

Low-Cost Solar Retrofit *Grid-Ready Plug-and-Play PV Kit* California Solar Initiative (CSI) RD&D Solicitation 2

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Low-Cost Solar Residential Retrofit

Webinar Structure

- 4- 20 min presentations, followed by 10 min for Q/A.
- Please hold questions to the end of each presentation
- To ask a Question, raise your hand and your line will be unmuted; or you can type your question into the comment box. Typed questions can be submitted at any time. Please keep your questions short and concise.
- The webinar will end at noon.

Agenda (sections with QA following each):

1. Program and Project Overview, *P&P PV Kit* Description, Install & Test Prototype + Installation Best Practices
2. Beta-Test installations, Commissioning, Performance
3. Cost Analysis, Financing, Business Models
4. ZNE Home Design and Performance, Conclusions

Section 1

Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

- 1. Program and Project Overviews**
- 2. Grid-Ready Plug-&-Play PV Kit**
- 3. Install & Test Prototype + Installation Best Practices on Showcase Home**



California Solar Initiative (CSI)

In 2006 the California Public Utilities Commission (CPUC) established a budget for the California Solar Initiative (CSI) Research, Development, Demonstration and Deployment Program (RD&D)



Goal:

- Install 3,000 megawatts of distributed solar by 2016
- Move the market from the current retail solar price to the retail price of electricity
- Develop new business models



Rob Hammon, Ph.D.

Over 30 years experience: building science → quality construction, integrating energy-efficiency, clean & renewable energy

- Guiding and assisting building industry: builders, developers, architects, contractors, manufacturers, suppliers
- Utilities: program design and implementation
- US DOE Program Lead: Zero Energy Homes & Building America
- Co-Chair New Solar Homes Partnership Advisory Committee
- Led Residential Team in development of CA Long-Term Energy Efficiency Strategic Plan
- Benefitting CA Ratepayers: Quality, Comfortable, Efficient Homes and communities → reduce GHG emissions

Low-Cost Solar: Program Overview

Goal: Reduce first-cost barrier for Zero Net-Energy (ZNE) retrofits

Method: Reduce installed cost of solar retrofits; integrate with cost-effective energy efficiency improvements, demand response (DR), intelligent storage and a home energy management (HEM) system.

6 homes retrofitted with low-cost rooftop-solar in San Diego Gas and Electric (SDG&E) territory:

- Demonstration and evaluation of **low-cost, roof-mounted PV system** in different markets: 1-prototype and 5-beta test installations
- ***GE Smart-Grid Ready Insert-and-Capture Solar PV systems:*** Evaluation of 6 systems: installation, training, costs and performance
- **ZNE test home** – 1 test home also **retrofitted to be ZEH** by adding: energy efficiency, DR, HEM, Storage and HEM; detailed evaluation
- Market and Financing Analyses → Business Model for Grid-Ready Plug-and-Play PV Kit

“Grid-Ready Plug-&-Play PV Kit”

Grid-Ready Plug-&-Play PV Kit: Benefits to California Ratepayers

- **Target existing homes (currently asphalt only)**
 - Large portion of residential market
 - Could install on new asphalt
- **Low installed cost**
 - Rooftop solar
 - Target <\$4.25/Watt (LCOE \$0.14/kWh)
- **Large potential marketing, sales & installation base (roofers)**
- **Practical business model for roofers**
 - Market analysis
 - Innovative financing detailed
 - Solar contractors and electricians could also install
- **Moves toward practical ZNE retrofits**

Grid-Ready Plug & Play PV Kit

Major Tasks & Deliverables

- Best practices training program and materials
- Install prototype
- Monitor & evaluate prototype
- Installed system cost
- Market & financing analyses
- Install 5 beta-test homes
- Retrofit 1 test home to ZNE
- Monitor & evaluate
- Business model

Acknowledgements

Charles Korman, Ph.D., GE: Chief Technologist, Solar Energy, at GE Global Research. The BIRAenergy team commends Dr. Korman for his large contributions to this project and the solar industry as a whole.

Sunverge – Ken Munson, Steve Wolford, Jon Fortune, Stina Brock

The family in the ZNE Home (anonymous, but extremely helpful)

SDG&E – Nate Taylor, Ahmed (Sempra) - Support for ZNE retrofit

Thanks to our partners!

Section 1

Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

1. Program and Project Overviews
2. **Grid-Ready Plug-&-Play PV Kit**
3. Install & Test Prototype + Installation
Best Practices on Showcase Home

Grid-Ready Plug & Play PV Kit Microinverters → AC System



Micro-
inverter

Wire-
Harness
Connector

Electrical Components for a 2.5kW System

AC Module Assembly

Enphase microinverter



Star washer



AC module (Motech laminate)



Engage Harness



Harness cable clip



Engage harness installed onto rail



Harness terminator



8 Electrical components per baseline kit

Metal connector box



2-pole on-off switch



External switch cover



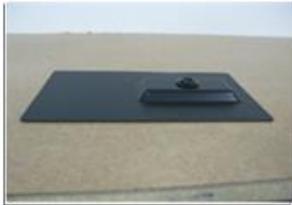
Flashed Junction Box



Switch/Connector Box

Mechanical Components for a 2.5kW System

Flashing (24/15)



Rail Coupling (0)



Grounding Side Panel (2)

Grounding Screws (4)



Front Finishing Panel (1)

Grounding Screws (4)



Stanchion (24/15)

Lag Screws (24/12)



Rail Clip (24/15)



Rail (3)

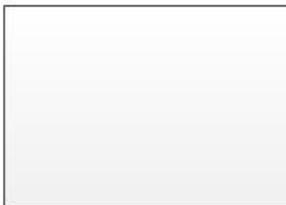


Securing Cover (10)

Grounding Screws (5)



Flashing Assembly



Rail Clip/Stanchion Assembly



Rail Assembly

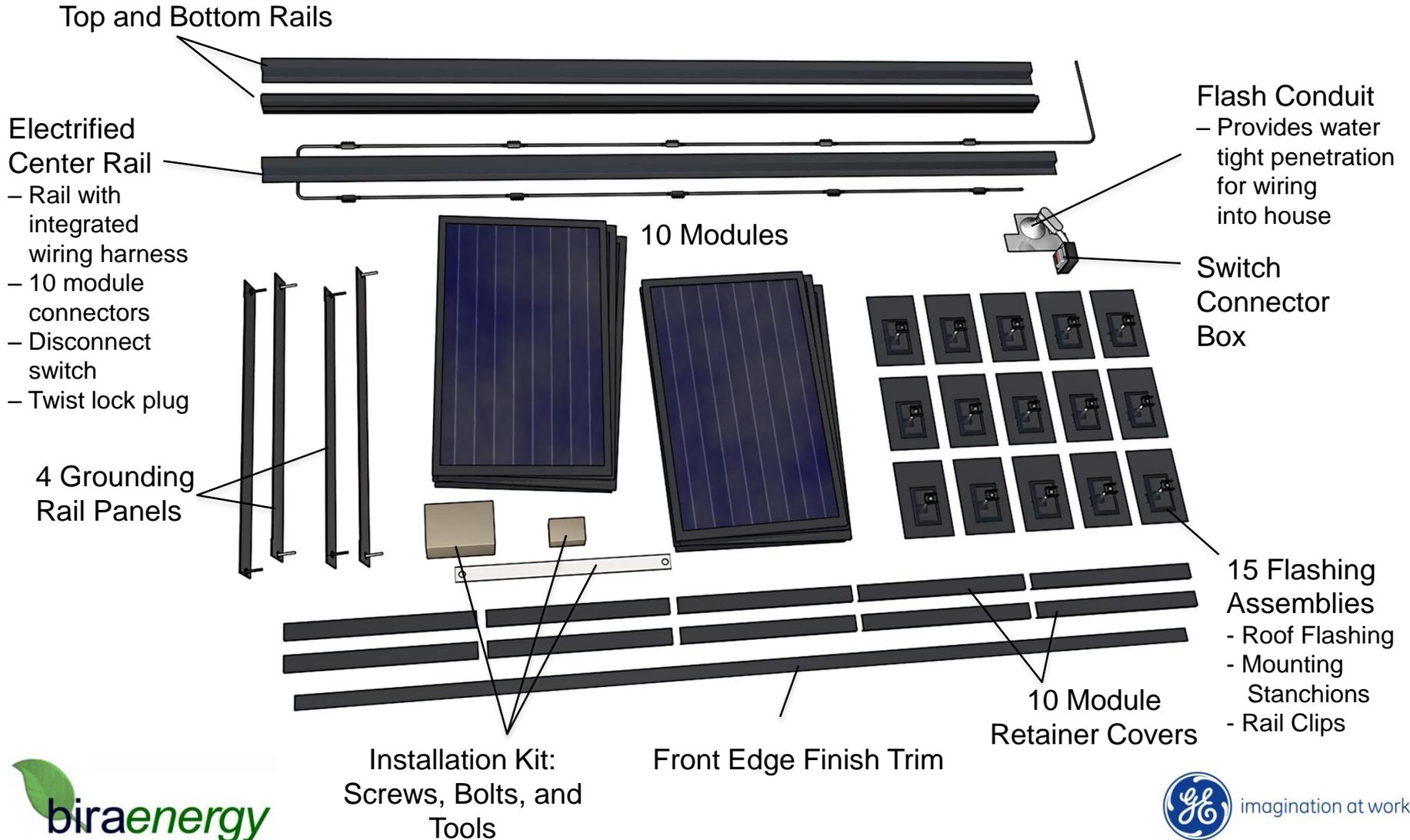


**11 Different
mechanical
assemblies per
baseline kit**

2.4 kW GE Insert and Capture Solar Array System

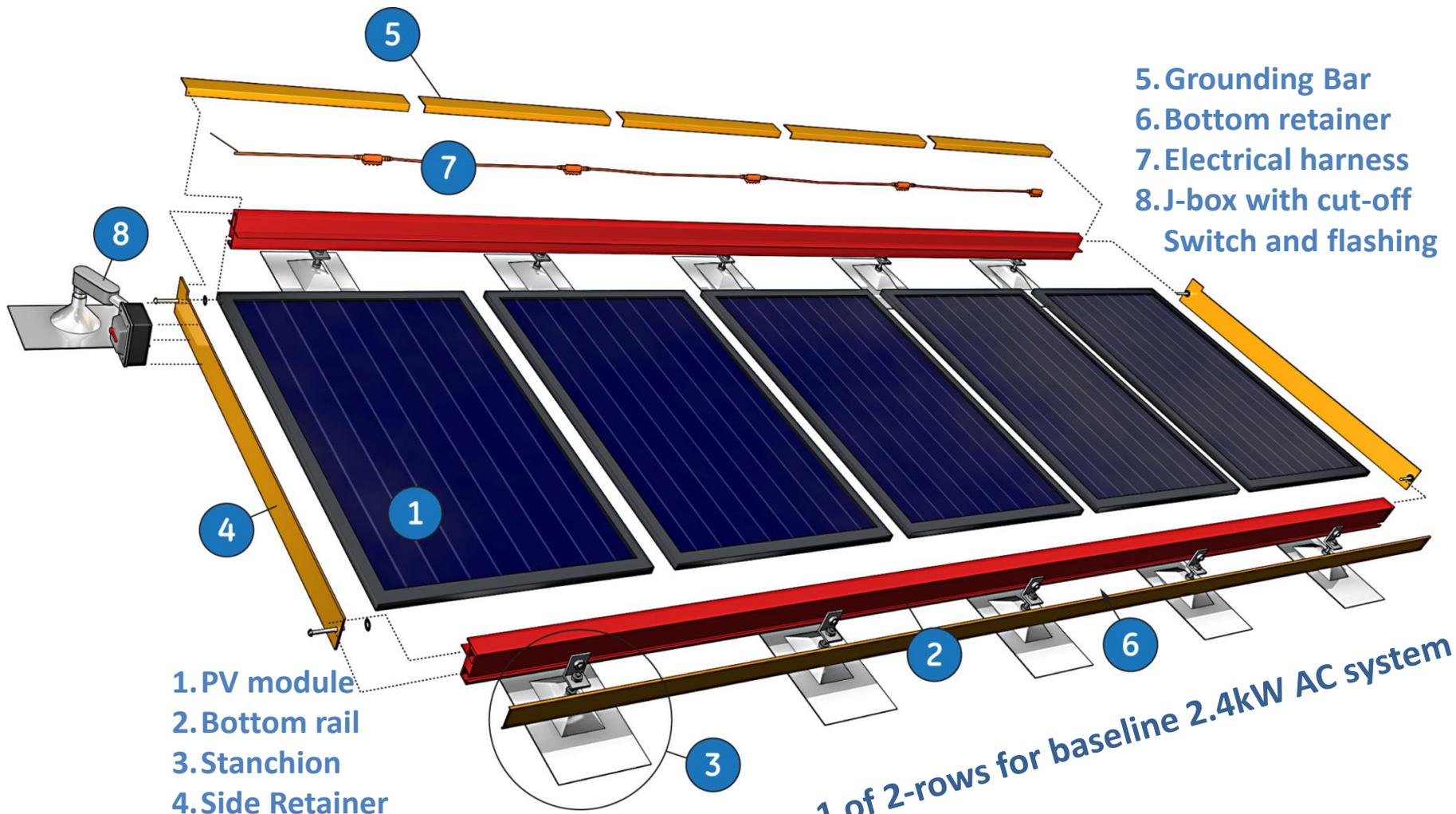
The Prime Example of a Grid-Ready, Plug-and-Play PV Kit

The PV Kit, as delivered to each site for installation and assembly



GE Insert and Capture PV System

Prime Example of Grid-Ready Plug-and-Play PV System



5-panels = 1 of 2-rows for baseline 2.4kW AC system

Section 1

Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

1. Program and Project Overviews
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Best Practices on Showcase Home

Grid-Ready Plug-&-Play PV Kit Prototype Installation (Showcase Home)

2.4 kW system installation – Chula Vista, CA

- Chula Vista showcase green home
- Retrofits completed early 2012
- Open to the public for ~6 months
- Loan assistance to deserving family
- Retrofits: repairs, modern kitchen, energy efficiency, green materials and renewable energy. Including:
 - Low VOC paint
 - Recycled glass countertops
 - **New efficient windows**
 - **EnergyStar appliances**
 - **LED lighting (interior & exterior)**
 - **GE Insert & Capture PV**
 - **Solar water heating**
 - **Efficient water & space heating**
 - Drought tolerant landscaping



Grid-Ready Plug-&-Play PV Kit: Installation

Locate rafter, lag stanchions, align V notch & chalk line



Flash & cap stanchions



Snap rails in "C" - attach wiring harness center rail



Insert modules, connect harness, trim



Grid-Ready Plug-and-Play PV Kit

Electrician Installation Tasks - Prototype

Install junction box & conduit/EMT and pull wire to roof



Install disconnect switch & surge protectors on roof



Install 240V breaker in Service panel & placards per code



Validate system function – meter spinning backwards, Amperage



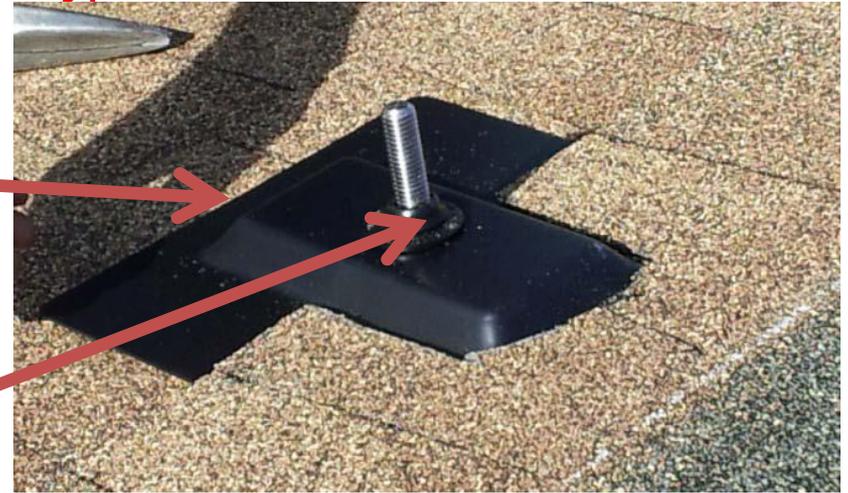
Grid-Ready Plug-and-Play PV Kit

Key Learnings from Prototype Installation -1

Design Improvements:

Big, square flashings to protect roof from leaking

Taller mounts w/ leak proof collar



Shorter wires, well contained and hidden

Grid-Ready Plug-and-Play PV Kit

Key Learnings from Prototype Installation -2



Design Improvement:
Lower profile Capture straps
& fewer screws (3 vs 5)

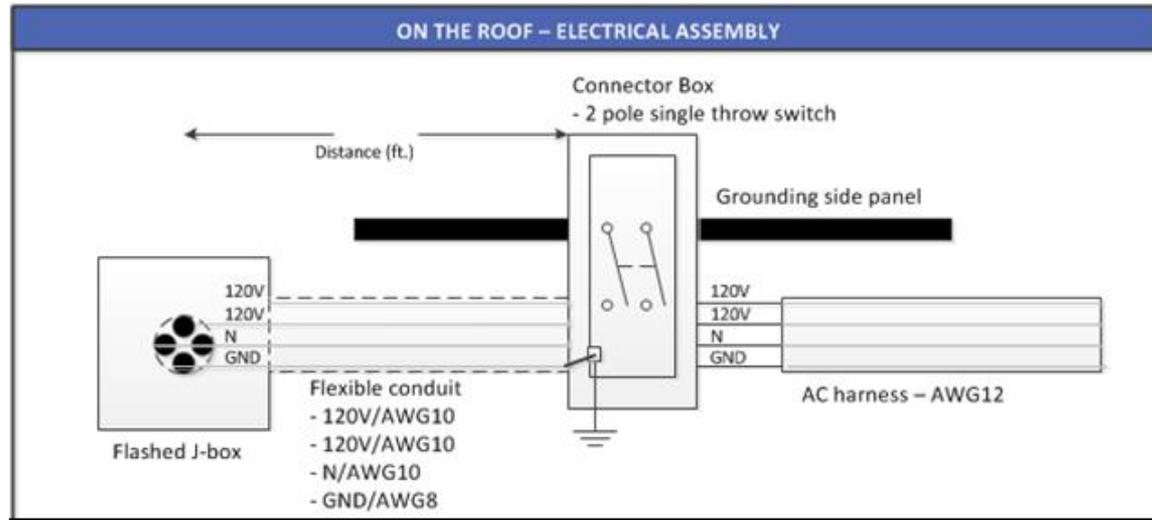
Inspection Issue:

Grounding: UL approved
but not visible



Grounding: Problem? Yes! and no...

The electrical harness carries a ground wire, but ...



It could not be visibly confirmed - Grounding became only show-stopper field inspection.

The electrician was required to install grounding lugs and run bare copper ground across each panel to obtain approval from the inspector.

Result: \$40 for lugs, 40' of #8 copper, 2 people X 1 hour to duplicate the ground.

Training will resolve this problem

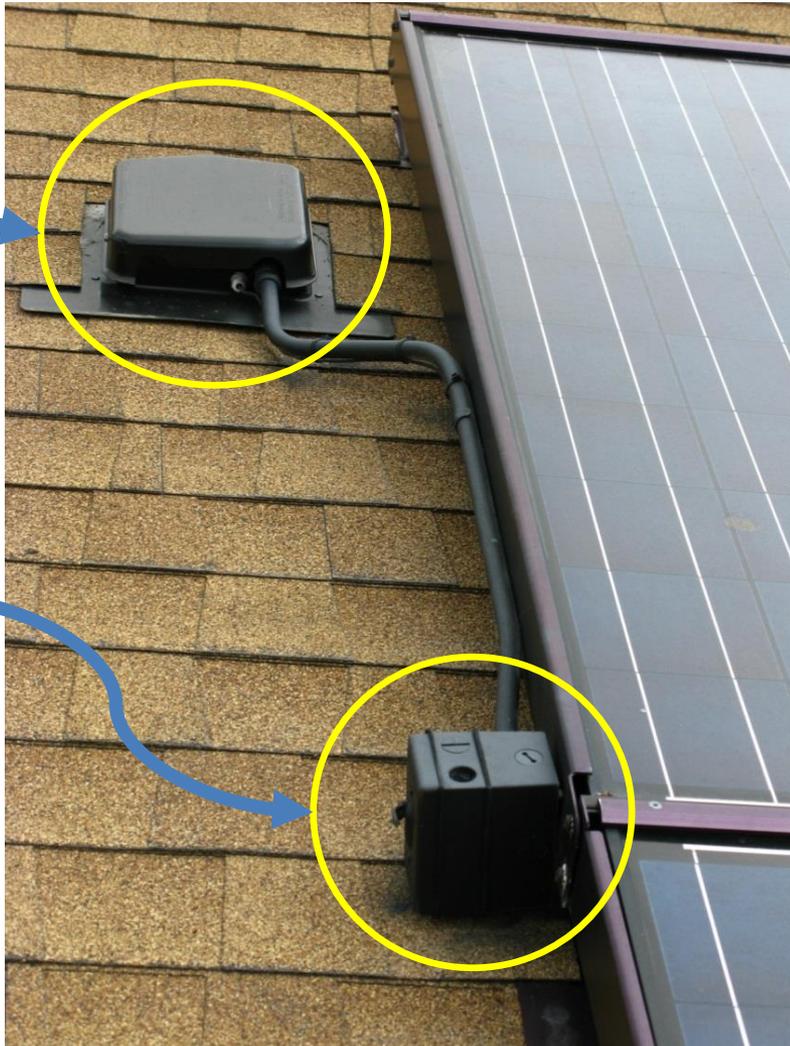
Grid-Ready Plug-&-Play PV Kit

GE Eliminated requirement for an electrician on the roof

Beta-System Electrical on Roof

Prototype

Penetration
junction box



Switch/
connector
box



Section 1

Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

BREAK – Q&A

- 1. Program and Project Overviews**
- 2. Grid-Ready Plug-&-Play PV Kit**
- 3. Install & Test Prototype + Installation
Best Practices on Showcase Home**

Section 2

Low-Cost Solar Residential Retrofit Grid-Ready Plug-&-Play PV Kit

- 1. Beta-Test Installations**
- 2. PV System Commissioning**
- 3. PV System Monitored Performance**

Prototype Success –

Installation Process:

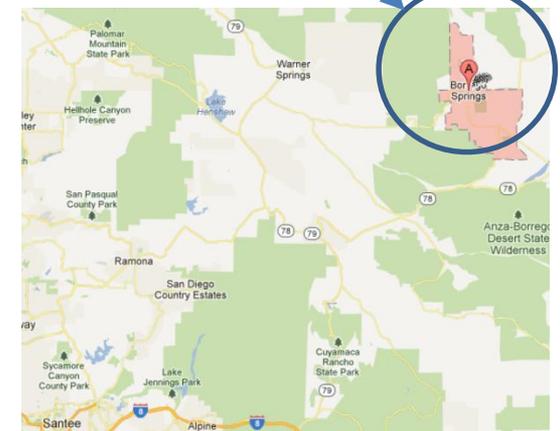
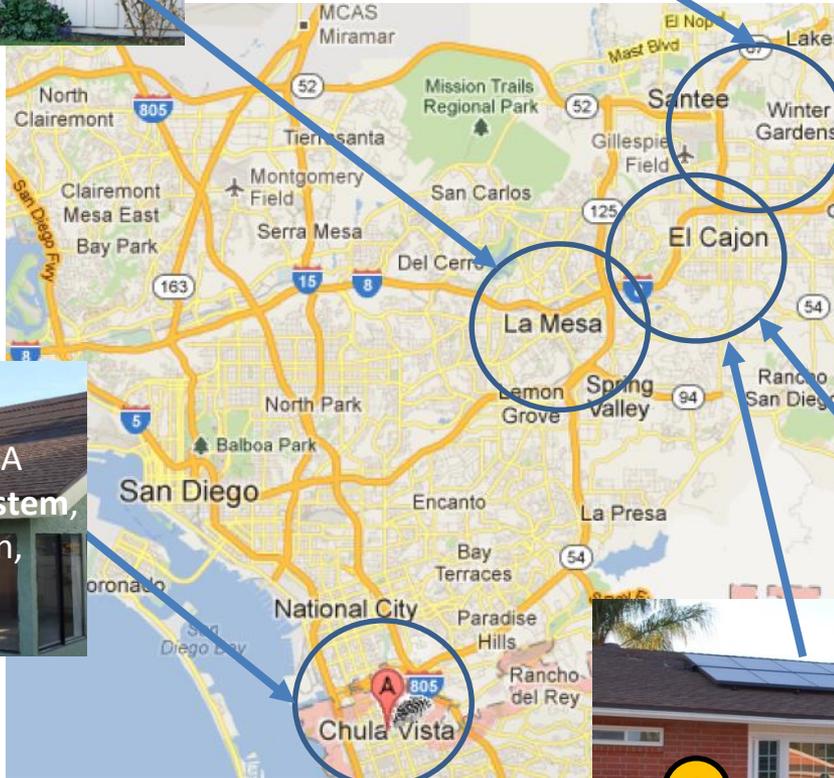
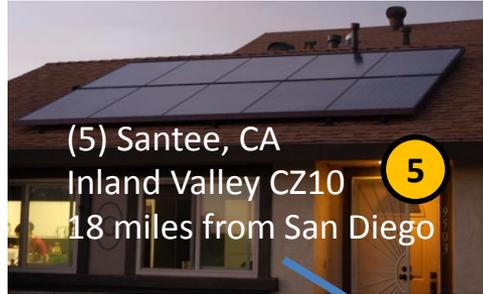
3 roofers plus Supervisor: Trained, reroofed, and installed solar on roof in 3 hours. 2 electricians: completed electrical wiring in 1.5 hours

With Lessons Learned and Design Changes Made – Ready for Beta-tests...

- *Demonstrate and train on grounding – have spare harness for inspection*
- *Eliminated all requirements for electrician on roof for installation*
- *Cut the installation time*
- *Cut the installed costs*

California Solar Initiative Pilot Installations

GE Smart Grid Ready Insert & Capture Plug-&-Play Residential Solar Retrofit



Low-Cost Solar Retrofit
Grid-Ready Plug-and-Play PV Kit

Best Practices Training Guide

Developed Under California Solar Initiative
Research, Development & Demonstration (RD&D)
Solicitation #2: Low-Cost Solar Retrofit

Training Program Author

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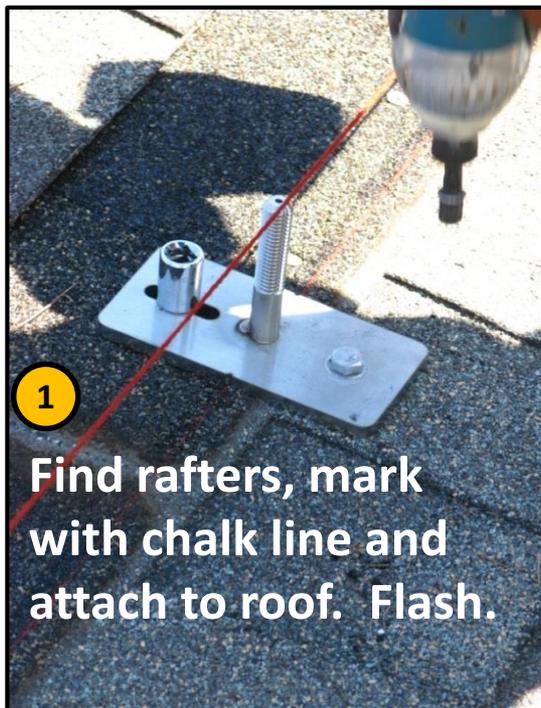


Kit - Unloaded and ready to go



Electrical contractors work in parallel with roofer to complete on-the-ground pre-wiring tasks – ac wiring of the powered middle rail

Attaching and Flashing Stanchions Then Rails



1

Find rafters, mark with chalk line and attach to roof. Flash.



2

Install clips on stanchion post

All tools the roofing contractors are familiar with + the GE spacing tool

A three-person crew can significantly increase speed of installation when the work is coordinated.



3

Adjust clip height and place rail



4

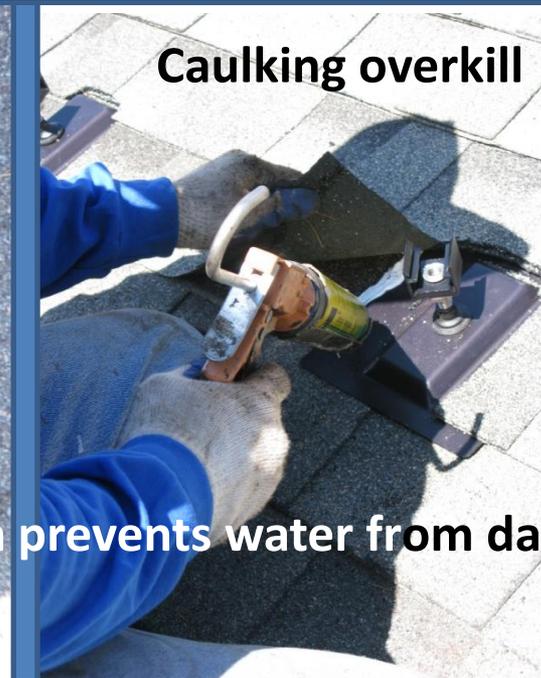
Press rail in place

- A best practice to look at each clip to be sure the rail is evenly seated on both sides
- properly seated rail will require 3,000 lbs of pull out force
- The rail can still slide (until modules installed) allowing the array to be squared

Best Practice

Making Flashing Weathertight

PVC Sealant is used to enhance weather tightness of flashing installation



- Notes:**
- Other option is use of an Everbond™ butyl pad underneath the flashing
 - Sealant on the bottom of the flashing should be sufficient
 - however the CA roofing contractors nail down the flashing

Grid-Ready Plug-&-Play PV Kit

Best Practice – Star Washer

Ensure System is Well Grounded

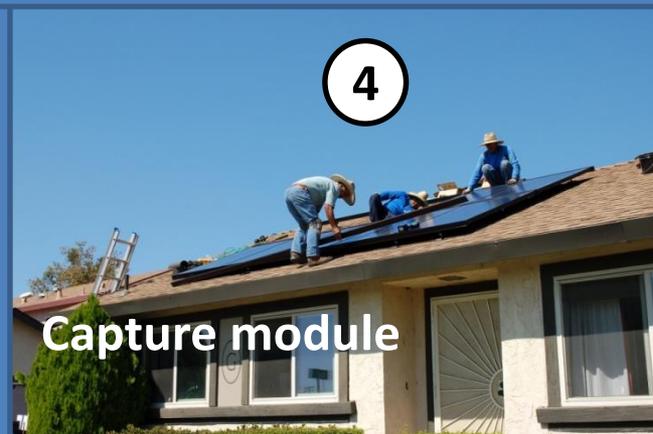
Grounding side panels overlap. A self-tapping screw and star washer combination are used for attachment to the rail and to achieve electrical bonding between rails



GE Insert and Capture – Installing Module

Module insert and capture

Insert an ac module in 4 easy steps



Roofer Can Make AC Connection and Through Roof

Rooftop electrical interface

Safety cutoff switch and flashed penetration assembly

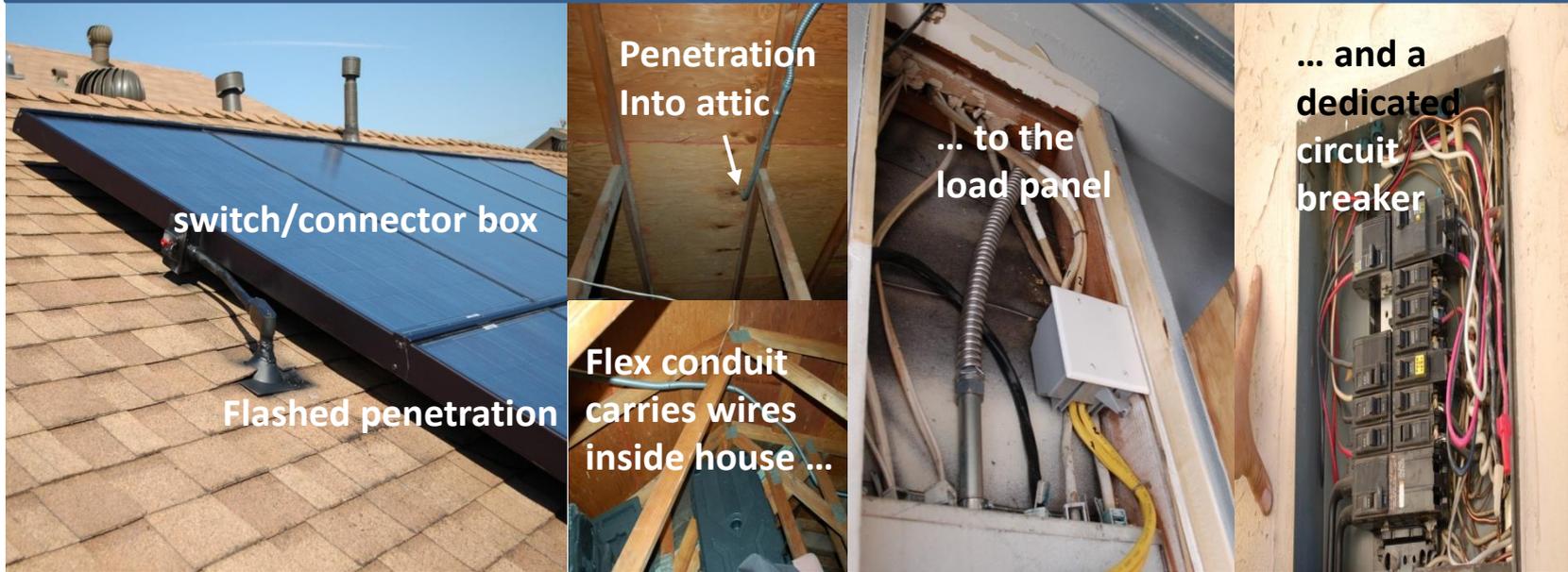
Use of a commercial flashing for the home run penetration is not ideal and requires additional sealing for weather-tight performance.



Electrical Path – Roof to Panel

Electrical contractor picks up under roof deck

From the roof to the load panel



Solar system is on a dedicated circuit having a 2-pole 240Vac circuit breaker

Section 2

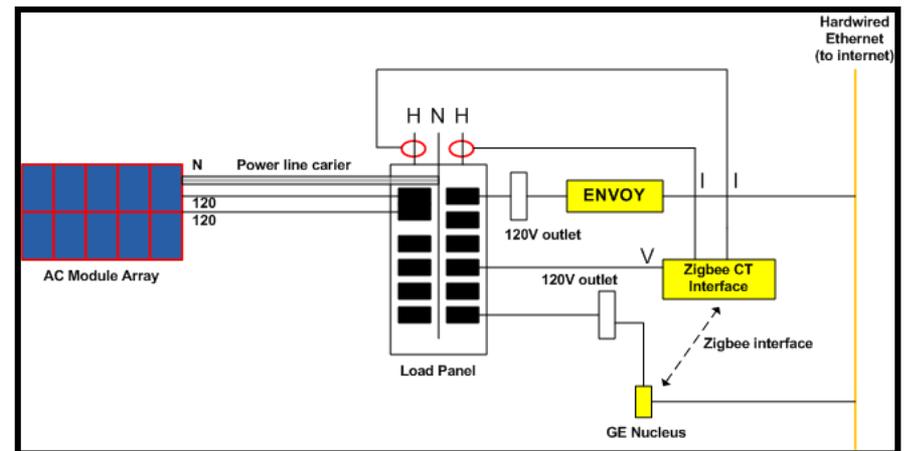
Low-Cost Solar Residential Retrofit Grid-Ready Plug-&-Play PV Kit

1. Beta-Test Installations
2. PV System Commissioning
3. PV System Monitored Performance

Grid-Ready Plug-&-Play PV Kit

Systems Commissioning

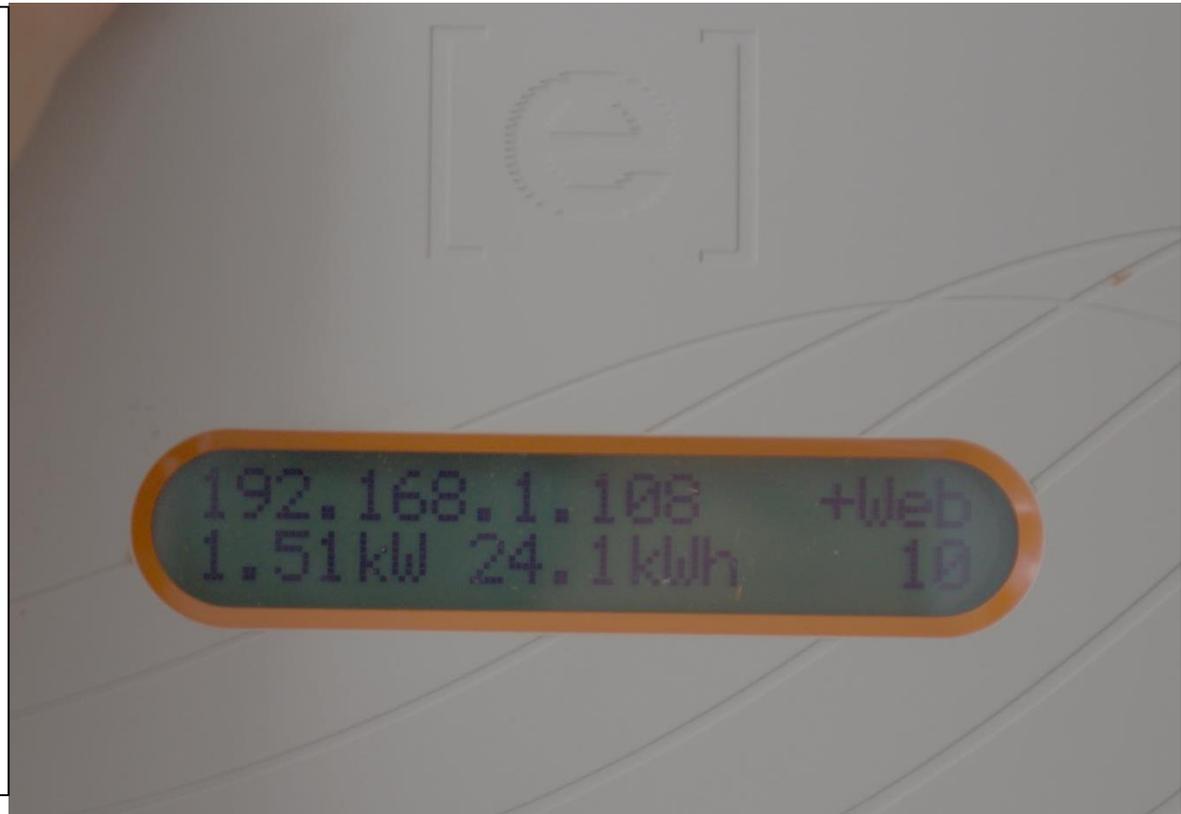
- Enphase microinverter on each module: DC → AC
- Microinverters gate output based on detection of 60Hz (US) line voltage
- Commissioning automated via Enphase Envoy system - monitors and can control the Enphase microinverters. Read via Enlighten software.
- Envoy requires commissioning prior to allowing current to flow to the electrical panel.
- ZNE home has a GE Nucleus HEM:
 - monitor electricity generation
 - house electric loads (CTs) on the electrical mains)
 - Control Demand Responsive (DR) appliances and outlets



Wiring diagram modules, Envoy, load panel, GE Nucleus

Grid-Ready Plug-&-Play PV Kit System Commissioning – Envoy Meter

- **Enphase Envoy Meter identifies all 10 ac modules**
- **Grid interconnection tests**
- **Establish UL1741 compliance**
- **Then allows parallel connection to the grid.**



Commissioning Initiated

2.4 kW Beta-Test Installation

The screenshot shows the Enphase Enlighten web interface. At the top, there is a navigation bar with the 'e|Enlighten' logo and menu items: DASHBOARD, SYSTEMS (selected), ACCOUNT, SUPPORT, My Account, and Help. Below the navigation bar is a 'Systems List' section with a 'Full System' dropdown menu and buttons for View, Graph, Reports, Devices, Events, and a settings gear. The main content area is titled 'Overview' and displays system details: '*System Name: J', 'System Location: United States', 'PV Module (Panels) Make/Model: Motech MTPVp-235-MSB', and 'System ID: 128112'. A 'Timezone: US/Pacific' label is also present. At the bottom left, there is a checkbox labeled 'Site is Operational' which is checked, and a 'Save' button. A vertical orange 'Feedback' button is located on the right side of the page.

Example page from the Enphase Enlighten system during commissioning the system installation. The system is identified by the homeowner's name (blocked out in these report examples).

Commissioning: 10 Modules Identified and Functioning

2.4 kW Beta-Test Installation

Systems List

Devices ▾

View Graph Report

Envoy Communication Gateways

Name	Type	Last Report	Status
Envoy 121145085237	Envoy 800-00069-r05	11/14/2012 04:24 AM PST	✓ Normal

Microinverters

change columns

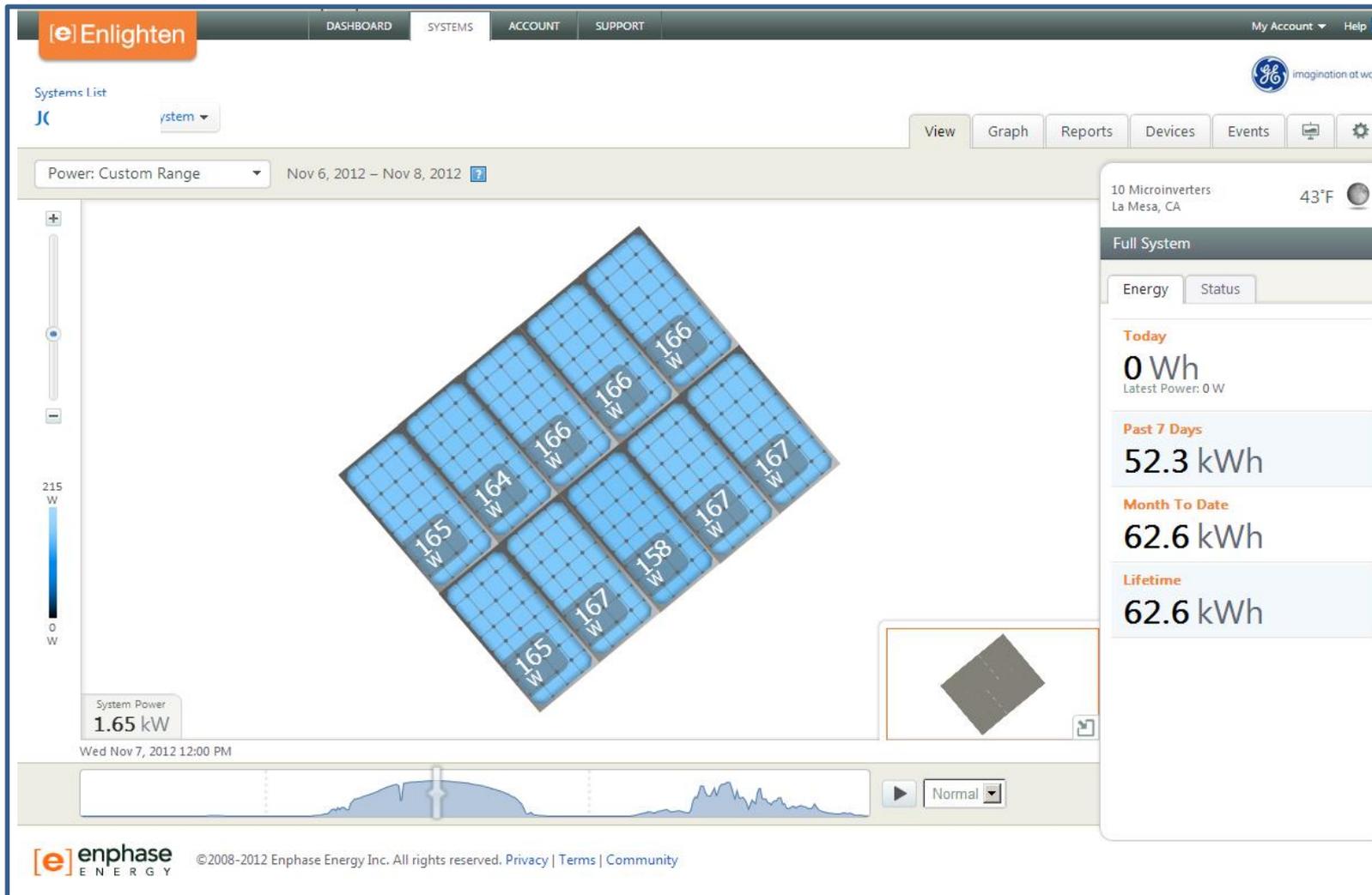
Showing 1 to 10 of 10 microinverters

Serial #	Part Number	Status
Serial #	Part Number	Active
121129941377	800-00103-r05	✓ Normal
121129941458	800-00103-r05	✓ Normal
121129941493	800-00103-r05	✓ Normal
121129941566	800-00103-r05	✓ Normal
121129941691	800-00103-r05	✓ Normal
121129942026	800-00103-r05	✓ Normal
121129942144	800-00103-r05	✓ Normal
121129942524	800-00103-r05	✓ Normal
121129942636	800-00103-r05	✓ Normal
121129942649	800-00103-r05	✓ Normal

At this stage of Commissioning, the Enlighten system has identified each module and verified that they are all working properly.

Grid-Ready Plug-&-Play PV Kit

2.4 kW Beta-Test Installation - Commissioning



All the modules identified and operation verified.

Now allowed to connect to the electrical box.

Enlighten graphic shows status and output of each module, and system statistics (at the right).

Measure and verify voltage at the Panel.

Commissioning Complete – Connect to Grid



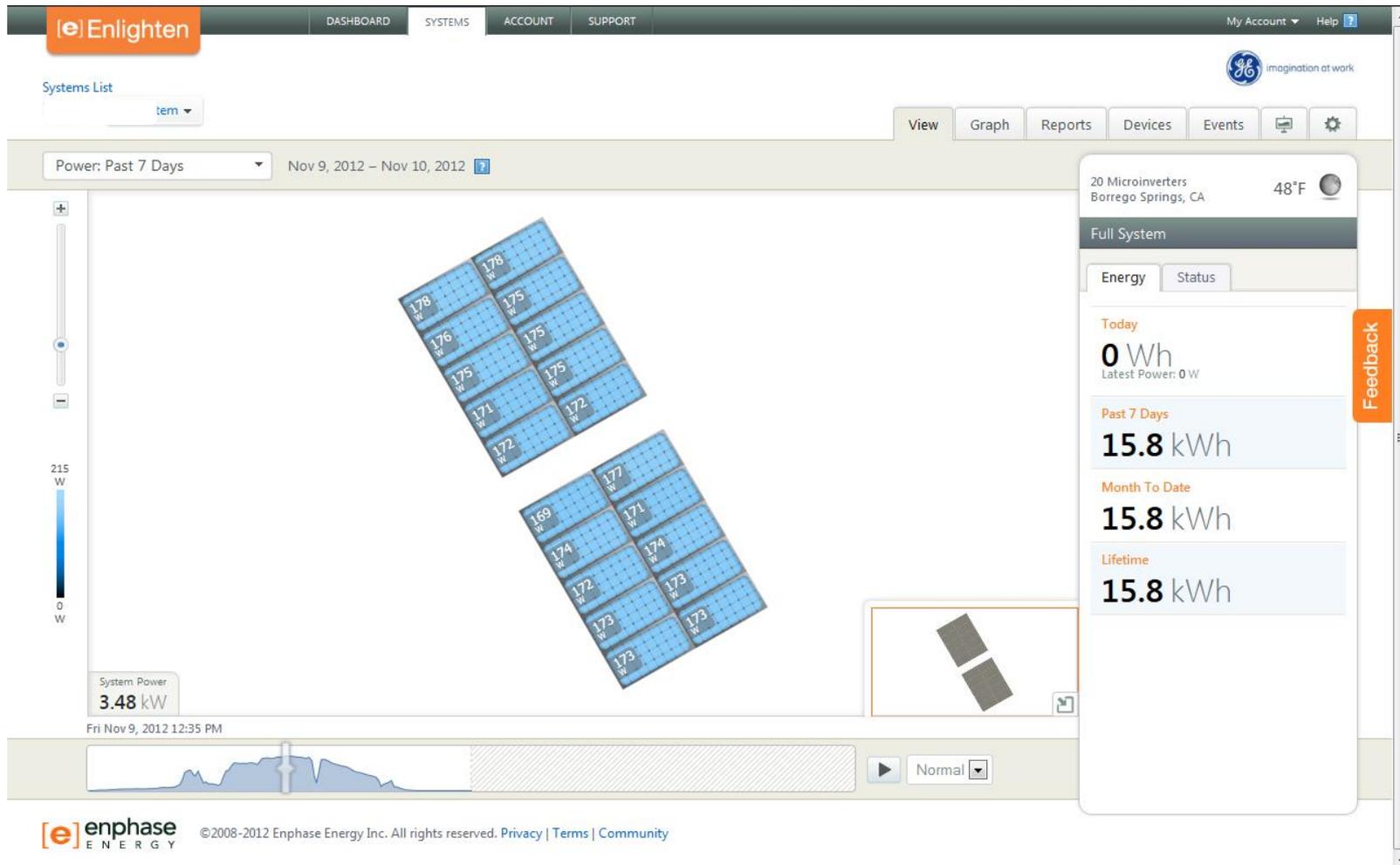
Section 2

Low-Cost Solar Residential Retrofit Grid-Ready Plug-&-Play PV Kit

1. Beta-Test Installations
2. PV System Commissioning
3. PV System Monitored Performance

4.8 kW Grid-Ready Plug-&-Play PV Kit

Enlighten on-line performance data

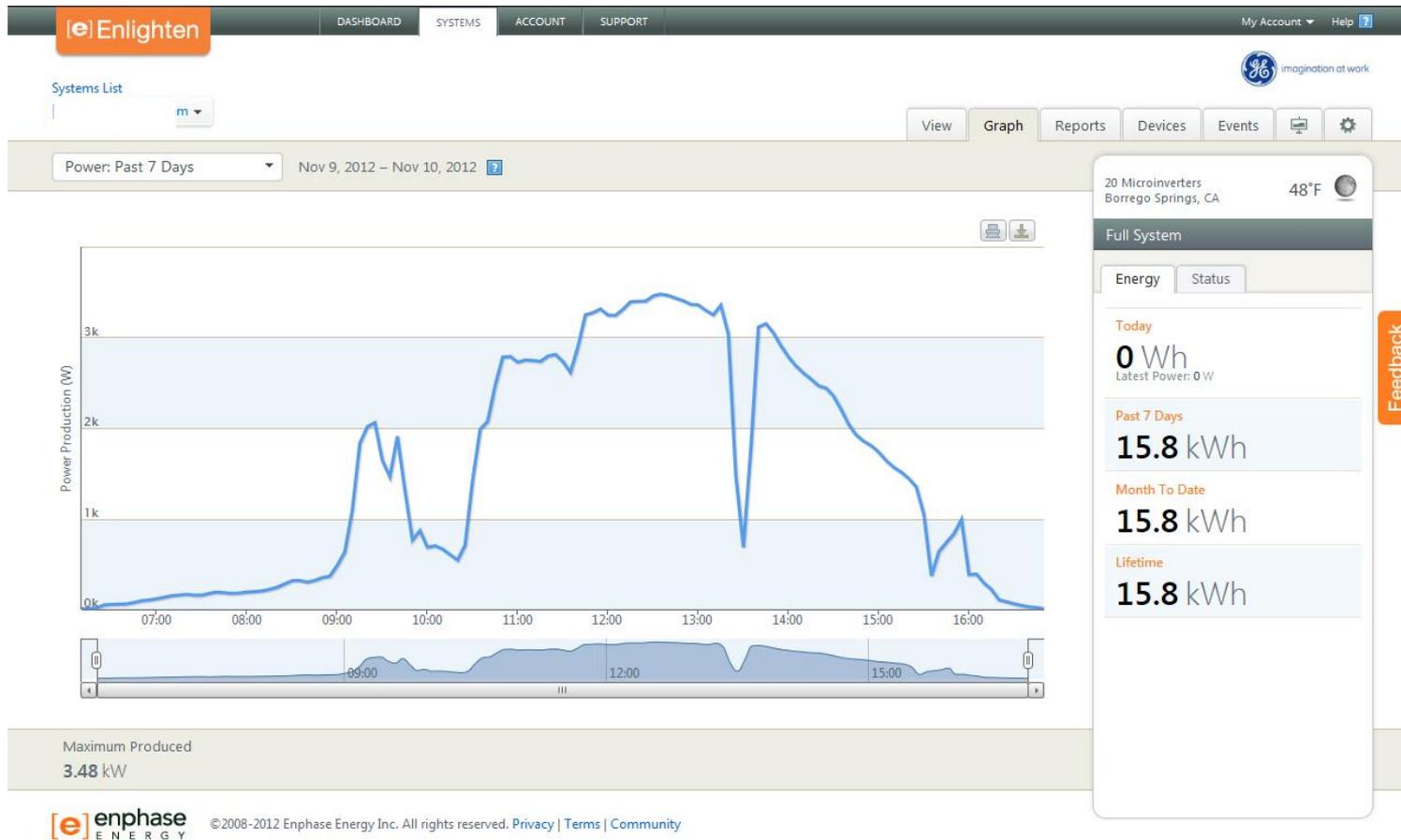


Borrego Springs home has 2 * 2.4kW systems = 20 modules.

Enlighten shows the status of all and total system stats

Test Home 5 – Borrego Springs

Enlighten on-line performance data



Enlighten can provide homeowner additional information when desired.

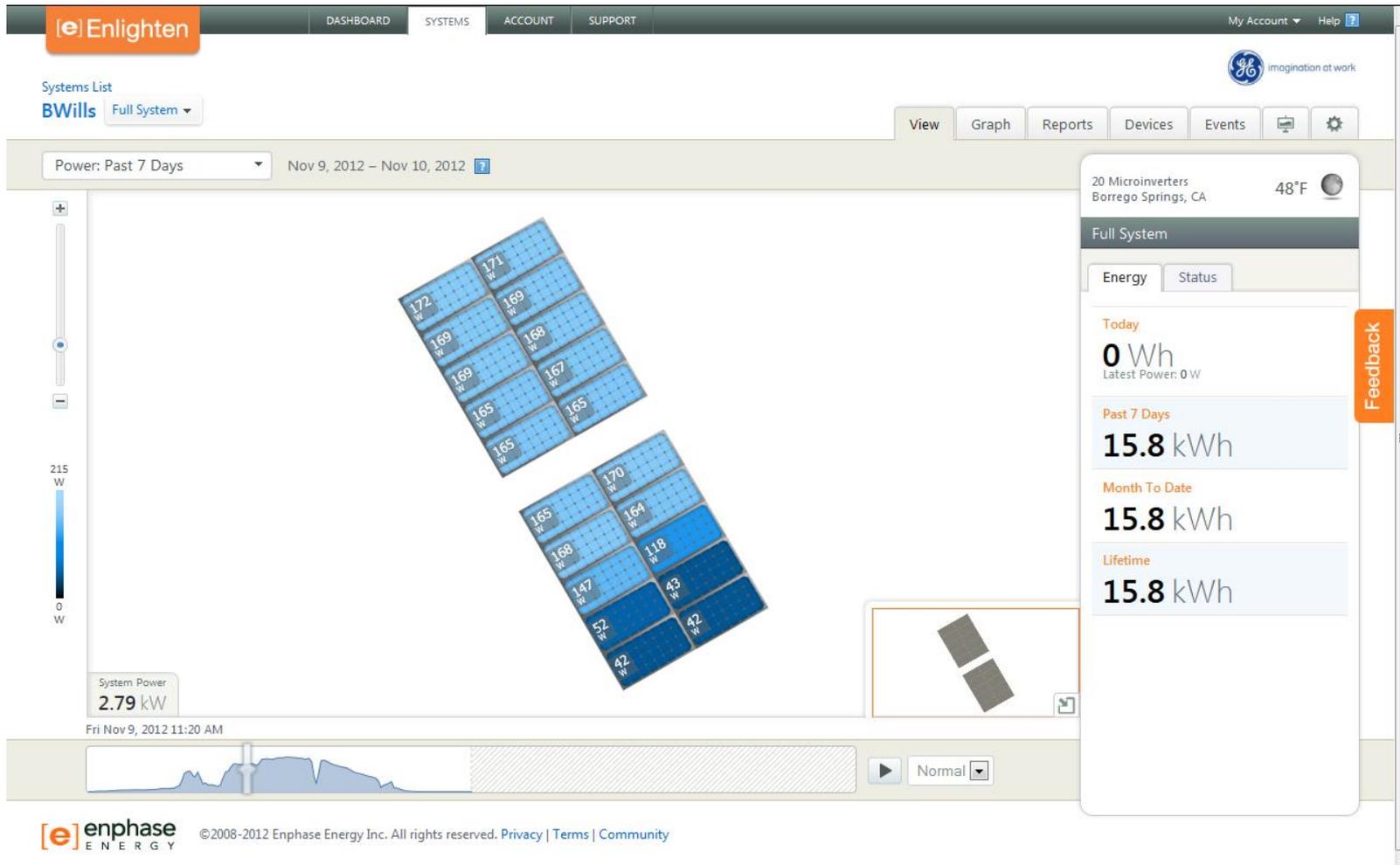
This graph generated after the first full day of operation by the Borrego Springs system.

It shows shading events that could be due to clouds, trees, or other obstructions resulting in reduced sunlight on the panels.

The Enlighten shows power produced, energy generated over various time periods from a day to a week to the life of the system. These can all be displayed numerically (as on the right) or graphically.

Borrego Springs Near Sunset – Shading Impacts

Enlighten on-line performance data



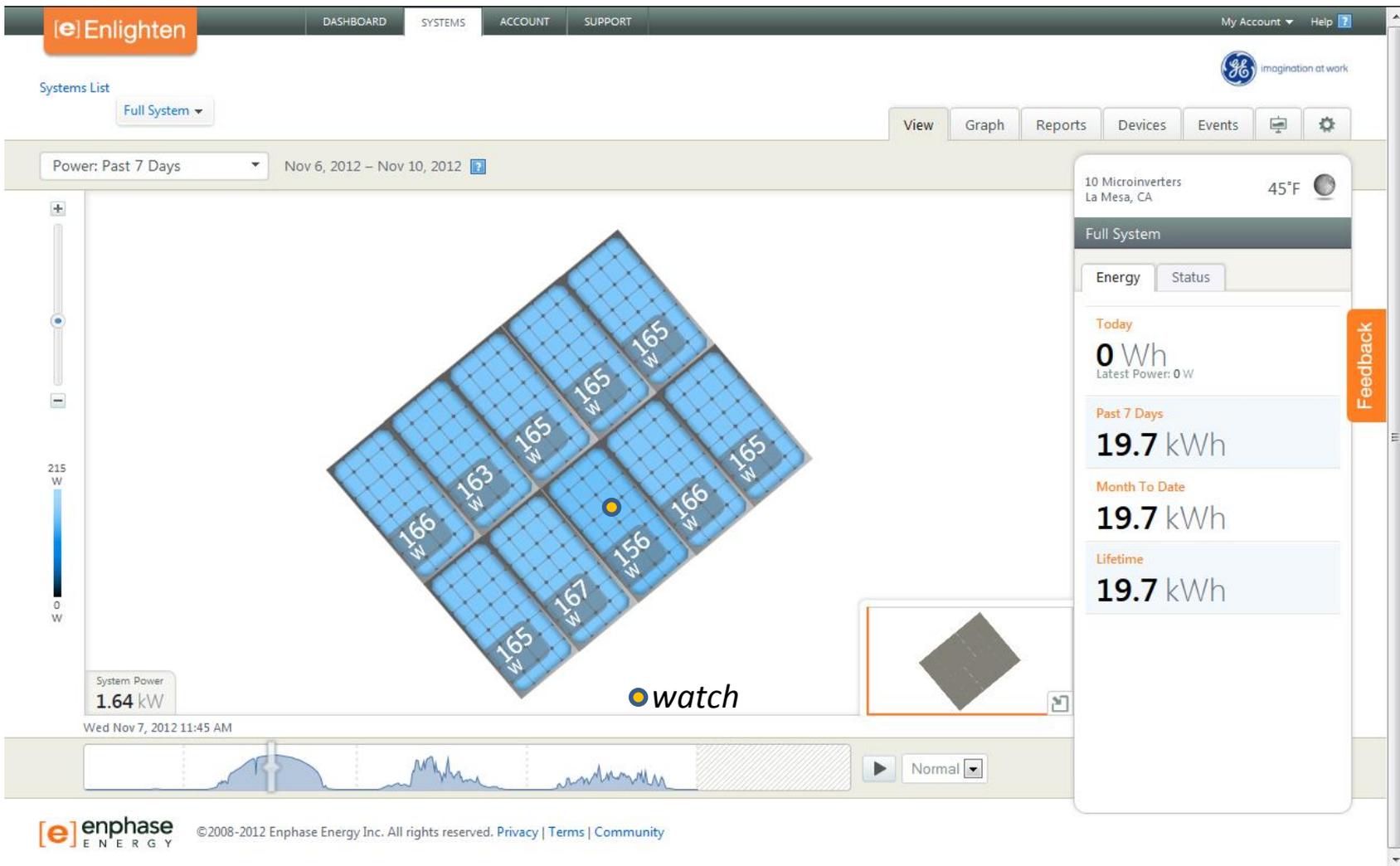
Near sunset the eastern-most panels on this system became shaded. They show decreased output due to lower insolation levels.

Note that the significant decrease in generation from some

panels losing insolation does not have a large effect on others in the string of interconnected panels. This array behavior is quite different from that of DC strings of panels, where, when the amount of sunlight on one panel in a string goes down, the entire string is significantly effected.

Enlighten Performance Map

Sunny day in November after commissioning

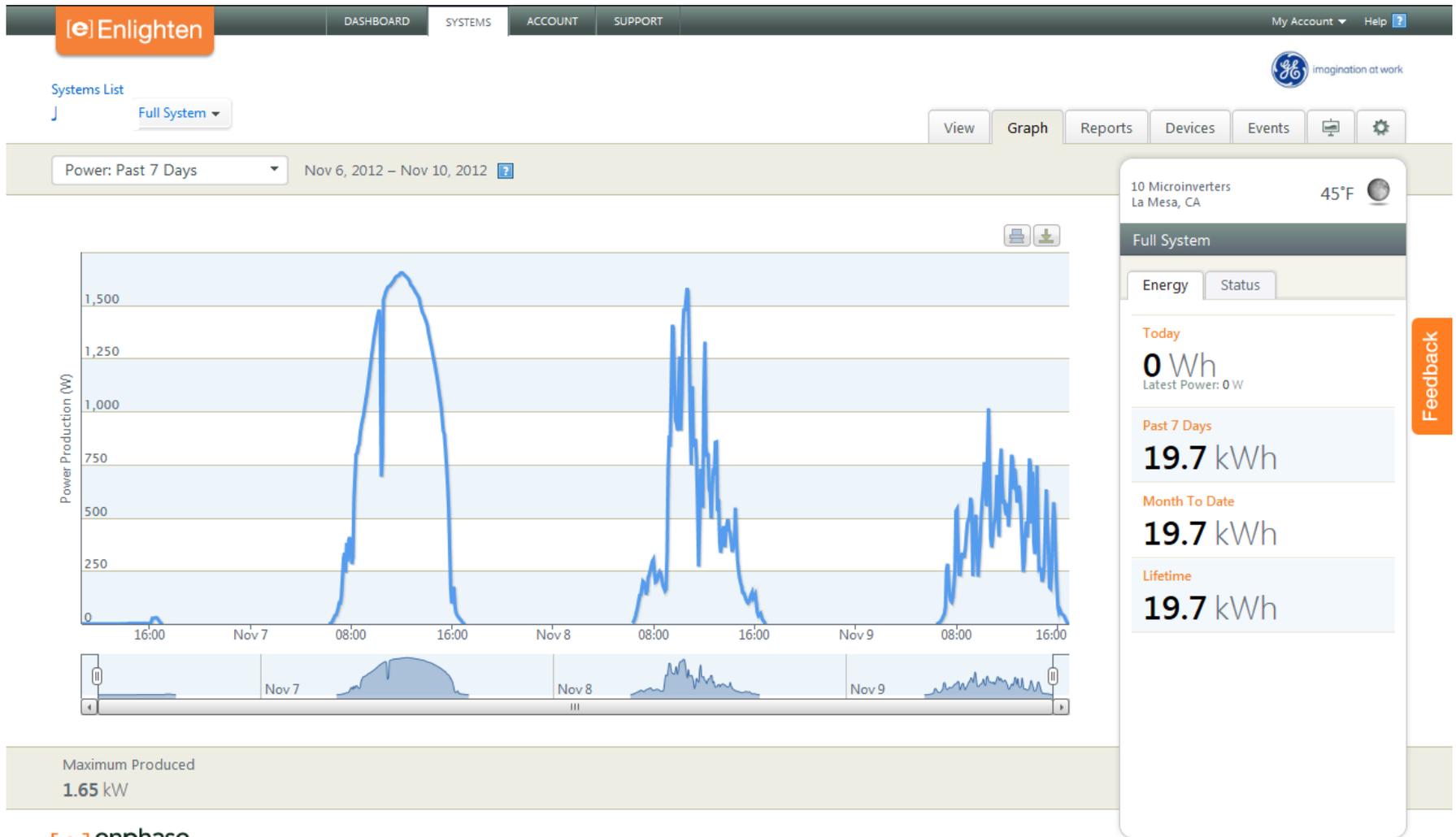


Enlighten shows one panel with low voltage - Monitor



Grid-Ready Plug-&-Play PV Kit

Power production after system commissioning



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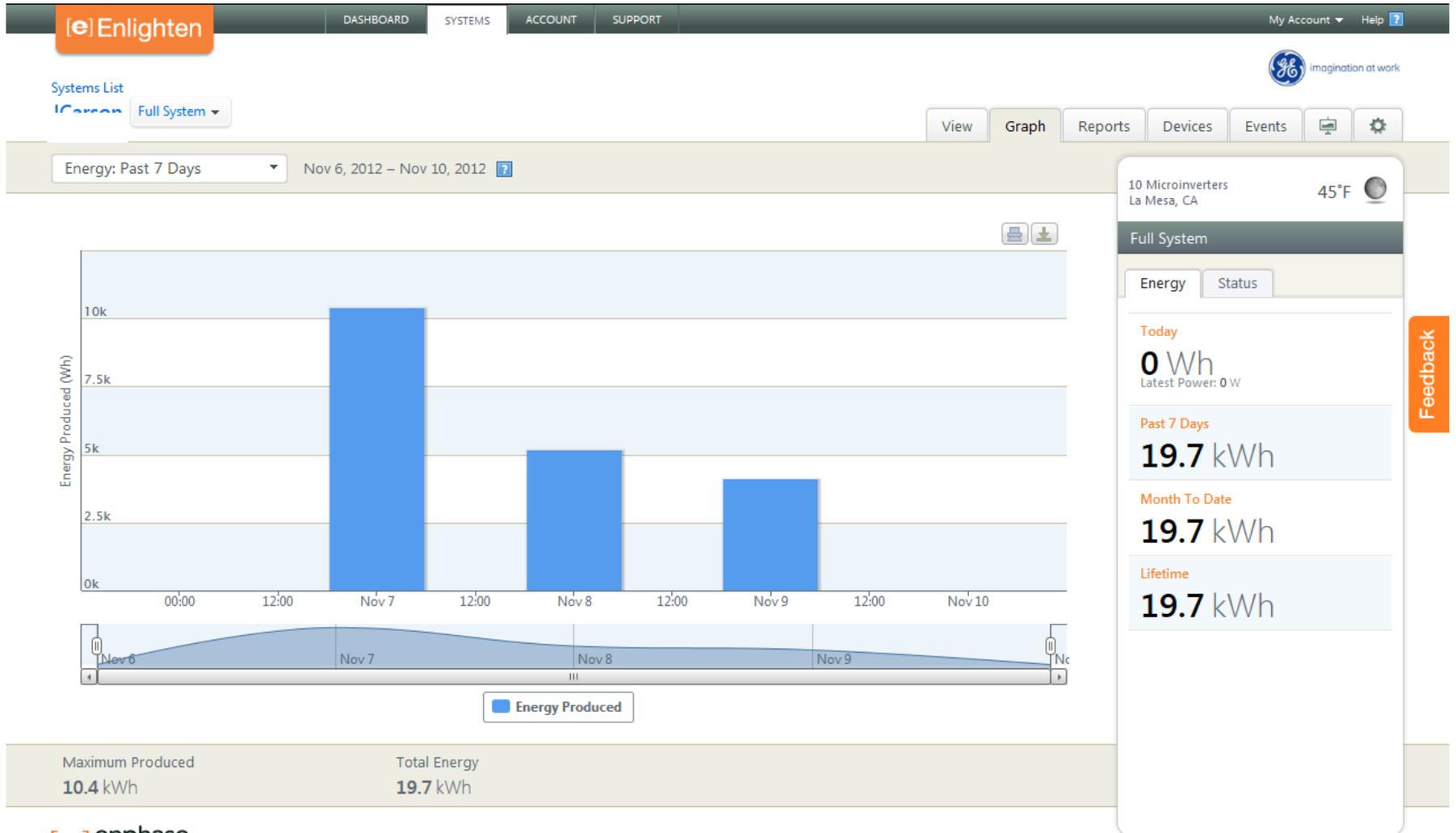


Monitor performance through Enlighten:
High resolution of system power



Grid-Ready Plug-&-Play PV Kit

Energy production after system commissioning



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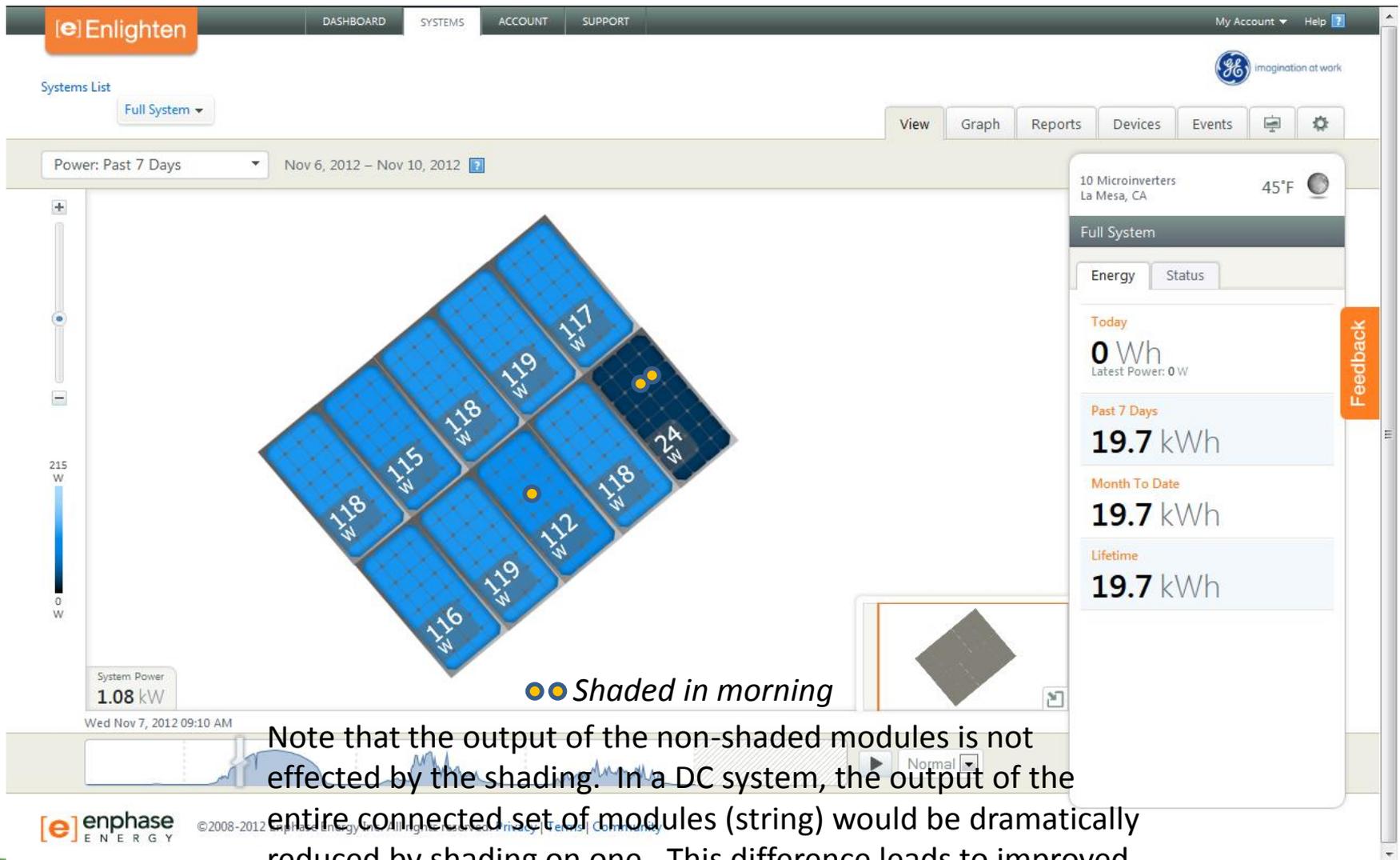


Monitor performance through Enlighten:
Low resolution - daily energy



Grid-Ready Plug-&-Play PV Kit

Enlighten map indicates period of shading – and minimum effect on total output



Note that the output of the non-shaded modules is not effected by the shading. In a DC system, the output of the entire connected set of modules (string) would be dramatically reduced by shading on one. This difference leads to improved annual system performance from the AC system relative to a DC system.

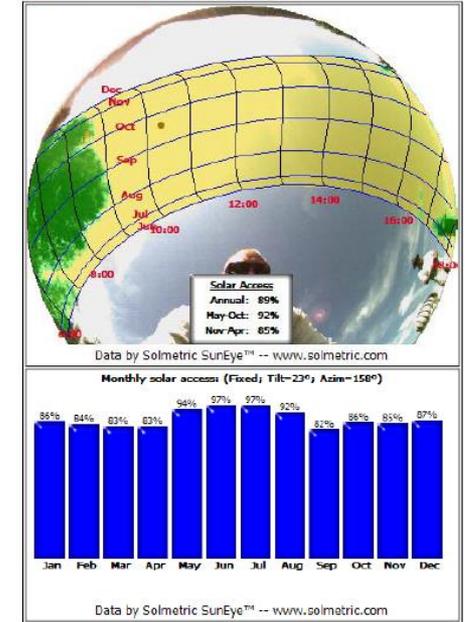
GE Smart-Grid Ready Insert & Capture Plug & Play Solar System

System Simulation – Projected energy yield vs. measured production

Performance Simulation			
Address:			
Azimuth:			
Roof Tilt:			
Month	Simulated Energy (kWh)	Measured (2012) Energy (kWh)	Measured (2013) Energy (kWh)
Jan	259.7		
Feb	257.9		
Mar	322.0		
Apr	346.2		
May	359.5		
Jun	354.2		
Jul	370.4		
Aug	366.8		
Sep	309.2		
Oct	310.5		
Nov	265.0		
Dec	246.0		
Total Annual Energy:	3766.9		
Energy Yield (kWh/kW):	1601.6		
Performance Factor:	0.866		

Sky03 -- 10/5/2012 14:12 -- (no skyline note)

Panel Orientation: Tilt=23° -- Azimuth=158° -- Skyline Heading=192°
 Solar Access: Annual: 89% -- Summer (May-Oct): 92% -- Winter (Nov-Apr): 85%
 TSRF: 86% -- TOF: 97%



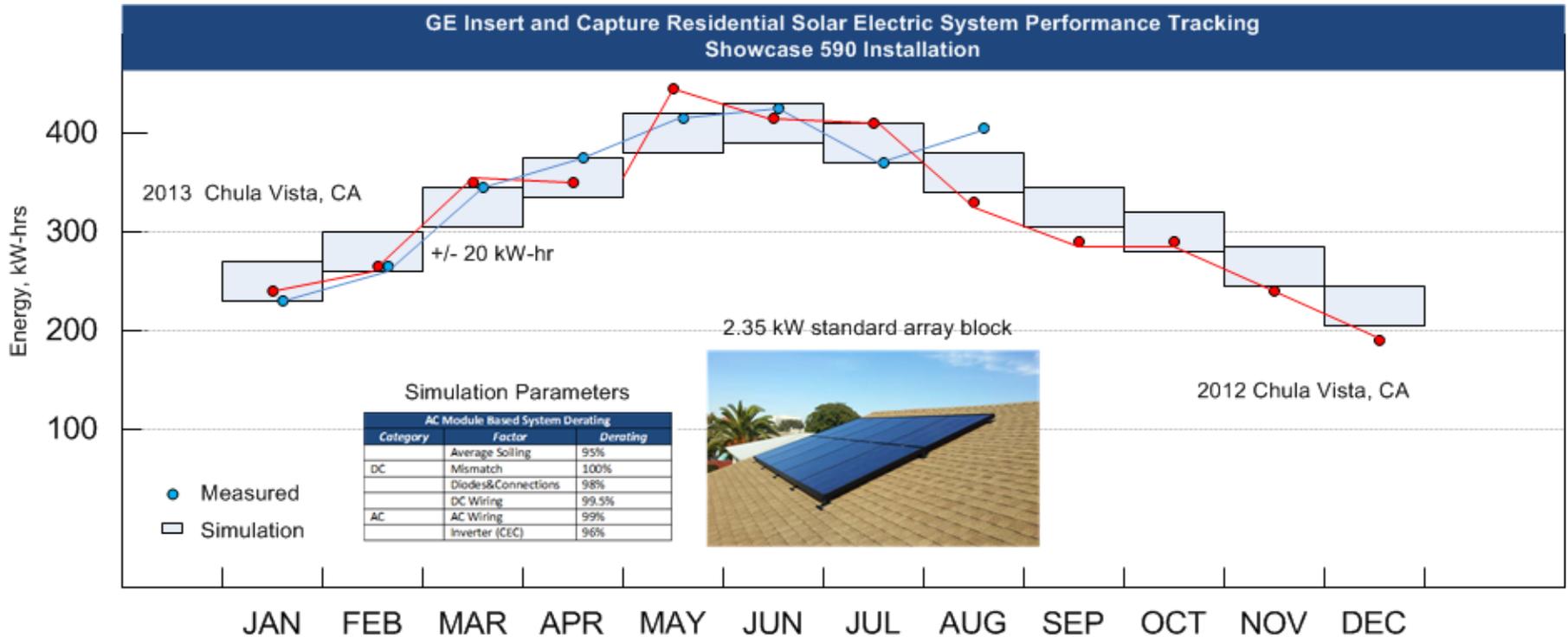
Suneye Shading Assessment

AC Module Based System Derating		
Category	Factor	Derating
	Average Soiling	95%
DC	Mismatch	100%
	Diodes&Connections	98%
	DC Wiring	99.5%
AC	AC Wiring	99%
	Inverter (CEC)	96%

Solar Advisor Model Derating Parameters (electrical losses; based on measurements and analysis)

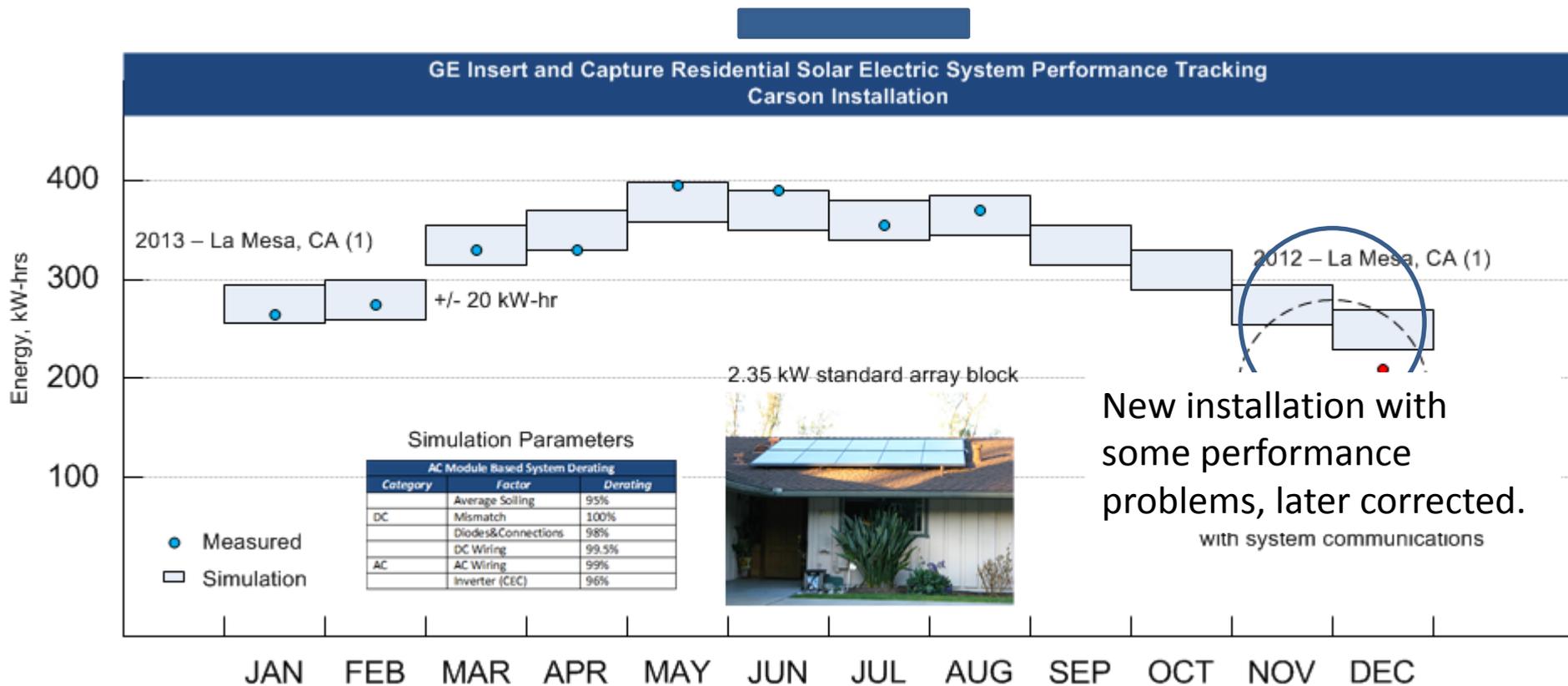
GE Smart-Grid Ready Insert & Capture Plug & Play Solar System Solar Advisor Model Predictions and Enlighten Data

Chula Vista Showcase, 2.4kW



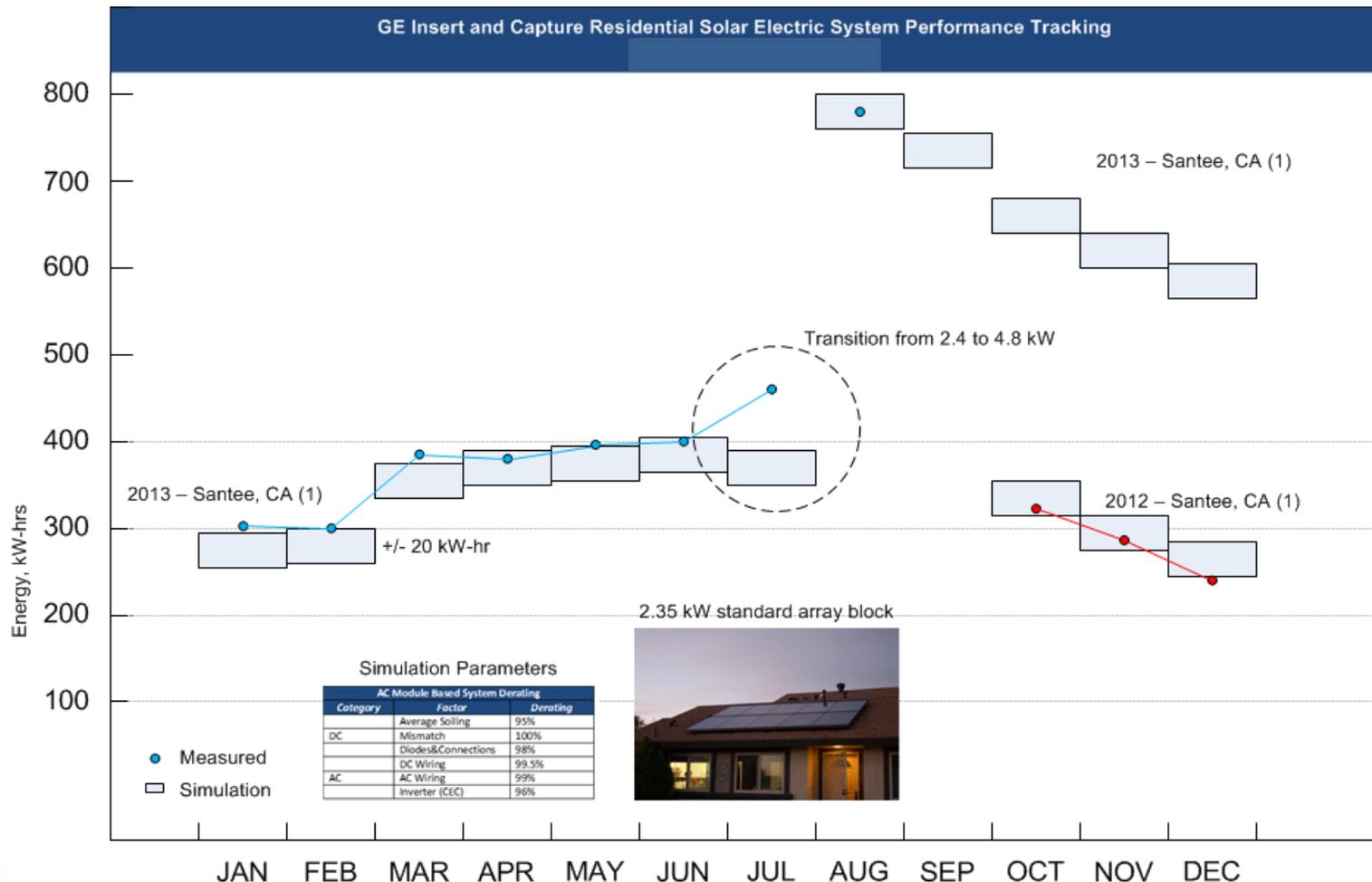
GE Smart-Grid Ready Insert & Capture Plug & Play Solar System Solar Advisor Model Predictions and Enlighten Data

La Mesa, 2.4kW



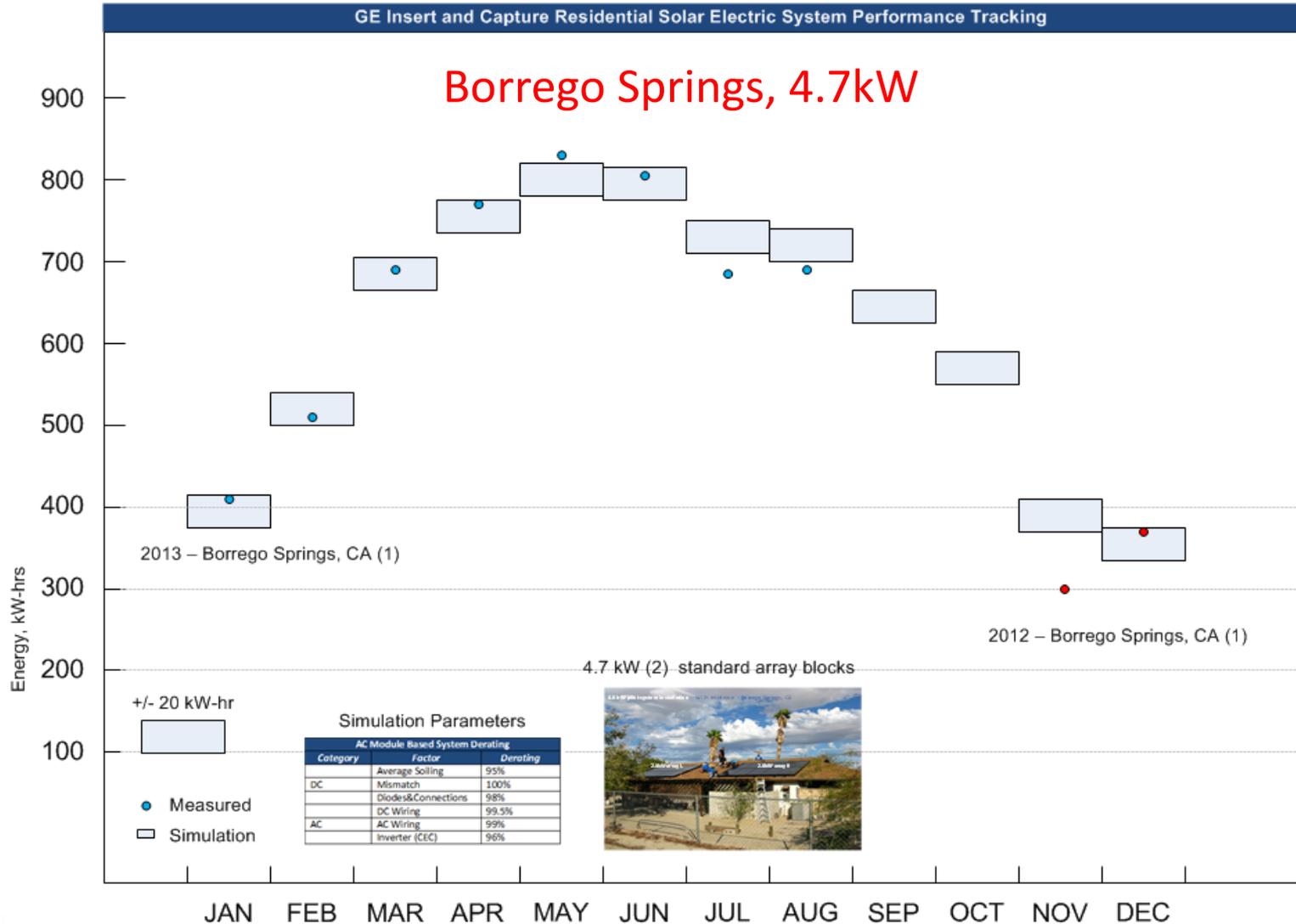
GE Smart-Grid Ready Insert & Capture Plug & Play Solar System Solar Advisor Model Predictions and Enlighten Data

Santee: 2.4 → 4.8 kW



GE Smart-Grid Ready Insert & Capture Solar System

Solar Advisor Model Predictions and Enlighten Data



Section 2

Low-Cost Solar Residential Retrofit Grid-Ready Plug-&-Play PV Kit

BREAK – Q&A

1. Beta-Test Installations
2. PV System Commissioning
3. PV System Monitored Performance

Section 3

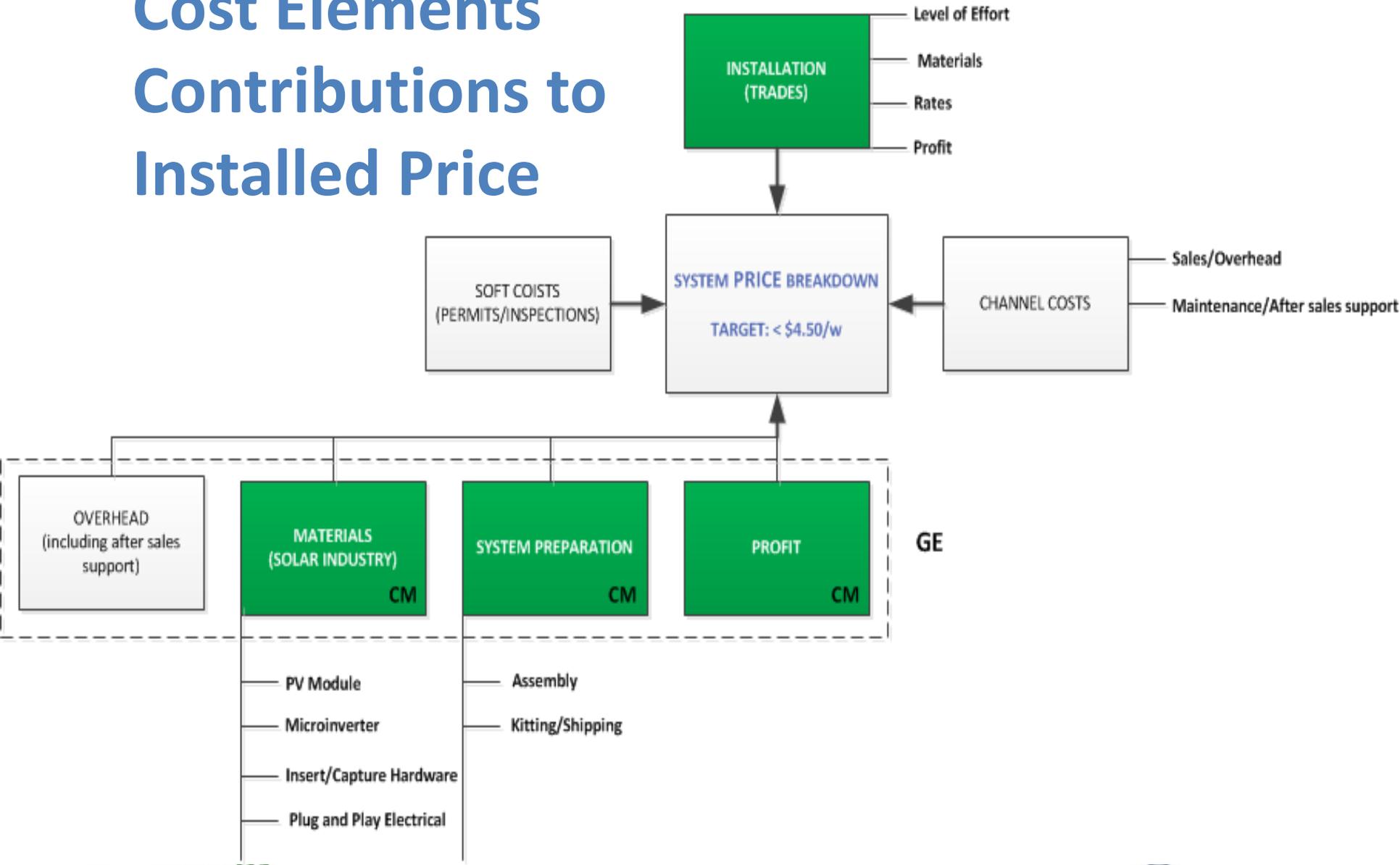
Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

- 1. Plug-&-Play PV Kit Cost Analysis**
- 2. Financing Considerations & Tools**
- 3. Plug-&-Play PV Kit Business Model**

GE Smart-Grid Ready Insert & Capture Plug & Play Solar System

Cost Elements Contributions to Installed Price



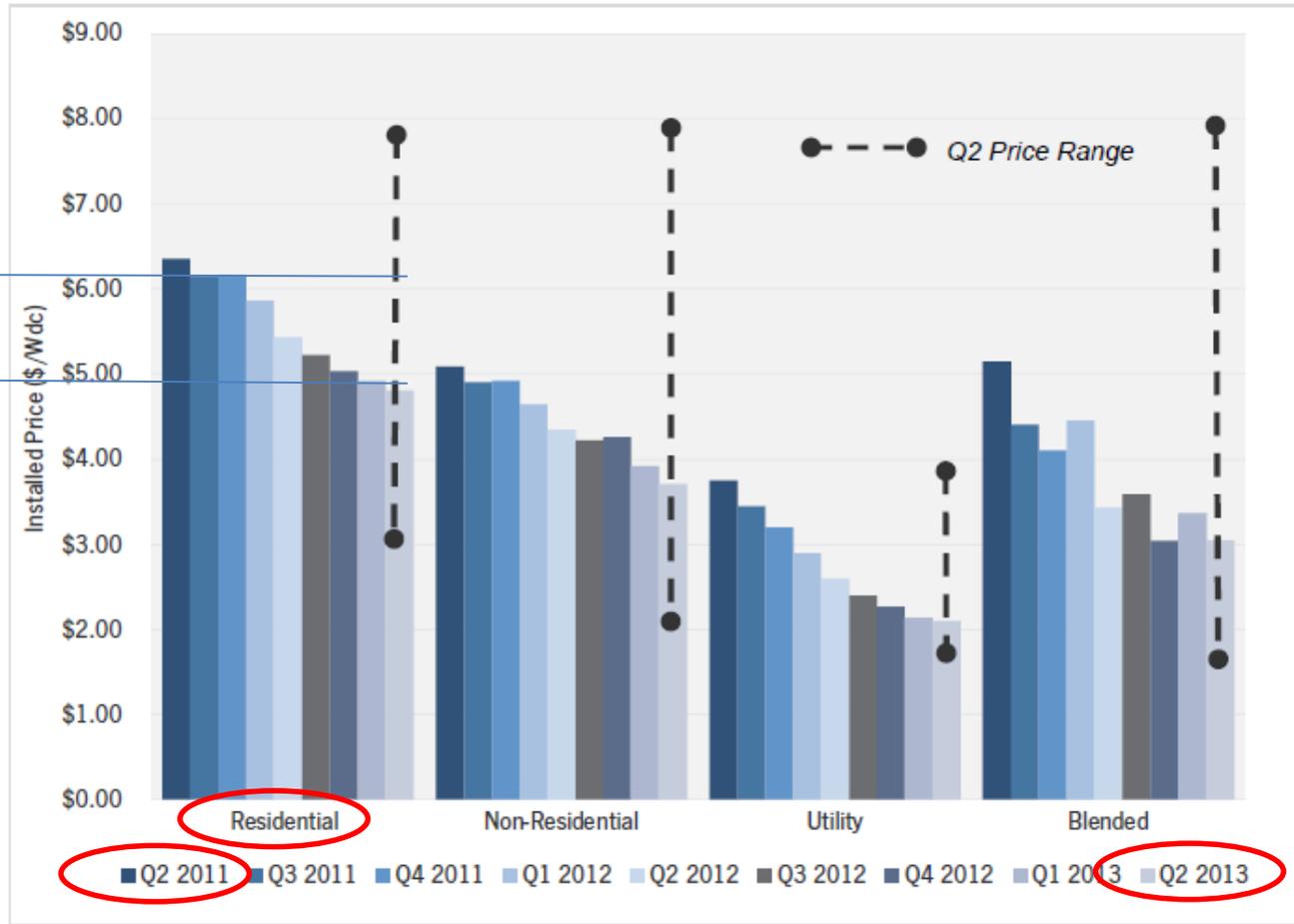
Average Costs of PV Systems (US)

Project Start:
Fall 2010
Target: \$4.50/W

Q2 2011
>\$6/Watt

Q2 2013
<\$5/Watt

Module
Prices:
2010 >\$3/W
2013 <\$1/W



GE Smart-Grid Ready Insert&Capture Plug & Play Solar System

Cost Analysis: 2.4kW Baseline System

- Components and Materials Costs
 - Bill of Materials
- Installation Costs
 - Different wind loads considered
 - Numbers of stanchions
 - Installation times – from beta-test installs
 - Different crew configurations – use best practice
 - Roofing crew + Electrical crew

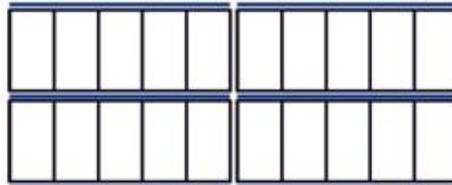
4.7kW - Bill of Materials for Residential Solar System

Assy.	Part Description	Qty.	Manufacturer	Manufacturer Part #	Material	Weight (lbs)	4.7kW Cost	Cost/Unit		
Main Asm	Roof Mounting System									
	Stanchion	Stanchion								
		Stanchion Base	54	American Douglas	152B3251	SS (304)	0.949	\$ 731.70	\$ 13.55	
		Stanchion Base Standoff	54	American Douglas	152B3250	SS (304)	-	\$ -	\$ -	
		5/16" x 3.5" SS Lag Bolt	108	American Douglas	587A0384	SS (304)	-	\$ -	\$ -	
		Rail Clip Assembly	54	McMaster-Carr	90123A247	SS (316)	-	\$ 24.60	\$ 0.23	
		Rail Clip	54	American Douglas	152B3252	SS/AI	0.278	\$ 326.16	\$ 6.04	
		SS Washer (0.75" ID, 1.5" OD)	54	American Douglas	122C8432	AI (6061)	-	\$ -	\$ -	
		SS Extrenal Retaining Ring (for 0.75" diameter shaft)	54	McMaster-Carr	96853A281	SS (18-8)	-	\$ -	\$ -	
		Flashing	54	McMaster-Carr	91590A128	SS (PH 15-7 MO)	-	\$ -	\$ -	
		Rapid Sheet Metal Inc.	54	Rapid Sheet Metal Inc.	122C8445	AI (6061)	0.636	\$ 458.46	\$ 8.49	
		Grommet	54	McMaster-Carr	63595K32	PVC (Flexible)	-	\$ 31.32	\$ 0.58	
		Rail	Rail							
	Short Click Rail (196" length)		6	American Douglas	152B3248	AI (6061)	20.384	\$ 402.42	\$ 67.07	
	Capture Strap (39" length)		20	American Douglas	152B3253	AI (6061)	0.860	\$ 152.40	\$ 7.62	
	Face Plate (196" length)		2	American Douglas	213D7326	AI (6061)	9.800	\$ 105.16	\$ 52.58	
	SS Counter-sunk Socket Cap Screw 10-24 x .5"		150	McMaster-Carr	93791A491	SS (18-8)	-	\$ 16.98	\$ 0.11	
	Splice Block		3	American Douglas	152B3249	AI (6061)	0.210	\$ 8.13	\$ 2.71	
	SS Screw 10-24 x 3/8"		12	McMaster-Carr	97763A214	SS (18-8)	-	\$ 1.85	\$ 0.15	
	Wire Harness Block		12	American Douglas	152B3256	AI (6061)	0.035	\$ 20.04	\$ 1.67	
	Wire Capture Straps		24	DIGI-KEY	WHC-375-01-ND	NYL	-	\$ 2.40	\$ 0.10	
	SS Screw 10-24 x 3/8"		24	McMaster-Carr	97763A214	SS (18-8)	-	\$ 3.69	\$ 0.15	
	Endcaps		Endcaps							
			Rail Tie Front	2	American Douglas	122C8442	AI (3003 H14)	2.824	\$ 33.84	\$ 16.92
Rail Tie Back Left		1	American Douglas	122C8444	AI (3003 H14)	2.576	\$ 19.16	\$ 19.16		
Rail Tie Back Right		1	American Douglas	122C8443	AI (3003 H14)	2.576	\$ 19.16	\$ 19.16		
SS Thread Forming Screw 1/4 - 20 x 0.75" (Phillips Head)		12	Horizon	THWTFPXTAP025C050A	SS	-	\$ 5.88	\$ 0.49		
SS External Tooth Washer (Screw Size: 1/4")		12	McMaster-Carr	95584A207	SS (18-8)	-	\$ 0.47	\$ 0.04		
Appliance	AC Module									
	Motech 235 Watt Module	20	Motech	MTPVp-235-MSB	-	43.700	\$ 3,995.00	\$ 199.75		
	Enphase Micro-Inverter	20	Enphase	M215-60-240-S2X	-	3.500	\$ 2,208.00	\$ 110.40		
	SS Flange Button Head Socket Cap Screw 5/16" - 18 x 5/8"	20	McMaster-Carr	97654A304	SS (18-8)	-	\$ 19.24	\$ 0.96		
	SS External Tooth Washer (Screw Size: 5/16")	20	McMaster-Carr	95584A209	SS (18-8)	-	\$ 1.89	\$ 0.09		
	SS Hex Nut w/ External Tooth Washer (5/16" - 18)	20	McMaster-Carr	96278A519	SS (18-8)	-	\$ 5.36	\$ 0.27		
	SS Self-Drilling Screw 10 - 16 x 1/2"	20	McMaster-Carr	90821A355	SS (18-8)	-	\$ 5.61	\$ 0.28		
	AC Wiring									
	Enphase Trunk Cable for M215 Portrait Installation (Qty. is per module)	20	Enphase (Civic Solar)	ET10-240-001	-	1.000	\$ 337.20	\$ 16.86		
	Installation Kit (1 Disconnect Tool, 4 Terminators, 5 Watertight Caps)	1	Enphase (Civic Solar)	ET-INSTL	-	-	\$ 69.58	\$ 69.58		
	Electrical Flashing (SolaDeck: 3" Fixed Din Rail))	1	SolaDeck (Civic Solar)	SD-0783-41	Galv. Steel	-	\$ 66.32	\$ 66.32		
	Over Current Protection	0	Citel	DS72RS-120	-	0.840	\$ -	\$ 119.00		
Twist Lock Connector	0	???	???	-	-	\$ -	\$ -			
10/3 AWG w/ Ground (estimated per foot)	130	Lowes	Cerro Wire Estimate	-	-	\$ 243.75	\$ 1.88			

4.7kW System Layout

Part Count: 1017

- Tools Needed:** Tape Measure
Chalk Line
Clutched Drill
1/2" Socket Drive
Adjustable Crescent Wrench
1/8" Allen Drive
Phillips Driver Size: #3



System Weight	1235.56	Excluding Hardware
System Area	391.04	2 times 2.35kW Area
lbs / sq Ft	3.16	

	24" Spacing	48" Spacing
Total Cost:	\$ 9,315.76	\$ 8,529.64
Total Cost / Watt:	\$ 1.98	\$ 1.81
Hardware Cost / Watt:	\$ 0.50	\$ 0.34
Stanchion Cost / Watt:	\$ 0.33	\$ 0.17
Rail Cost / Watt:	\$ 0.15	\$ 0.15
Appliance Cost / Watt:	\$ 1.48	\$ 1.48
AC Module Cost / Watt:	\$ 1.33	\$ 1.33
AC Wiring Cost / Watt:	\$ 0.15	\$ 0.15

GE Smart-Grid Ready Insert&Capture Plug & Play Solar System

Bill of Materials

Bill of Material Costs for Installation Scenarios

<i>Installation Scenario</i>	<i>BOM Costs (\$)</i>	<i>BOM Costs (\$/W)</i>	<i>Comments</i>
2.4kWdc (80 mph) baseline	\$4549.53	\$1.94	48-in stanchion spacing per rafter (option to stagger) 5 stanchions per 16-ft. rail
2.4kWdc (130mph) baseline	\$4928.04	\$2.10	24-inch stanchion spacing per rafter 8 stanchions per 16-ft. rail
4.8kWdc (80mph) baseline	\$8529.64	\$1.81/W	5 stanchions per 16-ft. rail
4.8kWdc (130mph) baseline	\$9315.76	\$1.98/W	8 stanchions per 16-ft. rail
4.8kWdc (80mph) extended snow load	\$8905.18	\$1.86/W	Additional 13 stanchions required redistribute roof stress under snow loading.

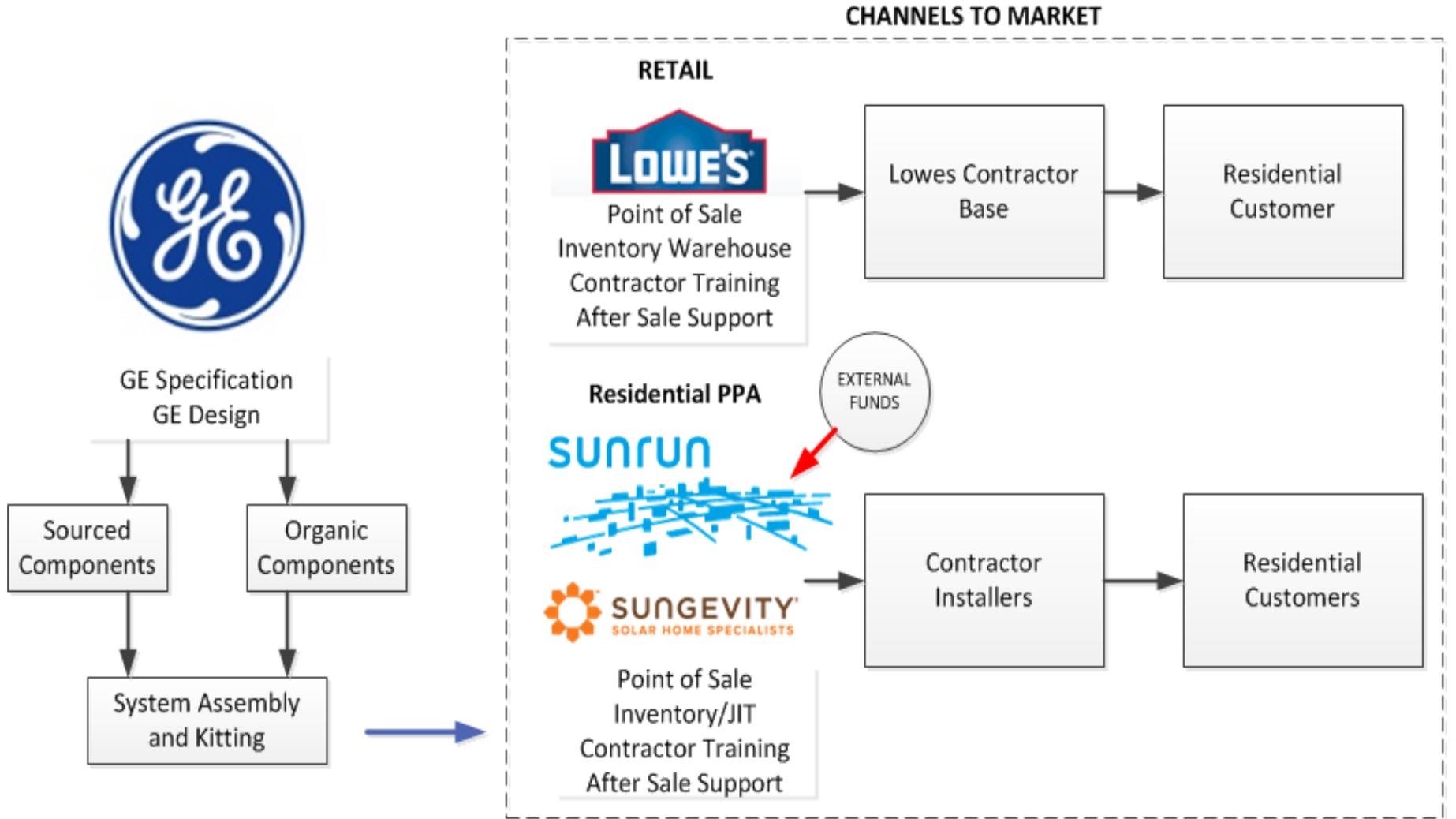
GE Smart-Grid Ready Insert&Capture Plug & Play Solar System

Installation Costs

Installation Costs for the GE 4.8 kW pre-wired Insert and System						
Category	Roofing Contractor Costs		Electrical Contractor Costs		Totals	
	\$	\$/W	\$	\$/W	\$	\$/W
Materials	50		250			
Effort	800		480			
Margin	255		219			
Total	1105	0.23	949	0.20	2054	0.43 \$/W

GE Smart-Grid Ready Insert&Capture Plug & Play Solar System

Channel and Soft Costs



Buildup to Residential Solar Electric System Price Comparison

Business as Usual 2010

Installed Price to Customer
\$6.65/W

Balance of System Costs

2013 GE System Pilot (Gen 1)

- Reduced module price
- Sourced microinverter (Enphase)
- Insert/Capture P&P Rack
- UL, ICC system certification

7.00

Average U.S. Price
4th qtr 2011 (SEIA)

6.00

Lowest current price

5.00

4.00

Installed Price to Customer
\$3.97/W

CM
+30%

3.00

2.00

1.00

0.50

\$/W

Levelized Cost of Electricity
<\$0.20/kWh
No incentives
\$0.14/kWh
Fed ITC only
(no CA incentives)

GE P&P Sunshot Goal
- \$0.12/kWh w/o incentive

Source: Photon Consulting

Source: GE NYSERDA project

PV Module
Inverter (including Software)
Mechanical (hardware and labor)
Electrical (components, wiring, labor)
Soft Costs (project admin, design, permitting)
Profit (including Distribution)

GE System
Misc*
P&P Rack
Inverter
Module
Mechanical (hardware and labor)
Electrical (components, wiring, labor)
Soft Costs (project admin, design, permitting)
Profit

\$2.37/W
* junction box, kitting, monitoring, shipping
- \$0.42/W (includes harness)
- \$0.52/W
- \$0.90/W

\$0.20/W

\$0.10/W

Section 3

Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

1. Plug&Play PV Kit Cost Analysis
2. Financing Considerations & Tools
3. Plug&Play PV Kit Business Model

Financing: Key Concepts to Consider

- Goals for retrofit
 - Financial, comfort, environmental, re-sale, add EV...
- HERs to evaluate opportunities
 - Useful life and decay over life of improvements
 - LCC as well as 1st Cost and Cash Flow
 - Direct and indirect benefits
 - Energy efficiency *and* PVs
 - Cost-effective to go deep rather than in steps
- National Appraisal Institute Certified “Green”

So you want to finance an efficiency and PV retrofit...

- Secured Loans
 - Traditional mortgages: 1st, 2nd, LOC
 - FHA PowerSaver Loan Pilot
 - FHA 203k Loan Program
 - ENERGYSTAR Mortgage Pilot
 - Revolving Fund - Loan Programs
- Innovative Financing Models
 - Property Assessed Clean Energy (PACE)
 - Utility financing: On-Bill “Financing” (*Repayment*)
 - Power Purchase Agreement (PPA)
 - Solar PV Lease
 - Energy Performance Contracting (ESCO – typically Commercial)
- Rebates & Incentives

FHA Power Saver

Advantages

- Simplified home inspection
- Long payback → simple terms
 - 15 years
 - Finance 100% of approved improvements
 - Max \$25K
- Low interest: at or below market rates

Disadvantages

- 2yr pilot; not nationally available
- Limited selection of eligible improvements
- Relatively high qualification requirements

Innovative Financing: PACE Program

Advantages

- Eligibility tailored to area
- Longer loan term with low monthly bill
- Below market interest rates
- Loan attached to house; may be transferrable upon sale

Disadvantages

- Lien priority
- Local or state bond districts required for funding
- FHFA (Fed Housing Finance Agency) → FHA, Fannie Mae & Freddie Mac: Oppose
- Possible forced repayment of FHFA-related mortgages on property

On-Bill Financing (Repayment)

Advantages

- Simple qualification and administration
- Simple repayment
 - Part of / in parallel with utility bill payment
- Practical for simpler retrofits

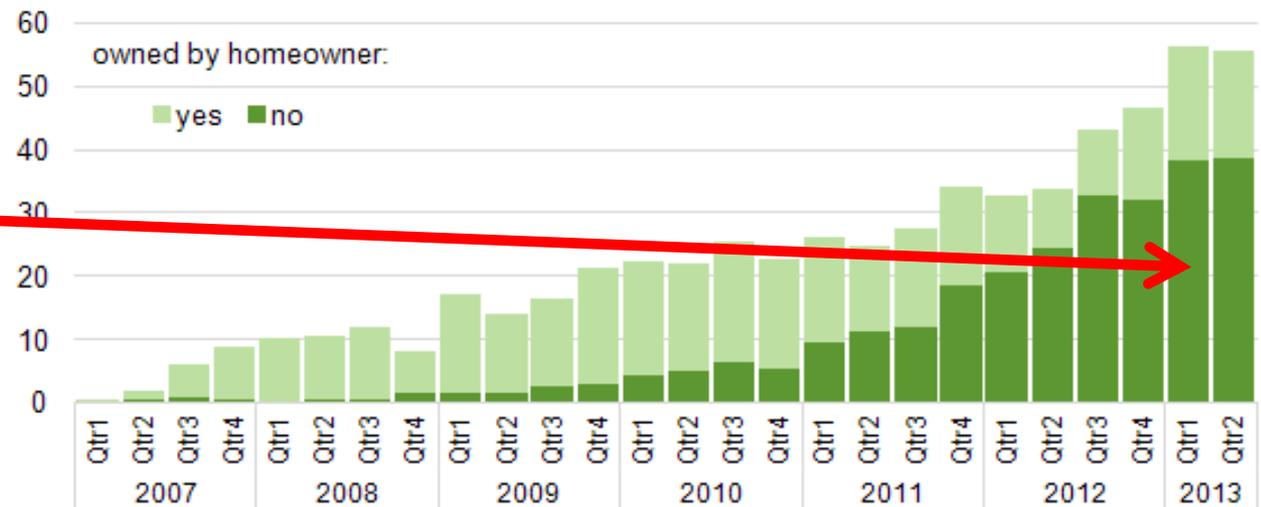
Disadvantages

- Could complicate property sale (if tied to meter rather than homeowner)
- Default could result in utility disconnect
- Availability varies by utility

Third-Party PV Ownership

- Third-party installs and owns PV system
 - Both models could apply to EE but currently do not
- Two basic models:
 - Power Purchase Agreement (PPA)
 - PV Lease

Residential solar PV capacity installed in California Solar Initiative program
nameplate capacity (megawatts_{DC})



75% of 2013 CSI Residential PV systems 3rd Party owned

PPA & Solar Lease Highlights

- 3rd Party installs and owns PV system
- PV gen offsets some electricity from utility

PPA

- 3rd party paid for electricity generated
- Pay for actual production
- Often has increasing rate structure, typically designed to be lower than utility rate
- Typically includes standard maintenance

Solar Lease

- PV leased to homeowner
- Lease payments based on baseline performance
- Lease can be paid up-front to 3rd Party (new const.)
- Retrofit varies in amount up-front and monthly fees
- Typically includes standard maintenance

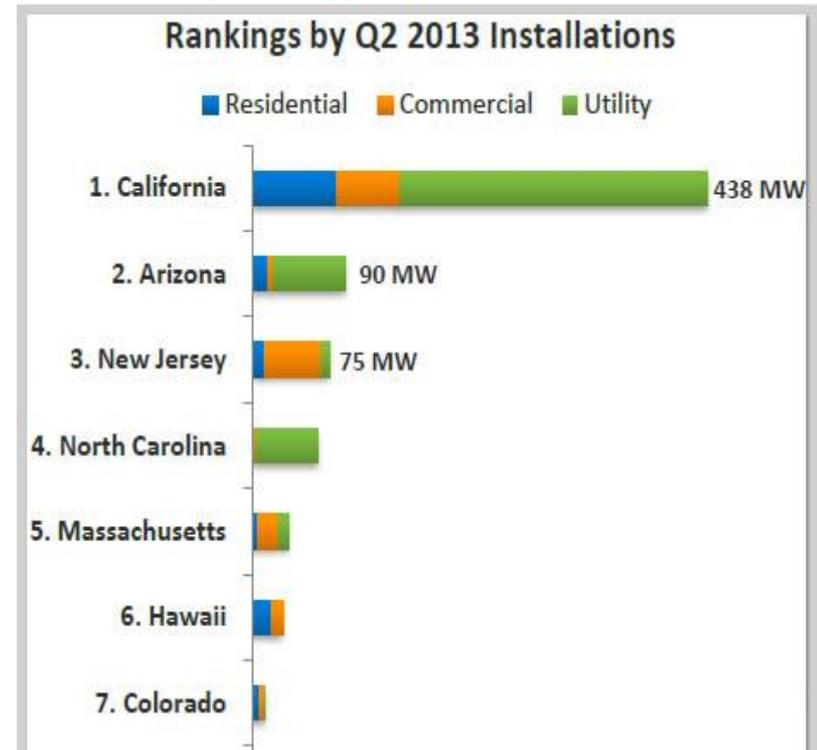
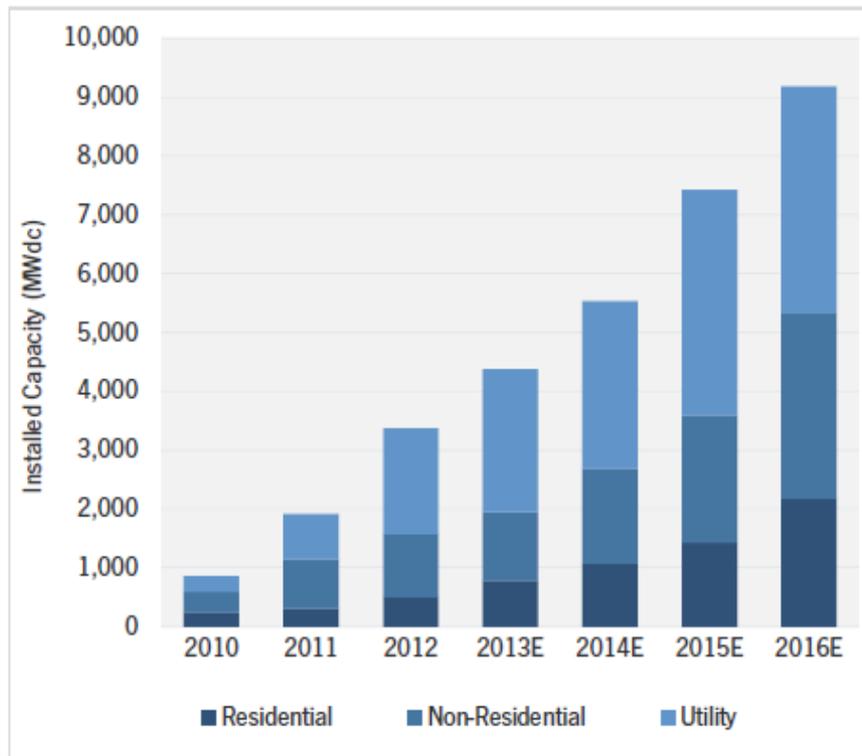
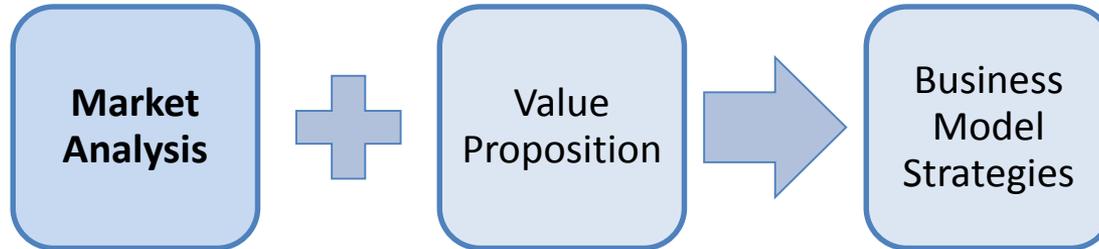
Section 3

Low-Cost Solar Residential Retrofit

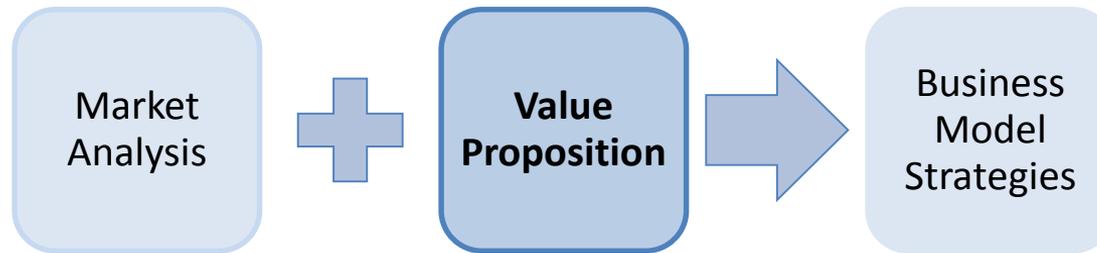
Grid-Ready Plug-&-Play PV Kit

1. Plug&Play PV Kit Cost Analysis
2. Financing Considerations & Tools
3. Plug&Play PV Kit Business Model

Business Model: Plug & Play PV Kit

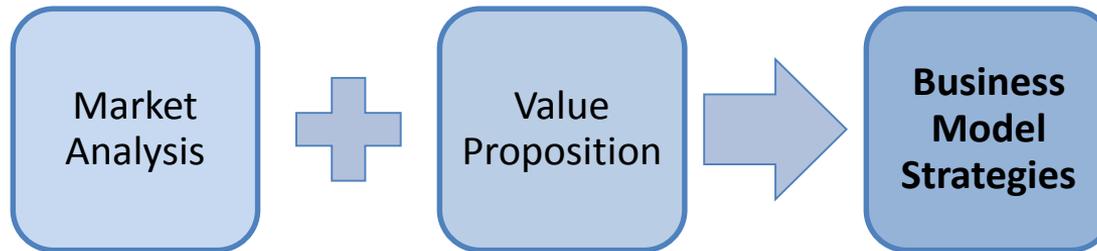


Value Proposition: PV Cost-Effective



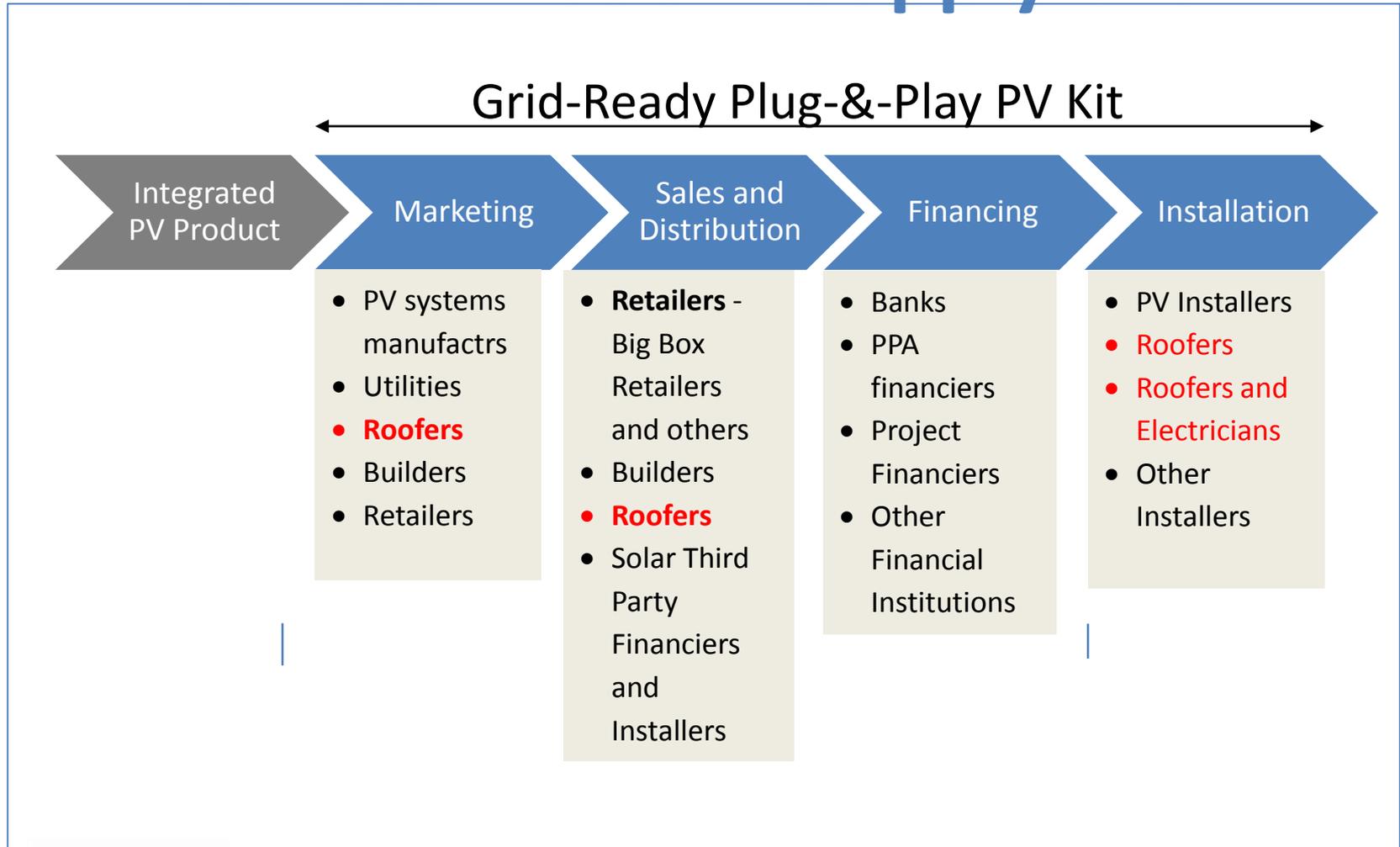
- GE LCOE at \$4/W = \$0.14 / kWh
- CA average \$0.15/kWh (Planet Money)
- At \$4.50/W electricity cost lower than from utility (NREL OpenPV: CA <\$6/W)
- Under current net-metering rules and tariffs
- Currently need more channels to consumers

Business Model: Roofer Channel



- Reduce labor costs (roofer)
- Wrap with re-roof
- Wrap with energy-efficiency upgrades
- Increased market saturation
- Simple economics – consumers need simple explanation

Grid-Ready Plug-&-Play PV Kit Business Model – Supply Chain



Section 3

Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

BREAK – Q&A

1. **Plug&Play PV Kit Cost Analysis**
2. **Financing Considerations & Tools**
3. **Plug&Play PV Kit Business Model**

Section 4

Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

- 1. ZNE Retrofit: EE, DR, Storage, HEM, +
Grid-Ready Plug-and-Play PV Kit**
- 2. Conclusions**

Grid-Ready Plug-&-Play PV Kit *Santee Zero Net-Energy Home*

2.4 kW system installation + Second 2.4 kW system installed later



ZNE Home: Simulation of EE Package + PV

	Source Energy Use (MBtu/yr)		Site Electricity Use (kWh/yr)		Site Natural gas Use (Therms/yr)	
	<i>Base Case</i>	<i>ZNE</i>	<i>Base Case</i>	<i>ZNE</i>	<i>Base Case</i>	<i>ZNE</i>
Misc.	30.39	29.09	2,583	2,469	7	7
Lg. Appl.	18.47	15.54	988	814	65	57
Lights	13.90	9.50	1,211	827	-	-
HVAC Fan/Pump	3.66	0.10	319	8	-	-
Cooling	9.95	0.56	867	49	-	-
Heating	12.28	4.39	-	-	112	40
Hot Water	18.68	14.01	-	1,220	171	-
Total	107.34	73.19	5,968	5,389	355	104
PV		85.74	3,831	7,468	-	-
Net (Total - PV)	107.34	-12.55	2,137	(2,079)	-	-

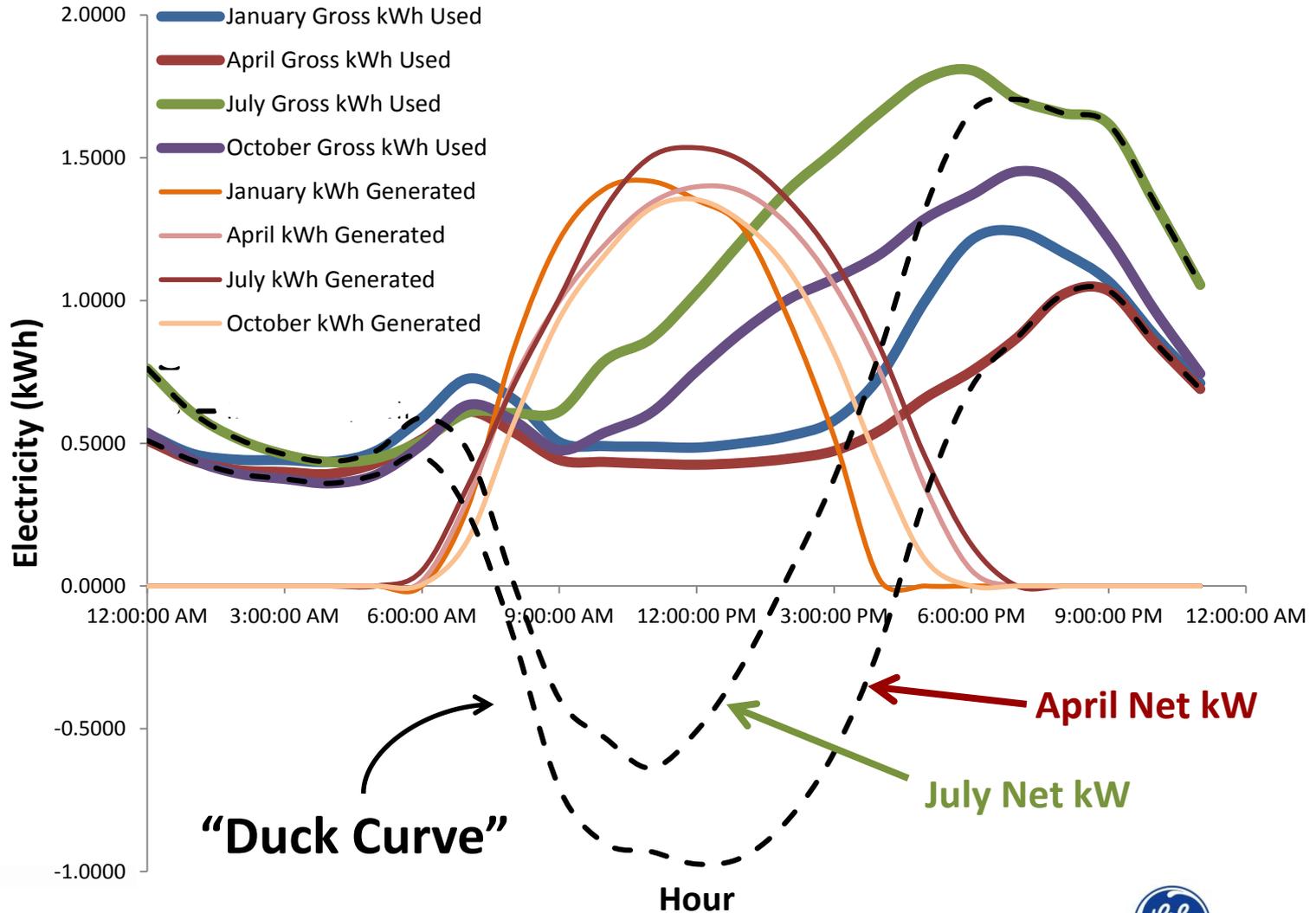
Energy Efficiency Savings 34.15 MBtu/yr, 32%

Plug & Play PV Kit, 4.8 kW: 85.74 MBtu/yr

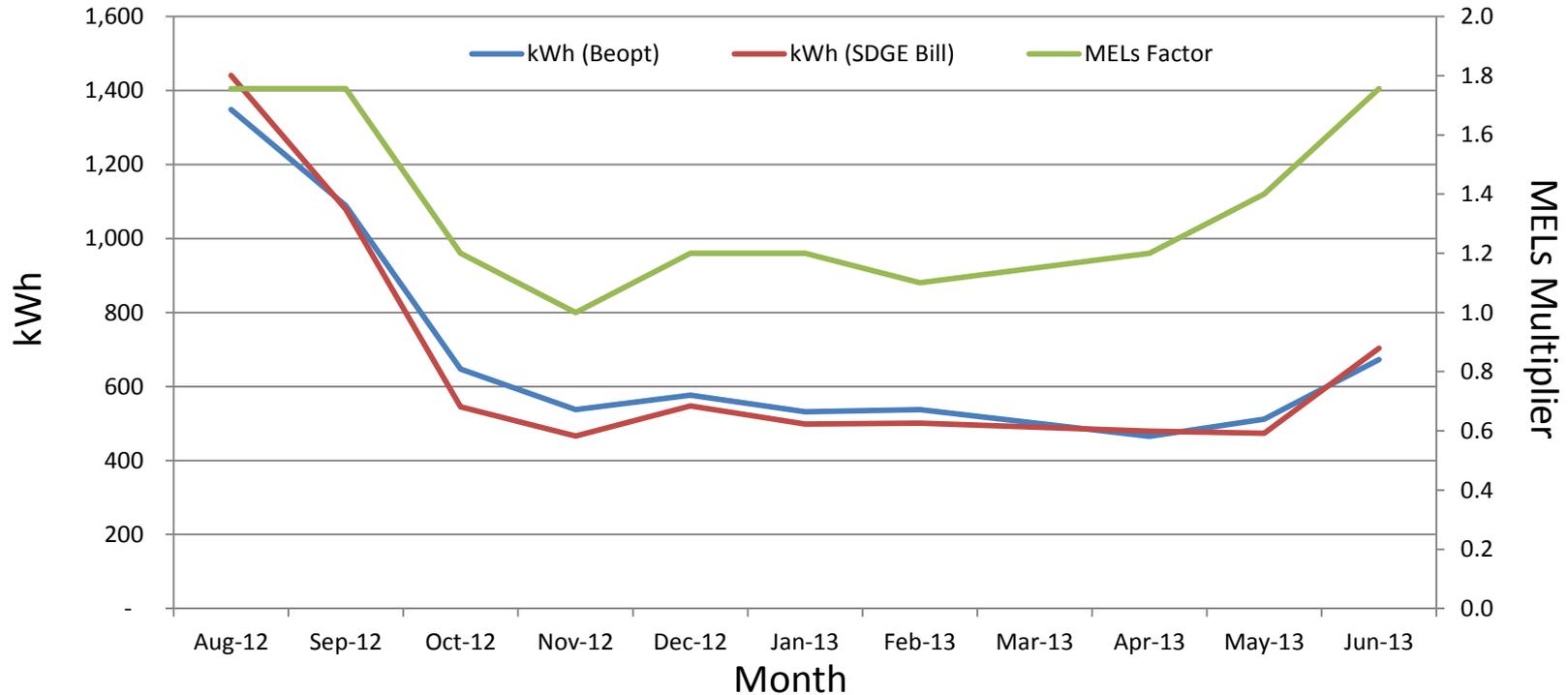
ZNE Energy Efficiency Upgrades

• R-49 Attic insulation	\$2,040
• Radiant barrier	\$1,955
• LowE windows & patio doors (0.24/0.27)	\$10,300
• Reduced air infiltration (<3.0 SLA)	\$2,125
• 18 SEER AC, 95 AFUE Furnace, new ducts, sealed, buried in R-49	\$13,900
• Ceiling fans	\$750
• GE Heatpump Water Heater	N/C
• 100% LED Lighting	\$1,800
• D'Mand hot-water on-demand recirc system	\$875
• Low-flow aerators, showerhead	\$225
• High Efficiency, GE Appliances (DR capable)	N/C
• GE Nucleus Energy Management System	N/C
• Total, Efficiency Improvements	\$33,970
• PV 4.8 kW @4.00/W	\$19,200
• Total upgrade cost (without appliances)	\$53,170

Simulations of Daily Power From Grid By Season: PV on EE Home



ZNE Baseline Monthly Energy Use

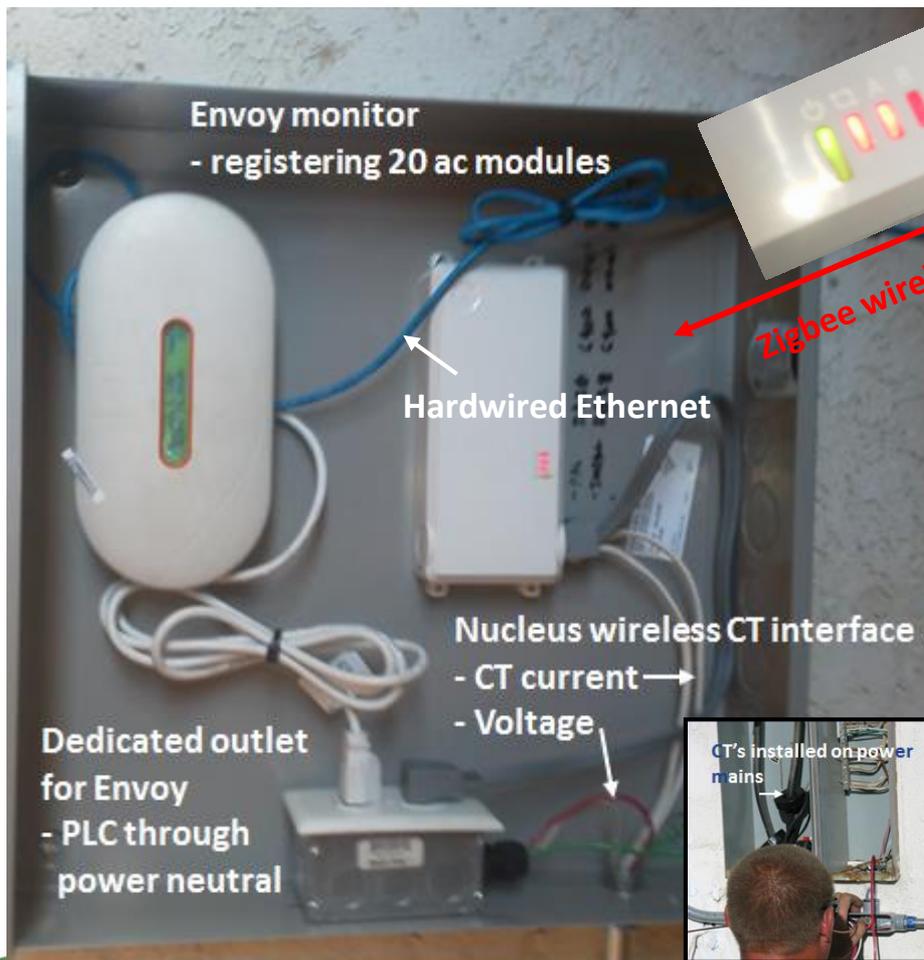


*Calibrating Simulation: Match TStat Set-points & MELs
to Occupant-Reported Values*

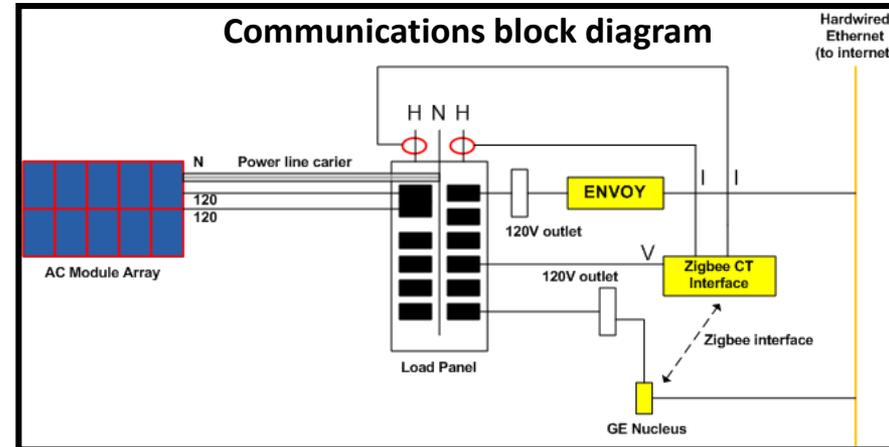
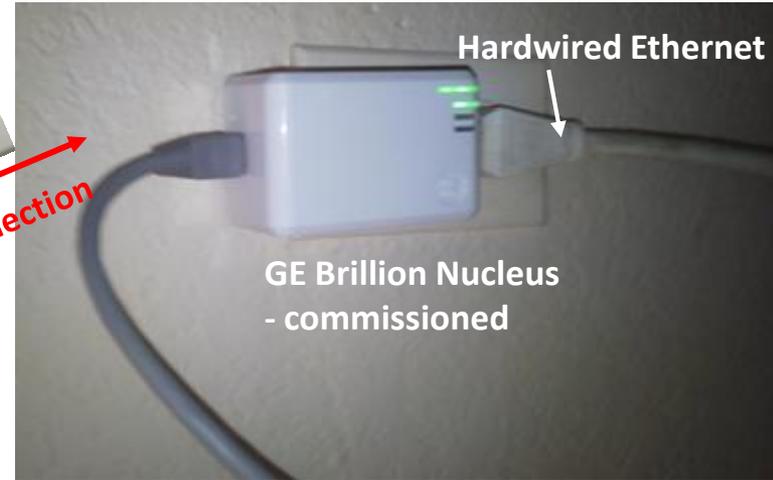
*Next: Compare ZNE Simulation Results to Actual
using Calibrated Software (BEopt)*

GE Smart-Grid Ready Insert & Capture Plug & Play Solar System Home Energy Monitor - Nucleus

GE Nucleus: a HEM System and Demand Response Controller of GE-DR appliances and DR-modules at desired electrical outlets.



Zigbee wireless connection

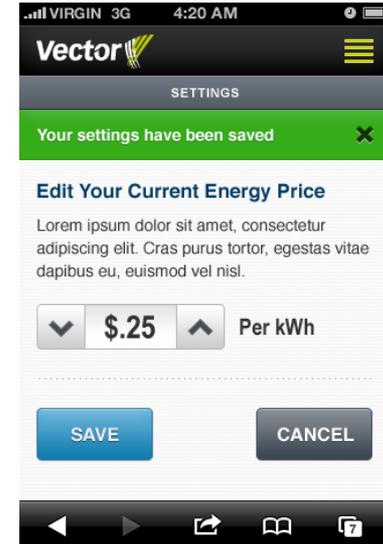
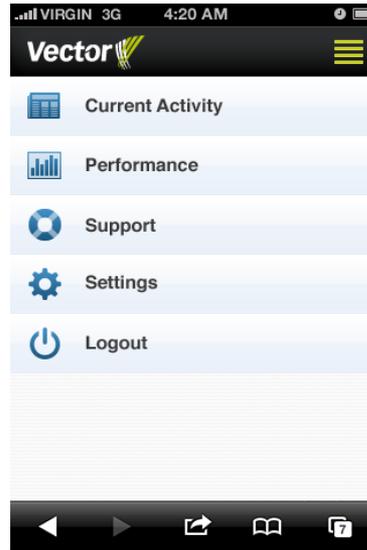


GE Nucleus Dashboard

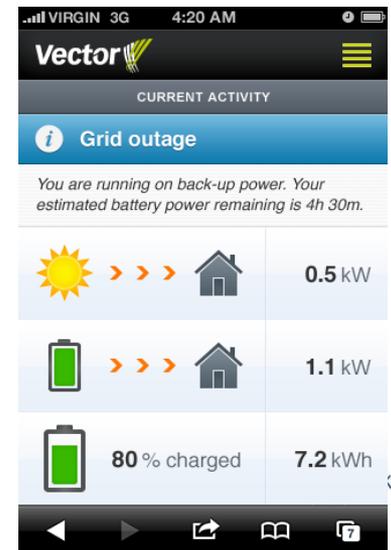
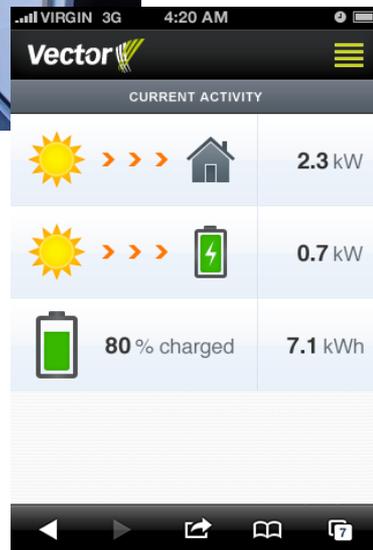


Sunverge SIS – Intelligent Battery

Smart-Phone Monitor & Control - Examples

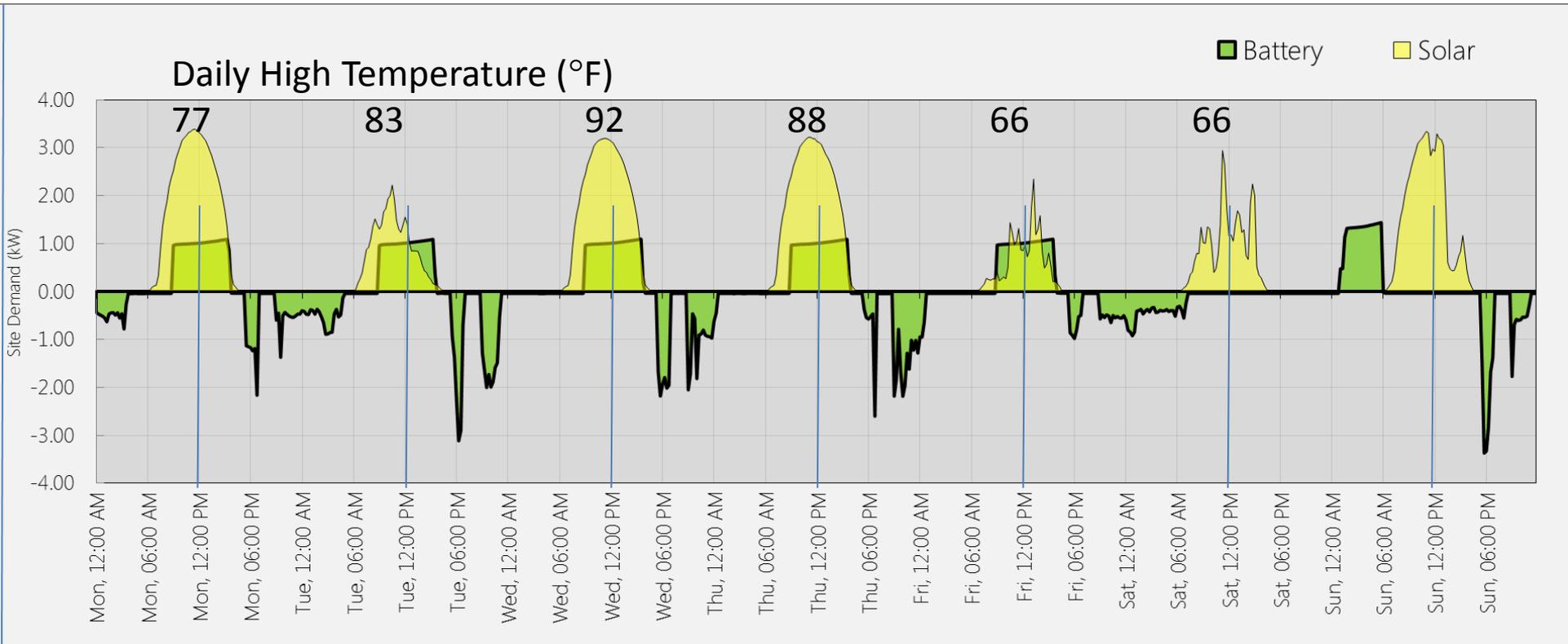


Sunverge in
ZNE Home



Optimizing ZNE Interactions with Grid

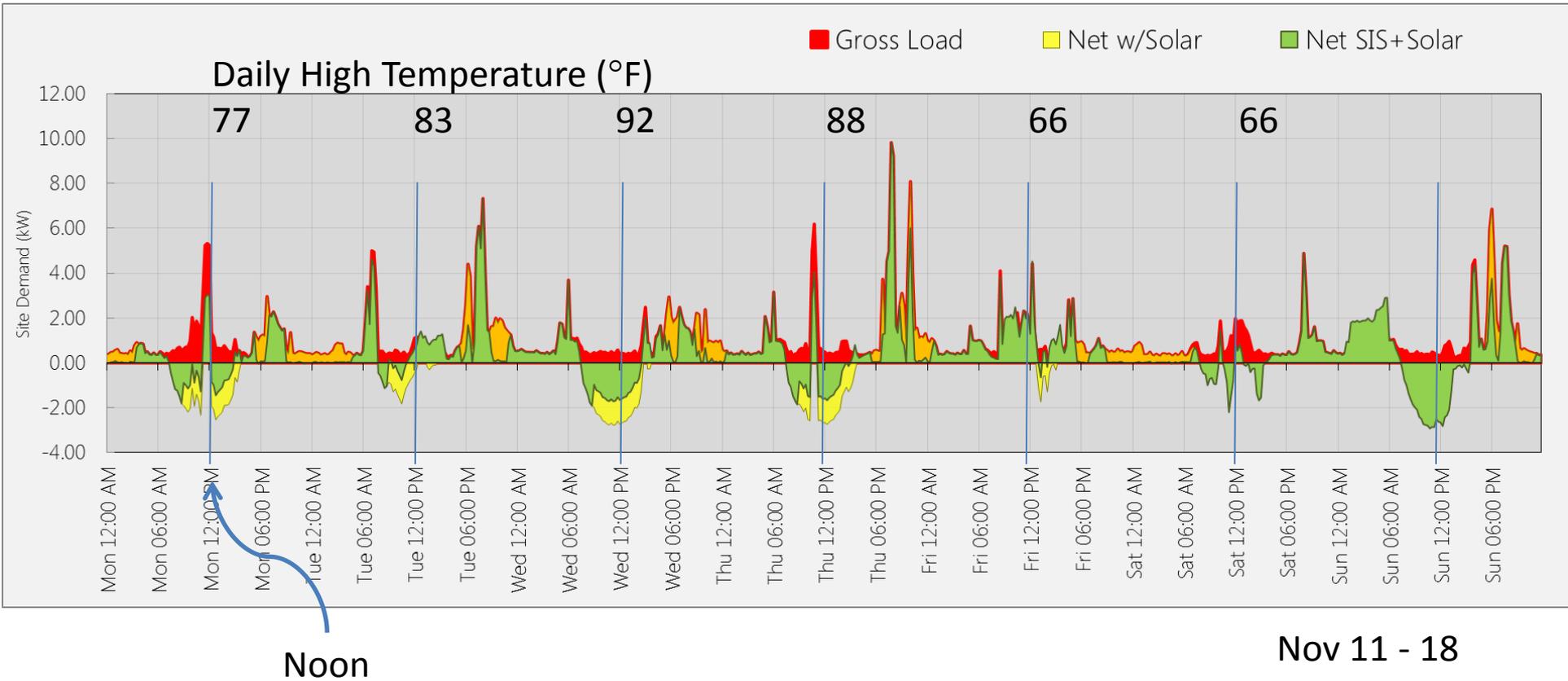
Sunverge SIS - Energy Storage

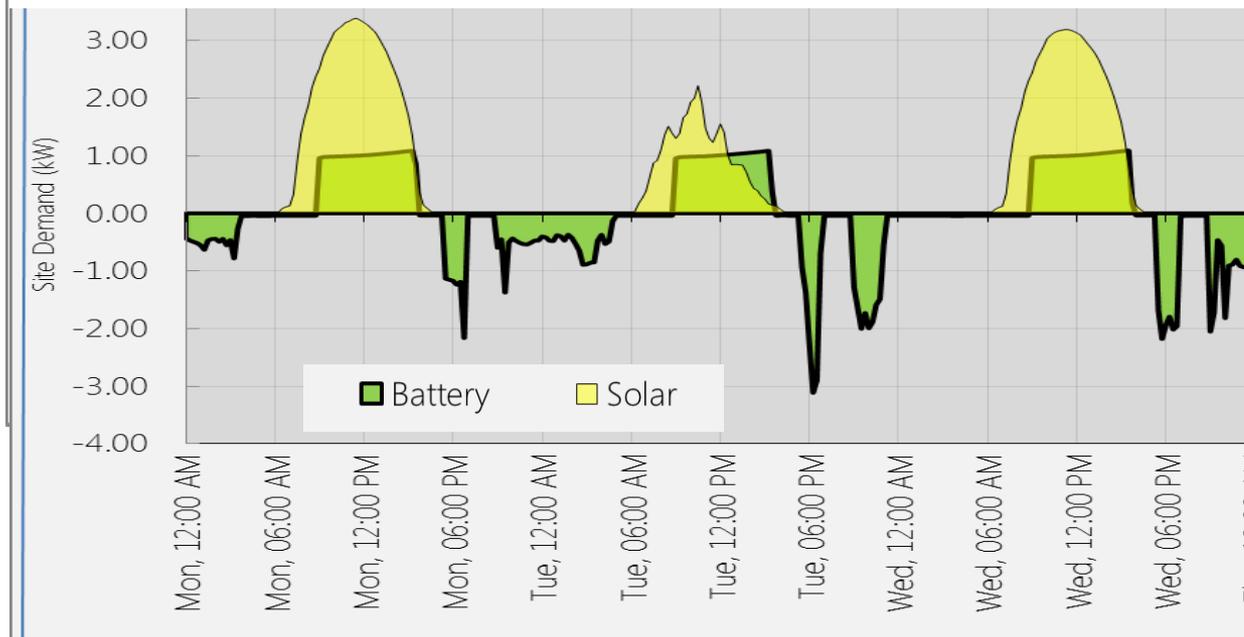
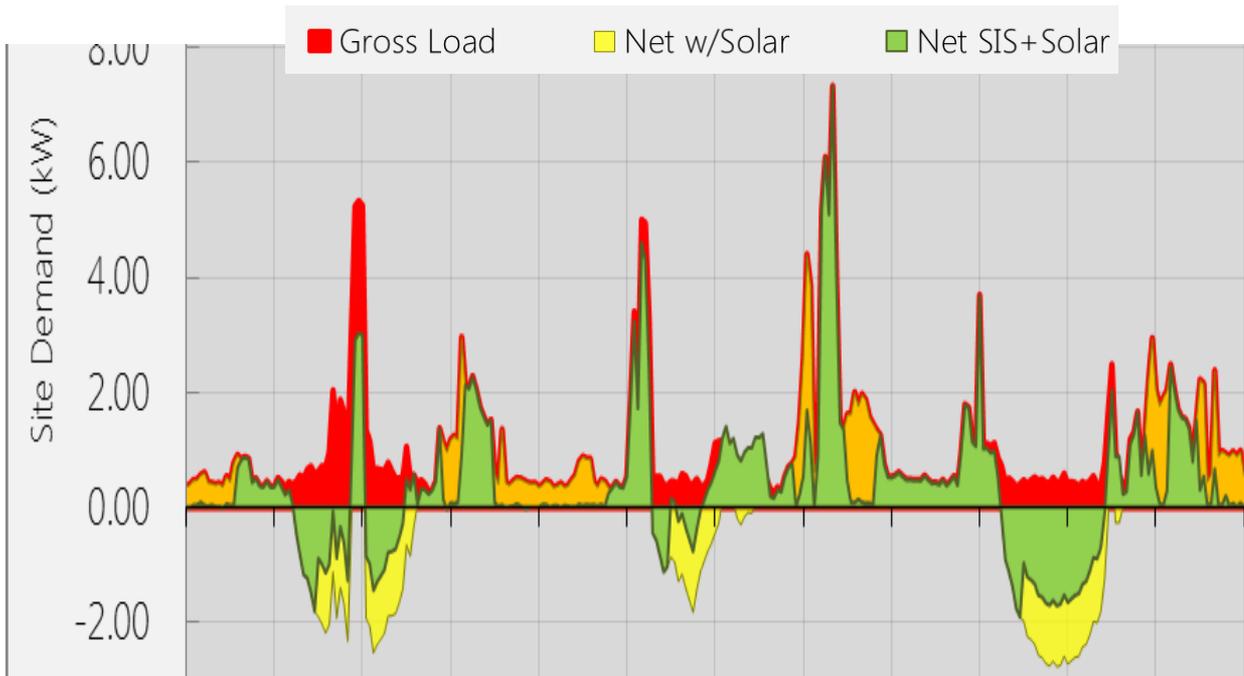


Nov 11 - 18

ZNE: Sunverge Performance @ Initial Settings

Reducing “Duck Curve” Effect





ZNE
Performance -
EE, PV,
Storage
 (Initial Sunverge
 Settings, no DR yet;
 need Nucleus)

Next:
 Train homeowners:
 HEMs, HPWH
 Tune Sunverge
 Implement auto tuning
 Configure DR
 Need full-year of data

Section 4

Low-Cost Solar Residential Retrofit

Grid-Ready Plug-&-Play PV Kit

1. ZNE Retrofit: EE, DR, Storage, HEM, +
Grid-Ready Plug-and-Play PV Kit
2. Conclusions

Grid-Ready Plug-and-Play PV Kit

Key System Attributes – Importance to Retrofit Market

Key attributes for this system include:

- Simple to install – crew trained within one installation, based on training two crews and total six installations
- Full installation can be completed in about a half day, with an experienced crew
- There is no requirement nor need for a electrician on the roof. This saves on salaries and insurance costs
- All six GE systems are performing at or above expectations
- The six GE systems are out-performing AC systems,
- Except for the module shaded, these AC systems are relatively unaffected by shading.

Grid-Ready Plug&Play PV Kit

Project Summary - 1

- Prototype → Improvements: Beta-Kit
- Installed 1 Prototype & 5 Beta-test homes
- Trained installers, Possible distribution channels
 - Bob Piva Roofing, Lowes, Sungevity, AFG
- Evaluated & Exceeded both Performance and Cost Goals:
 - Target cost <\$4.50/W; actual <\$4/W
 - Performance better than model, with standard assumptions
- LCOE for system = \$0.14 (@1% O&M; \$0.12 at 0 O&M costs)
 - Benchmark system output 4.3MWh/yr;
 - Assume 1% loss in efficiency/yr (conservative)
 - \$4.00/W installed cost, and O&M at 1% of installed cost / yr
 - This is at a par or less than the average cost of electricity to all but the most needy of CA ratepayers (CARE)

Grid-Ready Plug&Play PV Kit

Project Summary - 2

- LCOE for **ZNE** = \$0.29 - \$0.34/kWh (@1% O&M)
 - Simulation predicts **9.7MWh/yr**;
 - Assume 1% loss in efficiency/yr (conservative)
 - EE = \$33,970 + PV \$19,200 = \$53,170
- Plus benefits of **Peak Reduction**: PV + Intelligent Storage
 - Standard settings - Yet to optimize
 - Sunverge SIS: 93% round-trip efficiency
 - Shifted 35% of excess PV gen to late day after peak
 - Reduced peak by as much as 3kW
 - PV + SIS offset 57% of site-grid usage
 - Can provide auto-optimization (DC systems; working on AC)
 - Working on integrating Nucleus and DR

Grid-Ready Plug&Play PV Kit

Project Summary - 3

- **Outreach & Technology Transfer**
 - Local San Diego Roofers
 - AFG National roofing company
 - Lowes – national big-box retailer
 - Solar giants: SunRun & Sungevity
- **Advance CA Long Term Efficiency Strategic Plan Goals for Existing Homes**
 - New Channel: Roofers
 - Expand PV education, marketing, sales
 - Reduced impact of shading on PV system

Section 4

Low-Cost Solar Residential Retrofit Grid-Ready Plug-&-Play PV Kit

BREAK – Q&A

All 4 Presentations Open for Questions

Grid-Ready Plug & Play PV Kit

Conclusions

- **Plug & Play PV Kit Cost-Effective PV for Typical CA Ratepayers**
- **Provides Opportunity for New PV-Sales Channel**
 - Roofers
 - Equates to increased market penetration
- **Plug & Play PV Kit is Simple and Fast to Install**
- **ZNE Becoming More Practical**
 - Benefit of reduced peaks
 - Storage improves peak reduction and grid efficiency
 - Small energy loss

Rob Hammon, Ph.D.,
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