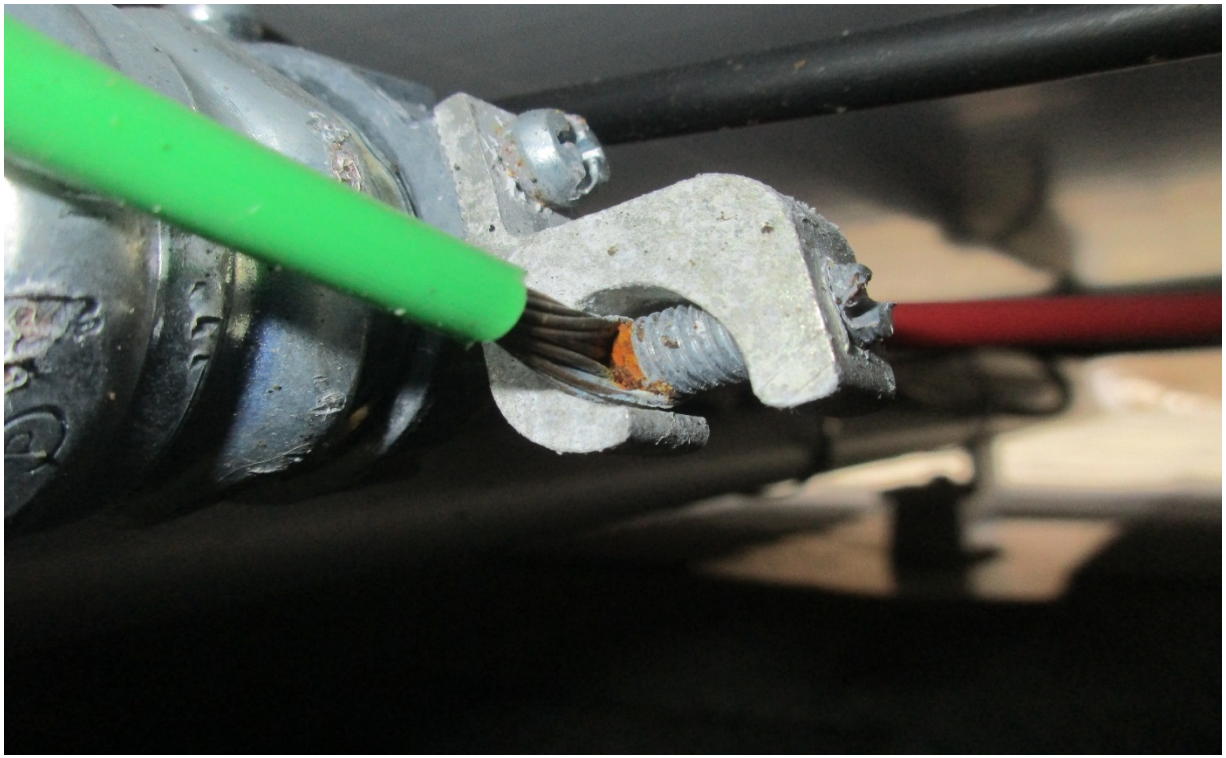
REG-Specific Issues

- Disconnect switches wired backwards
  - Utility conductors on LOAD terminals
  - Fuses always “live”



Other Identified Issues

- Indoor hardware used outdoors

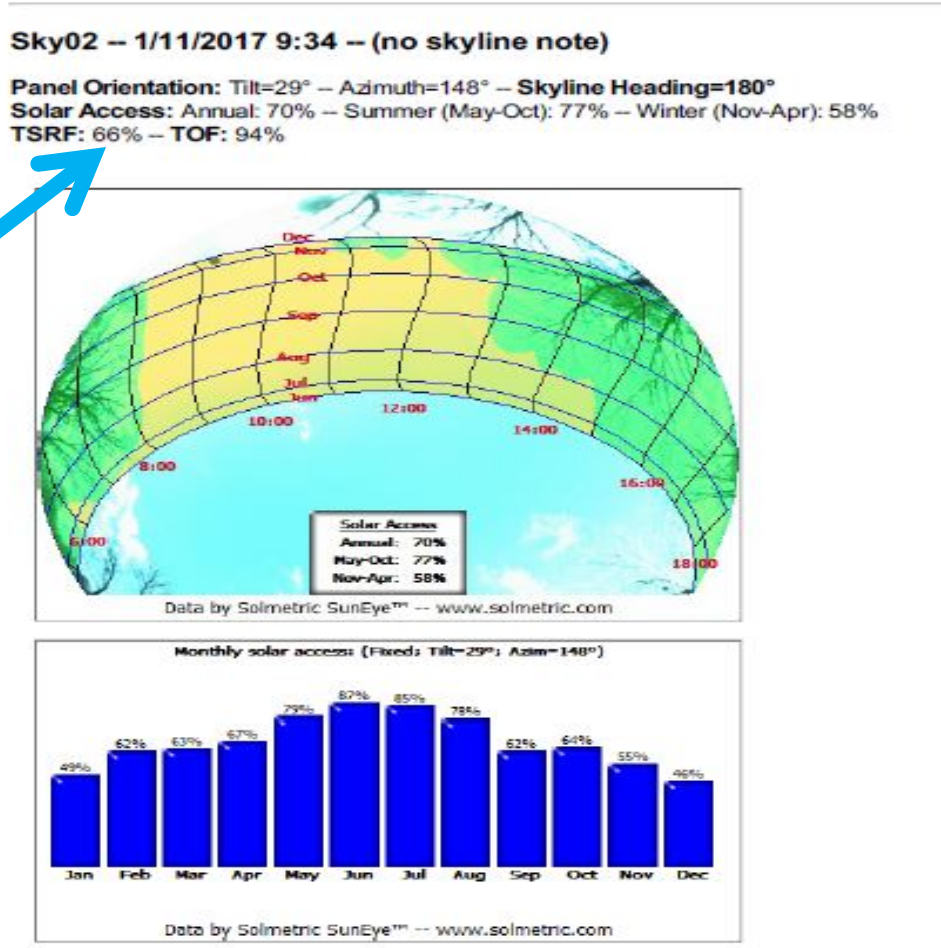


Other Identified Issues

- Grounding hardware against module backsheet

Other Identified Issues

- Excessive shading



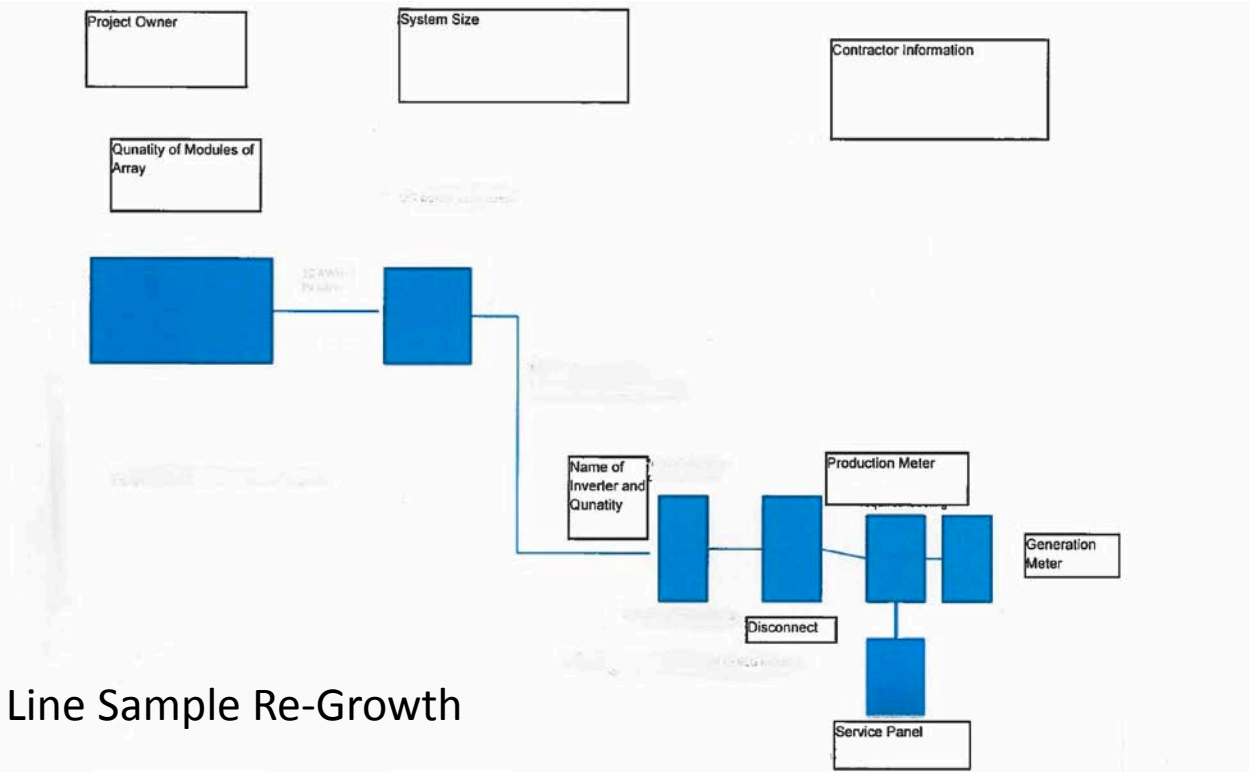
Installer/Inspector (AHJ) Feedback

Installer/Inspector Feedback

- Electrical inspector:
  - *"These solar inspections [redacted] are becoming more difficult to understand."*

Installer/Inspector Feedback

- Installer in response to sample wiring diagram from National Grid:
  - *"The diagrams attached don't indicate an additional meter socket other than the revenue grade socket which is typical in both MA & RI."*



Titled: One Line Sample Re-Growth

Installer/Inspector Feedback

- Installer:
  - *"I wired the interconnection one way, they told me to wire it a different way, they then rejected it, and I had to wire it back to the original way."*
- Installer:
  - *"They keep changing the rules as they go along, it is difficult to keep up with their requirements."*

Installer/Inspector Feedback

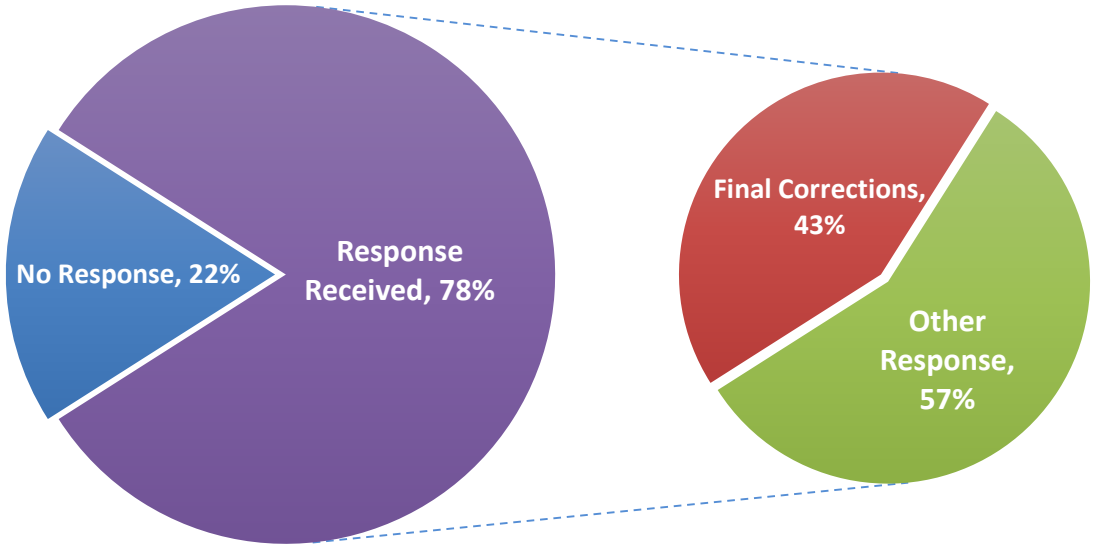
- National Grid (in response to installer photos):
  - *"Per the meter dept please change the stickers to placards and resend pictures of the change."*
- Cadmus note:
  - Placards
  - NEC-compliant label
    - Approved by AHJ & Cadmus
  - Not required by NEC
  - Redundant marking

Installer/Inspector Feedback

- Cadmus received over 20 calls/emails from installers and inspectors:
  - Looking for guidance, uncertain about rules
  - Installers unsatisfied about misinformation/changing rules
  - Inspectors not approving installations because unfamiliar with new interconnection method
  - Self-installer received bad advice from equipment sales person, resulted in dangerous installation with 24 violations

Results from Installer Responsiveness Tracking

Average Installer Responsiveness*



30 days — Allotted response time

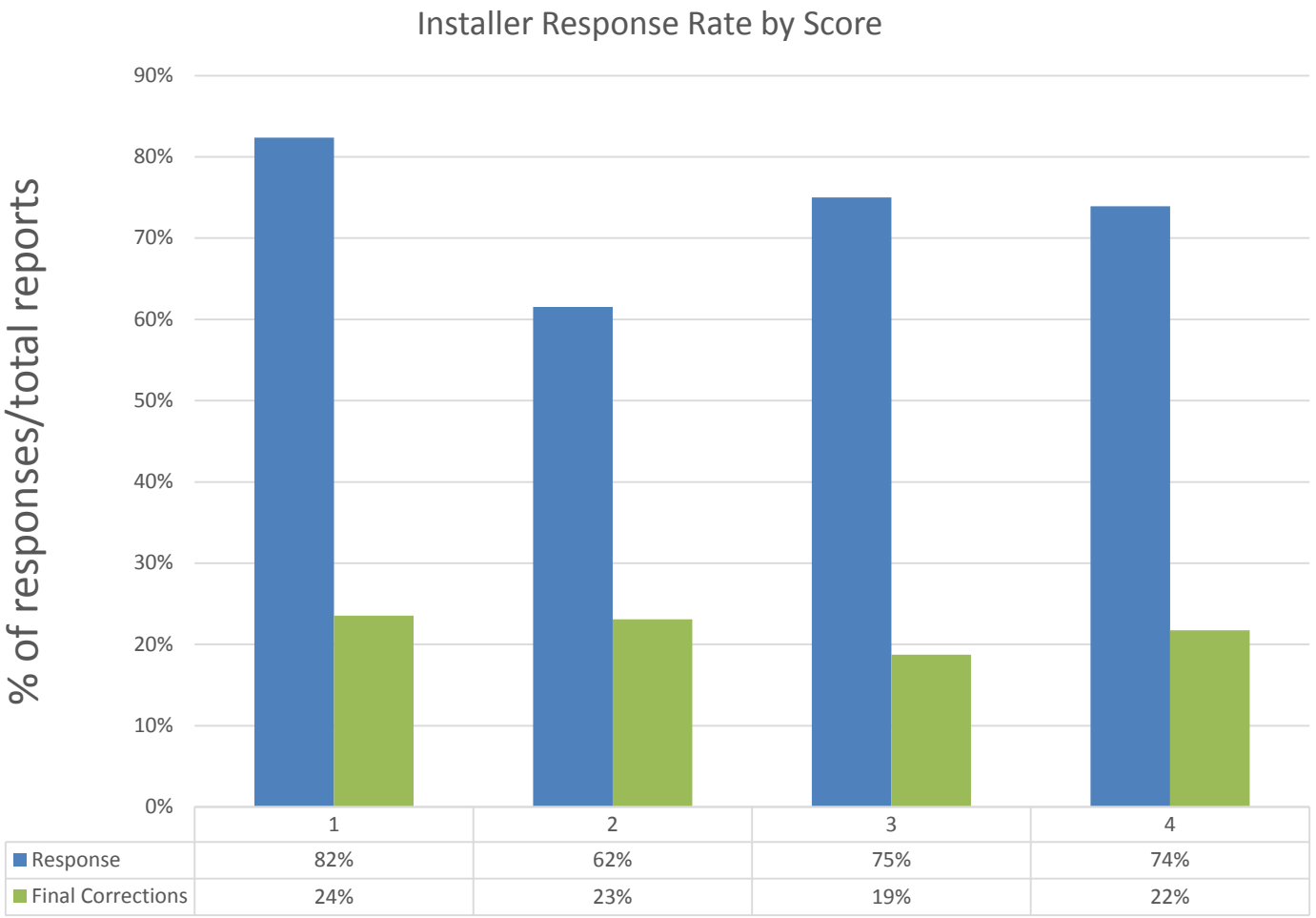
10 days — Report delivery to first installer response

17 days — Report delivery to final corrections

*Preliminary results only.




Responsiveness by Report Scores*



	1	2	3	4
Response	82%	62%	75%	74%
Final Corrections	24%	23%	19%	22%

*Preliminary results only.

Next Steps

- Conclude analysis
  - Compare quality and responsiveness comparisons between the REF and REG programs
  - Additional analysis of most common installation issues
  - Complete data gathering on installer responsiveness
  - Impact of overall installation quality on REG program goals
- Draft Report submitted to OER in mid-April
- Final Report pending OER feedback

Further Analysis and Recommendations

- Provide clear technical guidance documentation with photos/diagrams easy for electricians and inspectors to understand
  - *Cadmus took over 5,000 inspection photos*
  - *Cadmus developed informational material for Dec. 2015 Stakeholder meeting and distributed it to several installers and inspectors beyond OER distribution*
- Notify installers and document any program rule changes

Further Analysis and Recommendations

- For all overhead services, require upgrade with multi-gang meter
  - Do not allow connections at service point or tap boxes
  - Although an increased cost now, future upgrade savings and significant reduction of likelihood of failure
- Provide education to all metering staff involved to reduce inconsistencies and program violations
- Consider the role of self-installations in the REG program

Ongoing QA Review for REG-funded Renewable Energy Systems

- Based on our study findings, we would recommend some level of ongoing QA review
  - The extent and frequency of such reviews should be considered by OER, the PUC, and National Grid
  - Cadmus does not recommend 100% of systems be inspected (as required by the REF program)
    - Smart sampling such as low-volume or self-installers
    - Spot-check high-volume installers

Next Step: REG QA Study Round 2

- In November 2017, RI PUC approved OER's reconciliation funding request for further study and analysis of REG system quality
  - Cadmus will analyze 100 additional installations and produce a summary report of findings
  - Also surveying REG customers
    - To assess customers' perception of and satisfaction with system quality

REG QA Study Round 2 Timeline

Nov. 2017 – March 2018

- Sampling and onsite quality inspections

Jan. – March 2018

- Survey design and survey administration

Spring 2018

- Draft and final reports to OER; presentation of results

Questions?

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