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Building America U.S. Department of Energy

Building America

Advanced Technical Solutions for Zero Energy Ready Homes: Renewable Integration

November 16, 2016

Moderator:

Linh Truong– National Renewable Energy Laboratory

Panelists:

Tim Merrigan – National Renewable Energy Laboratory

Chrissi Antonopoulos – Pacific Northwest National Laboratory

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Agenda

- ✓Welcome and Introductory Remarks
- ✓Overview of Building America (buildingamerica.gov)
  - ➢ Linh Truong - National Renewable Energy Laboratory
- ✓Presentations
  - ➢ Tim Merrigan - National Renewable Energy Laboratory
  - ➢ Chrissi Antonopoulos – Pacific Northwest National Laboratory
- ✓Questions and Answers
- ✓Closing Remarks

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Building America Webinar Series - 2016

Advanced Technical Solutions for Zero Energy Ready Homes: Renewable Integration

Building America U.S. Department of Energy

Tim Merrigan, Senior Project Leader, National Renewable Energy Laboratory

Tim joined NREL in 1999. His research focuses on building-integrated renewables, solar water heating technology development, PV/thermal system development, and integrated solar heating and cooling systems.

Prior to joining NREL, Tim was with the Florida Solar Energy Center for 20 years, conducting research in solar thermal systems and building energy efficiency. Tim served as the chair of the ASHRAE Technical Committee for Solar Energy Utilization, served as the chair of the Standards Committee for the Solar Rating & Certification Corporation (SRCC), and was on the Board of Directors for the Colorado Solar Energy Industries Association (COSEIA).

Chrissi Antonopoulos, Senior Project Leader, Pacific Northwest National Laboratory

Chrissi Antonopoulos joined PNNL's Portland office in 2010 and has worked on a broad range of projects ranging from green buildings, residential energy efficiency, appliance efficiency standards and smart grid development. Chrissi is currently an Energy Research Scientist working with the Energy Technology Market Adoption Team to enhance the presence of green technologies in the commercial marketplace. Current work includes analysis of green building technology diffusion in the commercial building sector, valuation of energy efficient residential homes, and website development for energy efficient programs. Chrissi has lead research tasks focusing on code development for renewable energy technologies, and market forecasting of green building in the commercial sector. Chrissi has a B.S. in Business Administration, and a Master's of Urban Studies with a focus on energy technologies and sustainable development, from Portland State University. She is an active member of local energy efficiency organizations including Oregon BEST, and the Northwest Environmental Business Council, and has been an invited speaker to the American Council for an Energy Efficient Economy, Summer Study on Energy Efficiency in Buildings.

NREL
NATIONAL RENEWABLE ENERGY LABORATORY






Advanced Technical Solutions for Zero Energy Ready Homes: Renewable Integration

Tim Merrigan

NREL
tim.merrigan@nrel.gov

16 November 2016

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Zero Energy Ready Home

A Zero Energy Ready Home (ZERH) is a high-performance home that is so energy efficient, that a renewable energy system can offset all or most of its annual energy consumption.

ZERH program builders have requested guidance on designing for the future integration of renewable technologies as well as ensuring that they will be installed in accordance with code and utility requirements. This project addresses this ZERH program need.

ZERO
ENERGY READY HOME
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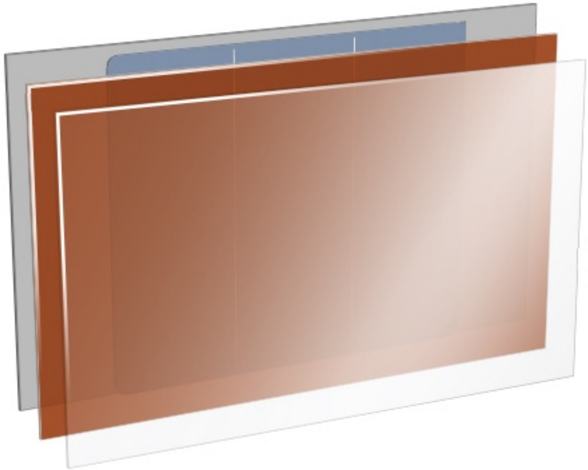
Webinar Outline

- Building-applied PV vs. Building-integrated PV (BIPV)
- Current U.S. BIPV Products
- Historical BIPV Price Premium
- BIPV Cost Analysis
- BIPV Cost-competitive Potential
- BIPV Performance
- BIPV Code Acceptance Criteria
- BIPV Glass Applications
- BIPV Summary

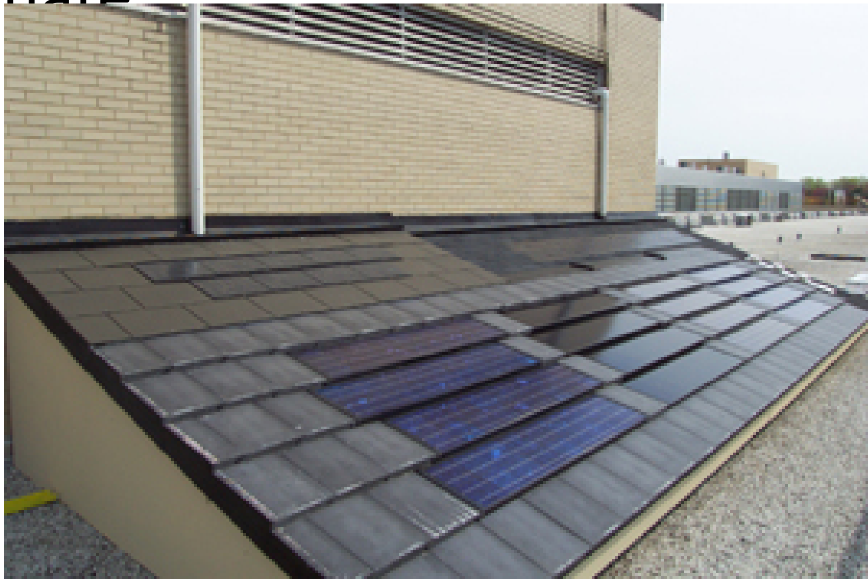
Tesla Solar Roof Unveiling – Oct. 28,



https://www.tesla.com/solar

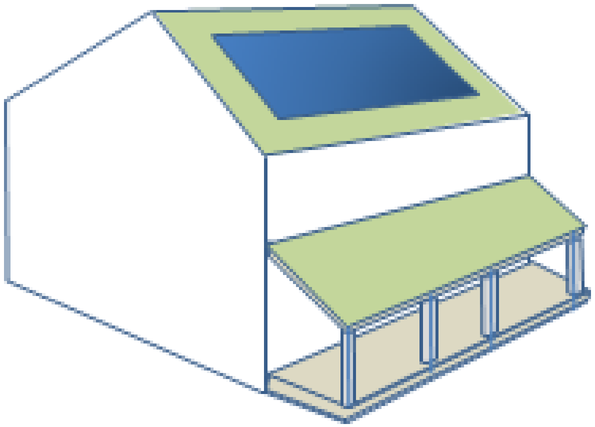
Discontinued PV Roof Integration Products

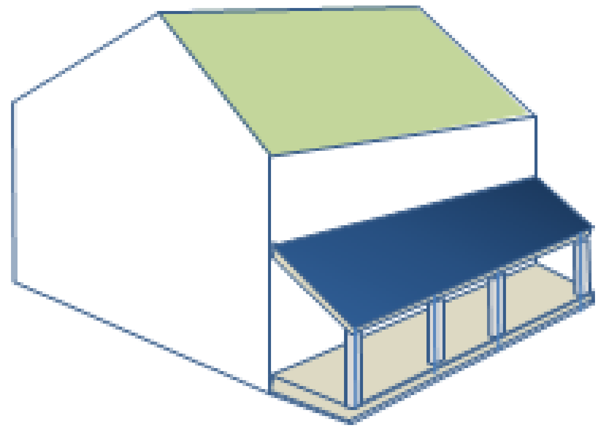
- Applied Solar – PV tile
- Astropower / GE Energy – PV tile
- BP Solar Energy Tile
- Dow Solar Powerhouse Solar System 2.0 – PV shingle
- ECD/Unisolar – flexible a-Si laminate
- Solexel (with Owens Corning) – PV shingle
- SoloPower – flexible CIGS laminate
- Open Energy SolarSave tile
- Powerlight /SunPower SunTile
- SRS Energy / Sole Powertile
- Sharp Solar – PV tile
- Suntech SolarBlend Roof Tile



NIST Residential Roof Photovoltaic Test Facility (2006)

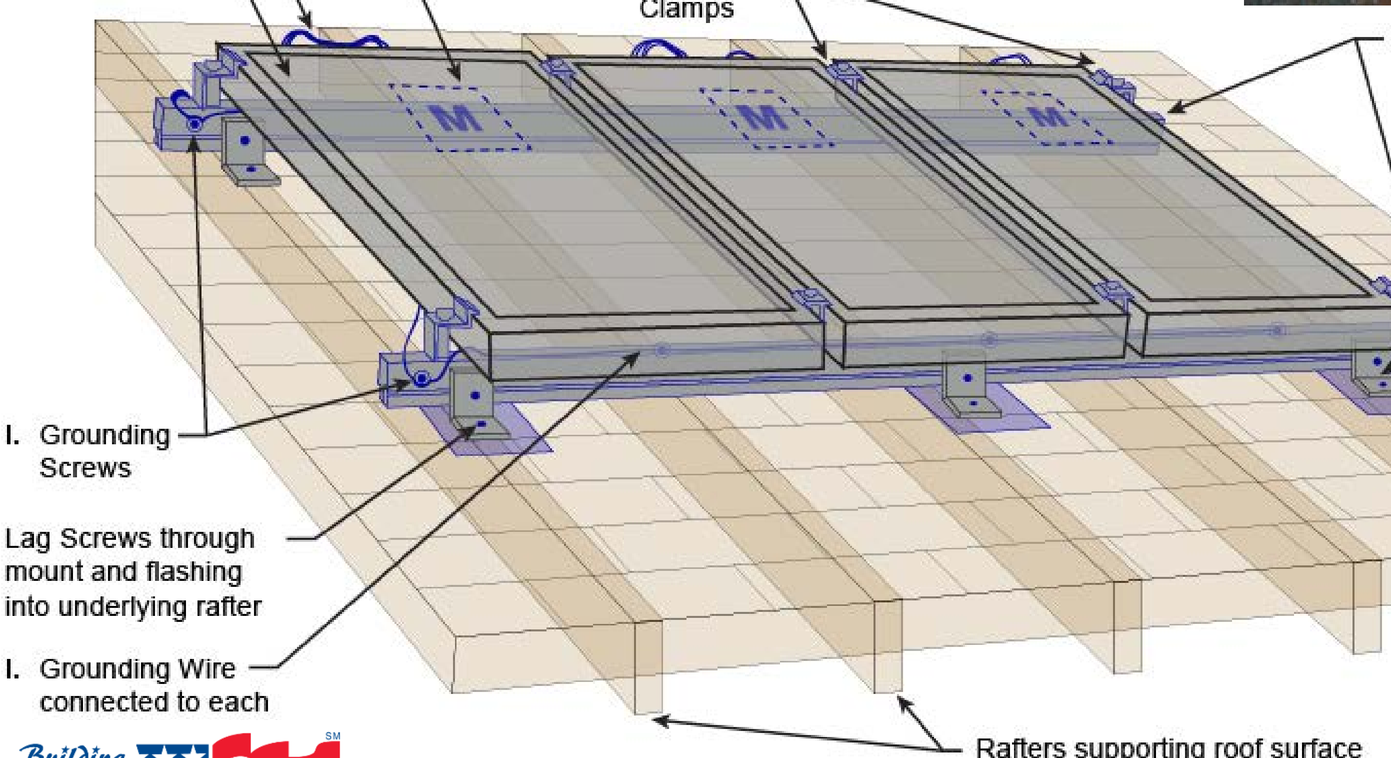
Building-applied PV (BAPV) vs.





Conventional PV System Installation vs. Integrated PV Porch Roof
(Source: Sam Rashkin, DOE BTO)

Stand-off Mounted BAPV



BAPV: Rail-Less Stand-off Mounting

SolarCity
Zep Solar

Module-Integrated

Andalay Solar
Spice

Universal Rail-Less

DynoRaxx
Roof Tech
Enable energy
Quick Mount PV
Zilla
SUNMODO

BIPV Roofing Tiles and Solar Shingles

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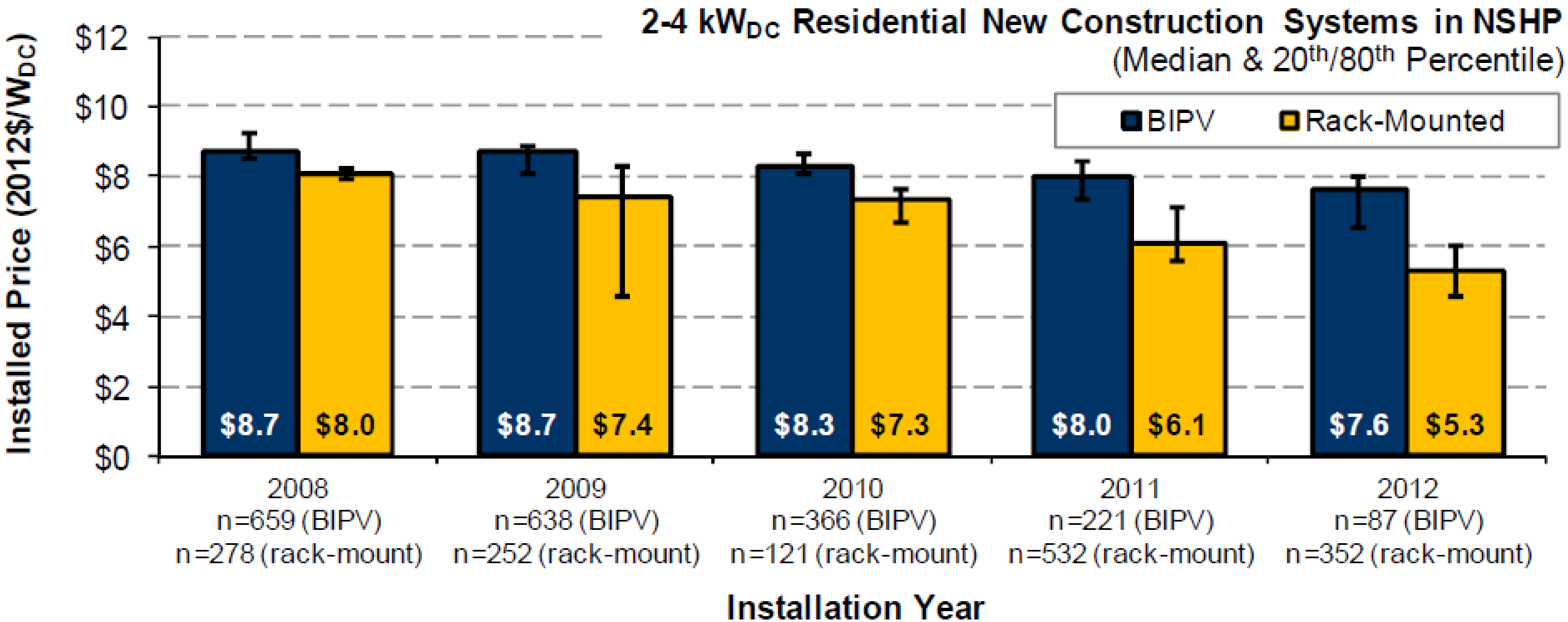
BIPV Products – Roofing shingles and roofing tiles

Company	Model	BIPV Type	Size (Length x Width)	Weight (lbs) (lbs per 100 sq. ft.)	PV Type	Power @ STC (Watts)	Temp Coefficient @ P_{mp} (% per C)	Nominal Operating Cell Temp (C)	Frame / Color	ASTM D3161 Wind Resistance	UL 790 Fire Rating	Impact Resistance (hail diameter)	Warranty (years @ rated W)
Atlantis Energy Systems	Sunslates6	Slate tile	19.625" x 14.5"	14.4 (730 lbs per square)	mc-Si	23	-0.108 (?)	51.2	Black frame /Blue	125 mph	Class A		20
Atlantis Energy Systems	TallSlate	Slate tile	47.25" x 12.125"	17	mc-Si	42			Black frame /Blue	125 mph	Class A		20
BIPV Inc.	BIPV050, 052, 054	Shingle, tile			pc-Si	50, 52, 54							
CertainTeed (Saint-Gobain)	Apollo II Tile	Tile	47" x 17.25"	13 (307 lbs per square)	mc-Si	60	-0.45	53.5	Brown frame / black cells	Class F (150 mph)	Class A		25
CertainTeed (Saint-Gobain)	Apollo II	Shingle	46.75" x 17.625"	12	mc-Si	60	-0.45	55.6	Black / black cells	Class F (150 mph)	Class A		25
Englert	SunNet	Metal roofing			Thin-film	68, 136, 144							
Global Solar / Hanergy	PowerFLEX BIPV	Flexible module	1.6'x6.6',12.8',8.7'	(68 lbs per square)	CIGS	90 - 300	-0.430		Frameless / Green				25 @ 80% W
SunTegra (Integrated Solar Technology)	SunTegra	Tile	52.75" x 15.875"	15 (300 lbs per square)	mc-Si	64, 67	-0.420	57	Black, gray, brown frame	110 mph	Class A	25 mm @ 25 m/s	25
SunTegra (Integrated Solar Tech)	SunTegra	Shingle	52.625" x 23.125"	18 (250 lbs per square)	mc-Si	95, 100	-0.420	55		130 mph	Class A	25 mm @ 23 m/s	25
Luma Resources	LRSS	Shingle	54.37" x 15.62"	19.8	pc-Si	60	-0.37		Black / Blue cells		Class A		25 @ 80% W
Lumeta	LPP-175S, LPP-185T	Shingle, Tile	3.28' x 3.94'	17.6	mc-Si	175, 185	-0.40	55 (+-2)	Frameless /Blue cells	120 mph	Class A		
Miasole / Hanergy	FLEX-02W, FLEX-02N, FLEX-02NL	Flexible module	102.3" x 39.4"	13.7	CIGS	340-380, 110-130, 265-305	-0.38				Class A (over TPO		10
Modular Solar Roofing	Soltrak	Polymer Tile	15.1" x 15.3"	4.9 (360 lbs per square)	pc-Si	11.5			Light gray		Class C		
Solarmass	Ergosun	Tile	11.7" x 13.5"	(123 lbs per square)	mc-Si	15.3	-0.4	48	Custom			25 mm @ 25 m/s	

BIPV Roofing Tiles – Premier Homes, California

BIPV vs. Rack-mounted PV Prices – California



Installed Price of BIPV vs. Rack-Mounted Systems in Residential New Construction

(Source: Barbose, Darghouth, Weaver, and Wiser, "Tracking the Sun VI," LBNL-6350E)

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BIPV Cost Analysis

Scenarios Used to Analyze Residential Rooftop PV System Prices

(Source: James, Goodrich, Woodhouse, Margolis, and Ong, NREL/TP-6A20-53103)

Scenario	Technology	Form	Efficiency	Module Area (m^2)
PV Reference Case	c-Si	Rigid	14.5%	1.28
BIPV Derivative Case	c-Si	Rigid	13.8%	0.58
BIPV Thin-film Case 1	CIGS	Rigid	11.2%	0.58
BIPV Thin-film Case 2	a-Si	Flexible	5.8%	0.58

BIPV Derivative Case Material Costs and Labor Requirements

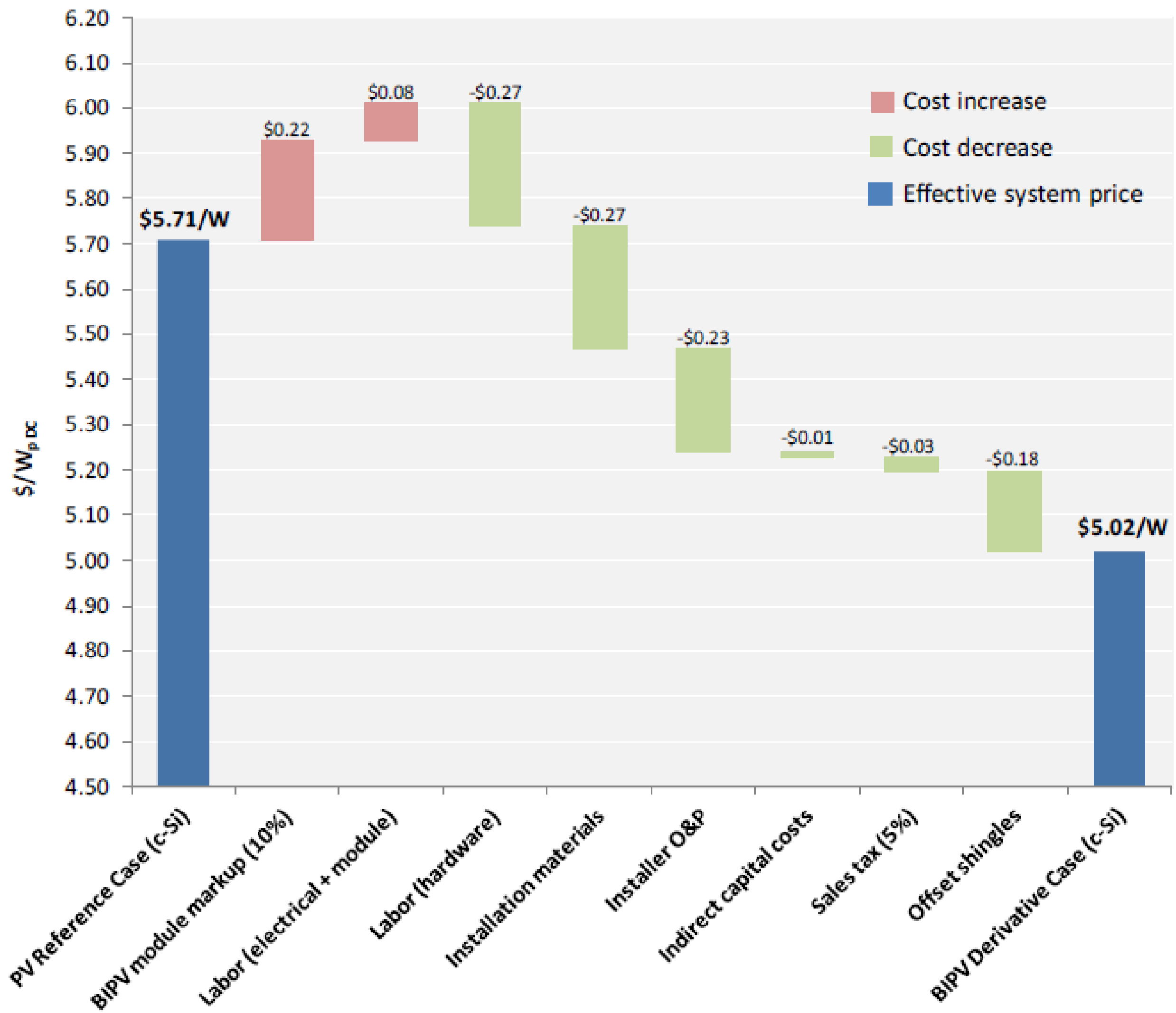
Material Category	Component costs ($/W)	Installation labor allocation requirements			
		Units	Units/ system	Electrical (hours/unit)	General (hours/unit)
Module	2.37*	Modules	68		0.07
Inverter	$0.42	Inverters	1	4	2
Wiring	$0.07	Linear feet (ft)	541†	0.05	
Other electrical‡	$0.17	Electrical subsystem	1	4.5	
Mounting hardware	$0.00	Module racks	0		0
Total materials cost	$3.03				
Total installation labor requirements				35.6	6.8

* Ex-factory gate price ($1.95/W, 2010 Photon) + retail margin (10%) + BIPV mark-up (10%) = $2.37/W

† Total wiring (541 ft) = home run wiring (141 ft) + row to combiner wiring (400 ft)

‡ "Other electrical" includes: meter, system monitor, and disconnects.

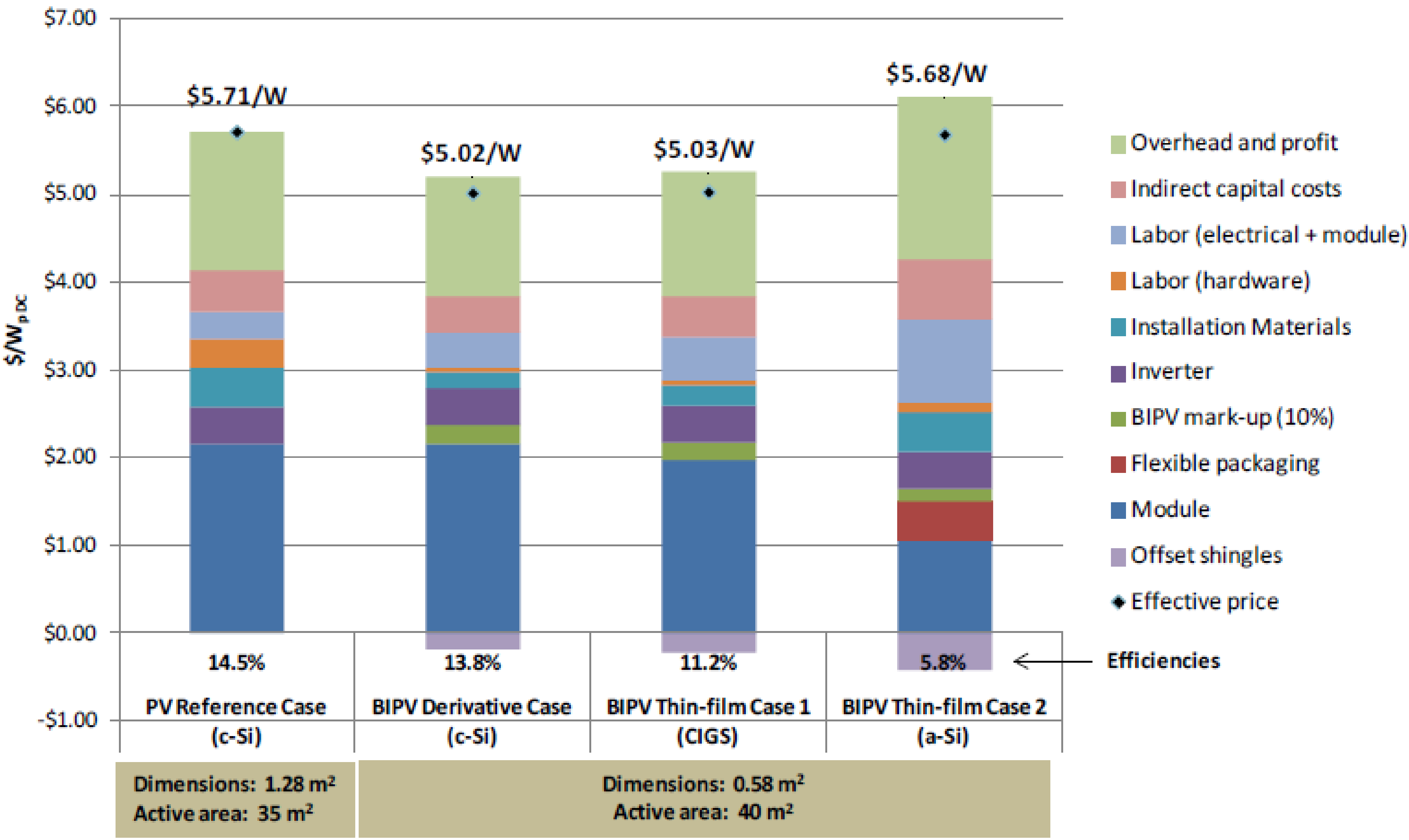
BIPV Cost Analysis



Price differences between the rack-mounted PV Reference Case and the BIPV Derivative Case

(Source: James, Goodrich, Woodhouse, Margolis, and Ong, NREL/TP-6A20-53103)

BIPV Cost Analysis

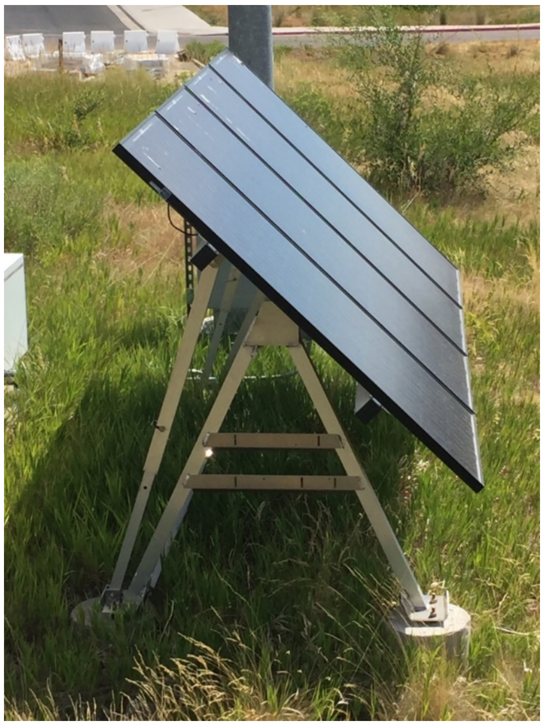


Price Comparison of PV Reference Case and 3 BIPV Cases

(Source: James, Goodrich, Woodhouse, Margolis, and Ong, NREL/TP-6A20-53103)

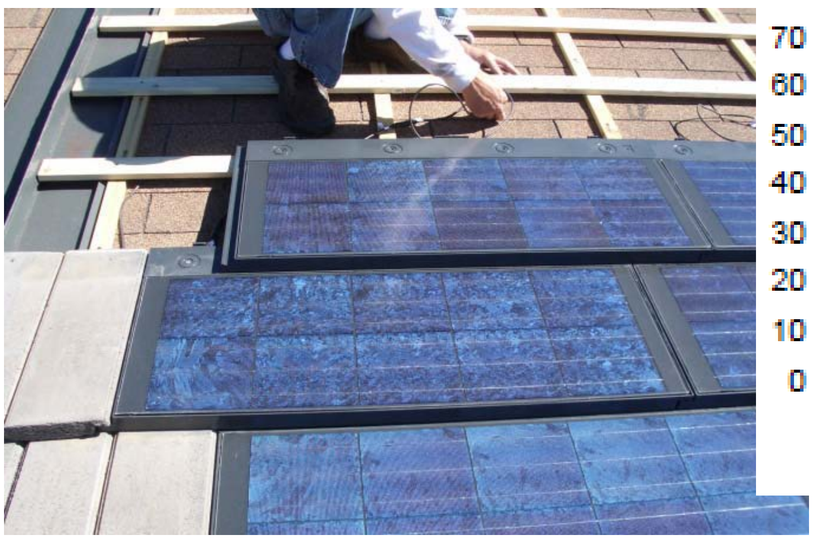
BIPV Performance – PV cell temperatures

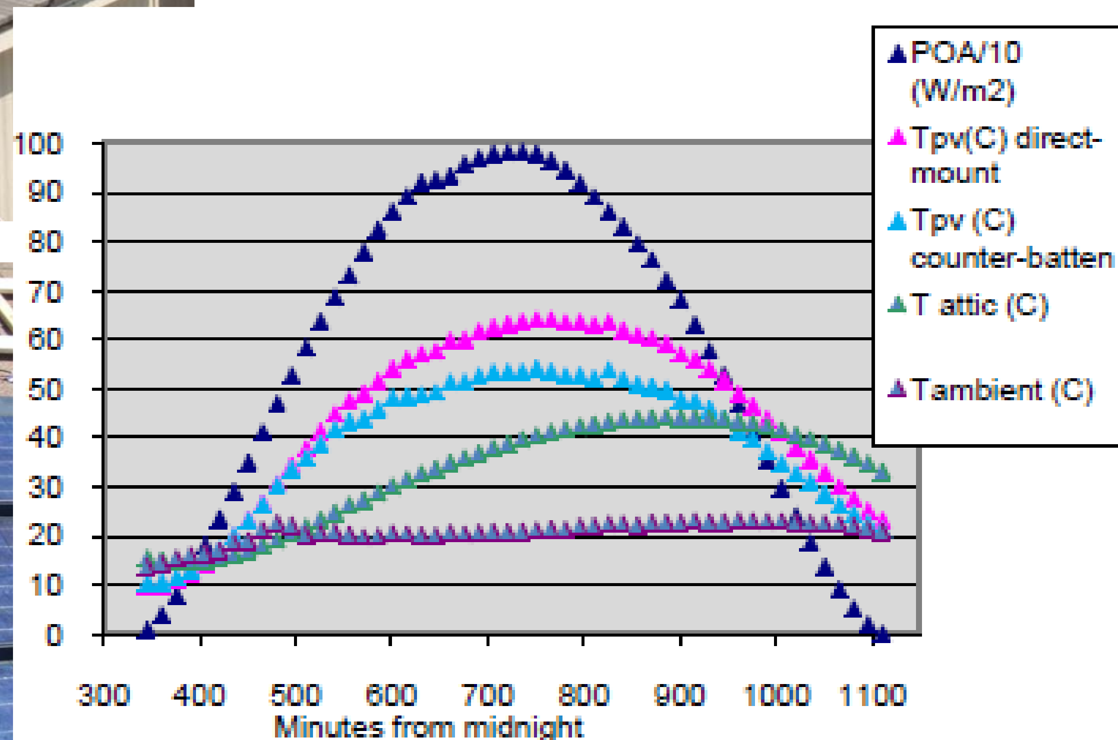
PV Module Mounting Configuration	**Typical Operating Cell Temperature**
• Free standing (open ground-mounted rack)	20-35 C above ambient
• Roof-mounted (stand-off mount above the roof)	30-40 C above ambient
• Roof-integrated (no backside ventilation)	40-50 C above ambient



BIPV Performance – Roofing tiles

Ventilated counter-batten installation produced 3.4% more direct current (DC) power than the direct-mount installation





Source: Muller, Rodriquez, and Marion, NREL/CP-520-45948

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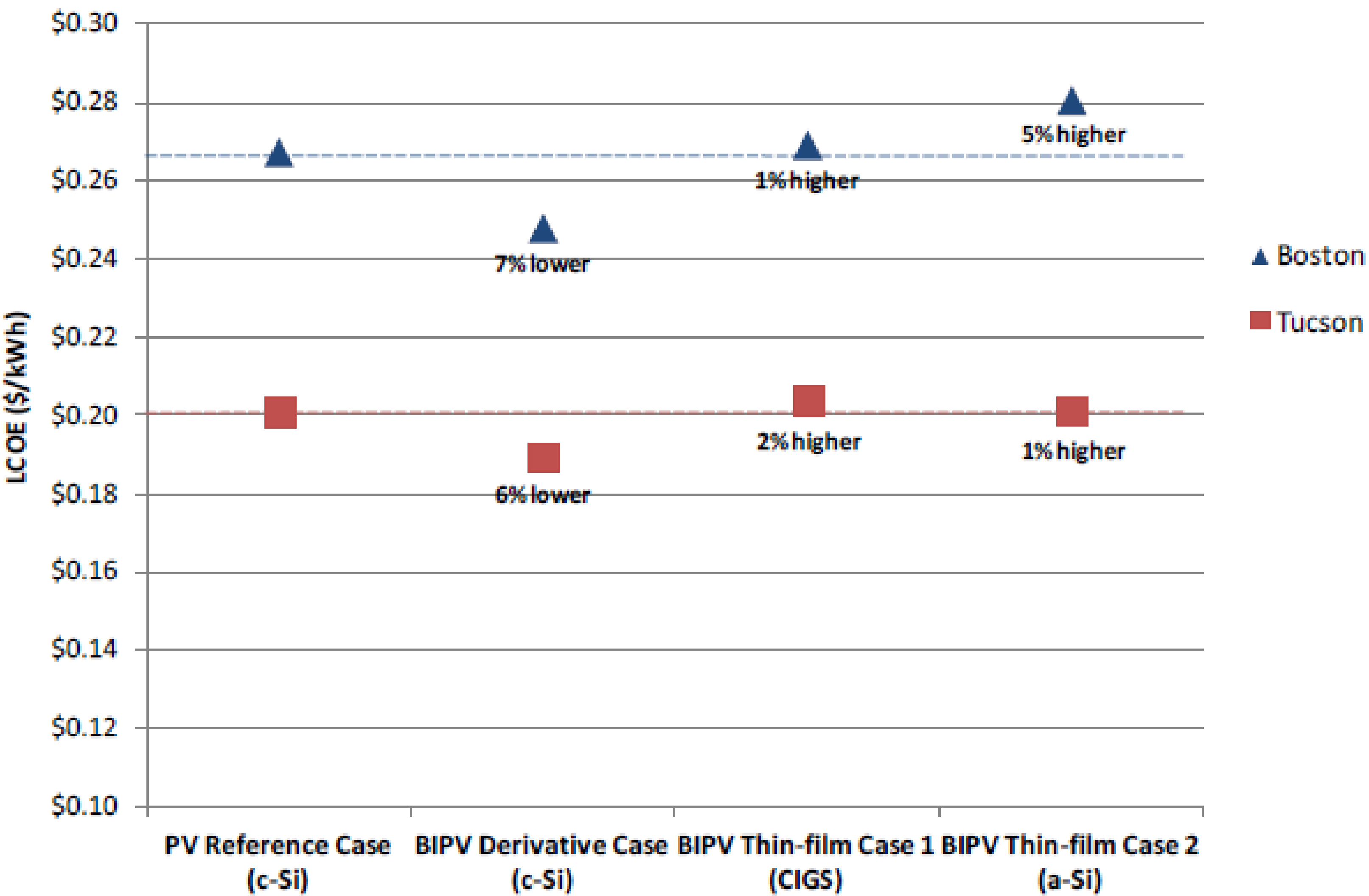
BIPV Levelized Cost of Energy (LCOE)



LCOE of PV Reference Case and 3 BIPV Cases

(Source: James, Goodrich, Woodhouse, Margolis, and Ong, NREL/TP-6A20-53103)

BIPV Code Acceptance Criteria

ICC Evaluation Service AC365

"Acceptance Criteria for Building-Integrated Photovoltaic (BIPV) Roof Covering Systems"

Scope: This criteria is applicable to BIPV roof modules, shingles and panels, complying with UL 1703, used in roof covering systems. The electrical safety requirements and solar energy performance of the BIPV roof modules, shingles and panels are outside the scope of this criteria.

TEST AND PERFORMANCE REQUIREMENTS

3.1.1 Fire Classification Test

3.1.2 Wind Resistance

3.1.3 Wind-driven Rain

3.1.4 Durability

- 3.1.4.1.1 Impact Resistance
- 3.1.4.1.2 Temperature Cycling Test
- 3.1.4.1.3 Humidity Test

ACCEPTANCE CRITERIA FOR BUILDING-INTEGRATED PHOTOVOLTAIC (BIPV) ROOF COVERING SYSTEMS

AC365

PREFACE

PV Awning

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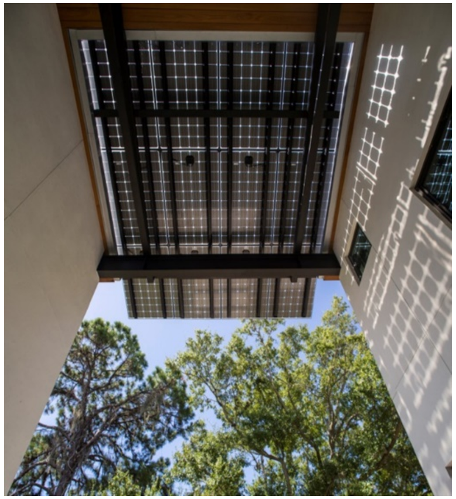
BIPV Porch Cover and Entrance Canopy



(Source: Lumos Solar)

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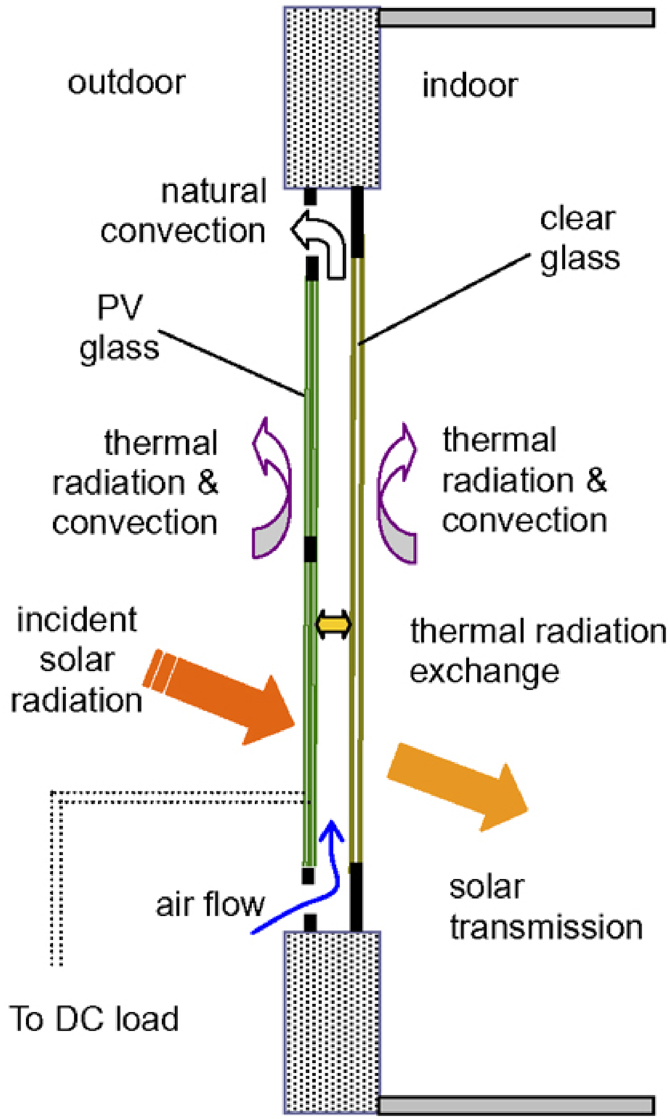
BIPV Products – Semi-transparent PV glass

Company (HQ Location)	Model	BIPV Type	PV Technology	Power @ STC (Watts)	Light Transmittance (%)	Impact Resistance (hail diameter	Availability (if not off-the-shelf)	Warranty (years @ rated W)
Atlantis Energy Systems	PV Skylight	Frameless glass-on-glass	pc-Si, mc-Si	120 - 125	7 – 50 (Custom)			10 (80%)
Brite Solar (Greece)	PanePower (Solar Windows)		Dye-sensitized solar cells					
Lumos Solar (USA)	LSX Module System	Frameless glass-on-glass	mc-Si	245 - 260	10 (Landscape) 12 (Portrait)	2 inch (FM 4473 Class 4)		12 (90%) 25 (80%)
Onyx Solar (Spain)	PV Glass	Frameless glass-on-glass	a-Si, CIS, CIGS, mc-Si, pc-Si		10, 20, 30			
Panasonic (Japan)	HIT (bifacial) Double 225	Glass-on-glass / Al frame module	Hetero-junction mc-Si w/ thin a–Si layer	190 - 330			Special order	10 (90%) 25 (80%)
Polysolar (UK)	PV Glazing	Frameless glass-on-glass	a-Si, CdTe, c-Si	85 - 135				5 – 10 (90%)
Prism Solar	PV glass (bifacial)	Frameless glass-on-glass	mc-Si	286 – 298, 362 - 375				
Sapa Solar		Glass-on-glass	a-Si, mc-Si, pc-Si					
Solaria	PV Window	IGU (glass-on-glass)	CIGS				Pre-commercial	
Stion	Elevation	Frameless glass-on-glass	CIGS	135 - 155				10 (90%) 25 (80%)
Sunpreme	Bifacial thin-film	Frameless glass-on-glass	Hybrid cell technology	310 - 370				10 (product) 5 (95%)

BIPV Porch Roof

All of the 962-ft2 porch roof is comprised of 69 solar panels that don't sit on top of the roof; they are the roof. The completely watertight structure allows about 15% of natural light to filter through the panels, lighting the space below. All wiring is hidden within the canopy's aluminum support beams.

Insulated Glass Unit with PV glass



Semi-transparent PV glass has recently been used as the outside layer of an insulated glass unit for building facades. By ventilating the airspace between the outside and inside layers of the IGU, SHGCs less than 0.15 were measured along with a visible light transmittance of 7% for an experimental IGU utilizing semi-transparent a-Si thin film.

(Source: Peng, Curcija, Lu, Selkowitz, Yang, and Zhang, “Numerical investigation of the energy saving potential of a semi-transparent photovoltaic double-skin façade in a cool-summer Mediterranean climate,” Applied Energy 165 (2016))

BIPV Summary

- Historical BIPV Price Premium. While aesthetically pleasing, BIPV roofing systems historically have had at least a 10 percent price premium over typical rack-mounted PV systems in new residential construction.
- BIPV Performance. Because residential BIPV roofing products operate at higher temperatures than typical rack-mounted PV modules, they produce 3 to 5% less energy on an annual basis than a comparably-sized rack-mounted system.
- BIPV Increased Modularity. Because BIPV roofing products typically come in smaller module sizes than rack-mounted PV modules, any small annual energy difference can easily be compensated for by increased system area.
- BIPV Cost-competitive Potential. By eliminating PV module mounting hardware and from offsetting the cost of traditional roofing materials, both c-Si BIPV shingles and CIGS thin-film BIPV systems have the potential to be competitive with rack mounted PV on a LCOE basis.
- BIPV Glass Applications. Semi-transparent BIPV glass has been used sparingly for porch and patio covers in residential construction, but its use is becoming more common to provide daylighting in commercial and institutional buildings. Typical visible light transmittance for semi-transparent BIPV glass is 10 to 15 percent.
- BIPV Installation. Most residential BIPV roofing products have undergone testing and evaluation to the International Code Council's "Acceptance Criteria for Building-Integrated Photovoltaic (BIPV) Roof Covering Systems." Another installation consideration for BIPV products that are mounted directly on the roof sheathing is that they typically do not allow for the use of module-level power electronics like microinverters and DC power optimizers.

Zero Energy Ready Home

DOE Tour of Zero

http://energy.gov/eere/buildings/doe-tour-zero

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Building America Solution Center Renewable Integration Resources

CHRISSI ANTONOPOULOS

Pacific Northwest National Laboratory

Building America Webinar, November 16, 2016

April 20, 2017

BASC Homepage

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DOE Zero Energy Ready Home Checklists

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The Building America Solution Center provides access to expert information on hundreds of high-performance construction topics, including air sealing and insulation, HVAC components, windows, indoor air quality, and much more. Click on the links below to explore the Solution Center.

As a community driven tool, we welcome your comments on how to continuously improve the Solution Center. If you are interested in submitting content, please become a registered user and see the criteria for submissions.

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Access guides directly from checklists for Zero Energy Ready Home, ENERGY STAR Certified Home, and Indoor airPLUS

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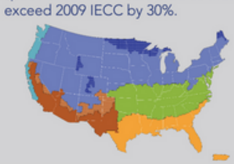

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Last Updated: July 27, 2016
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Reference Posted: August, 2016
Interior paints and finishes certified low-emission
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DOE Zero Energy Ready Home Program Checklist

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DOE Zero Energy Ready Home

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- Exhibit 1: Mandatory Requirements for All Labeled Homes
- Exhibit 2: Target Home
- Exhibit 3: Benchmark Home Size

Click accordions to expand checklist items and access BASC guides for installation

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  - 2.0 Envelope
  - 3.0 Duct System
  - 4.0 Water Efficiency
  - 5.0 Lighting & Appliances
  - 6.0 Indoor Air Quality
  - 7.0 Renewable Ready
    - PV-and Solar Hot Water-Ready Checklists
- Exhibit 2: Target Home
- Exhibit 3: Benchmark Home Size

Click to link to the PV/SHW checklists

DOE Zero Energy Ready Home Renewable Ready Checklists

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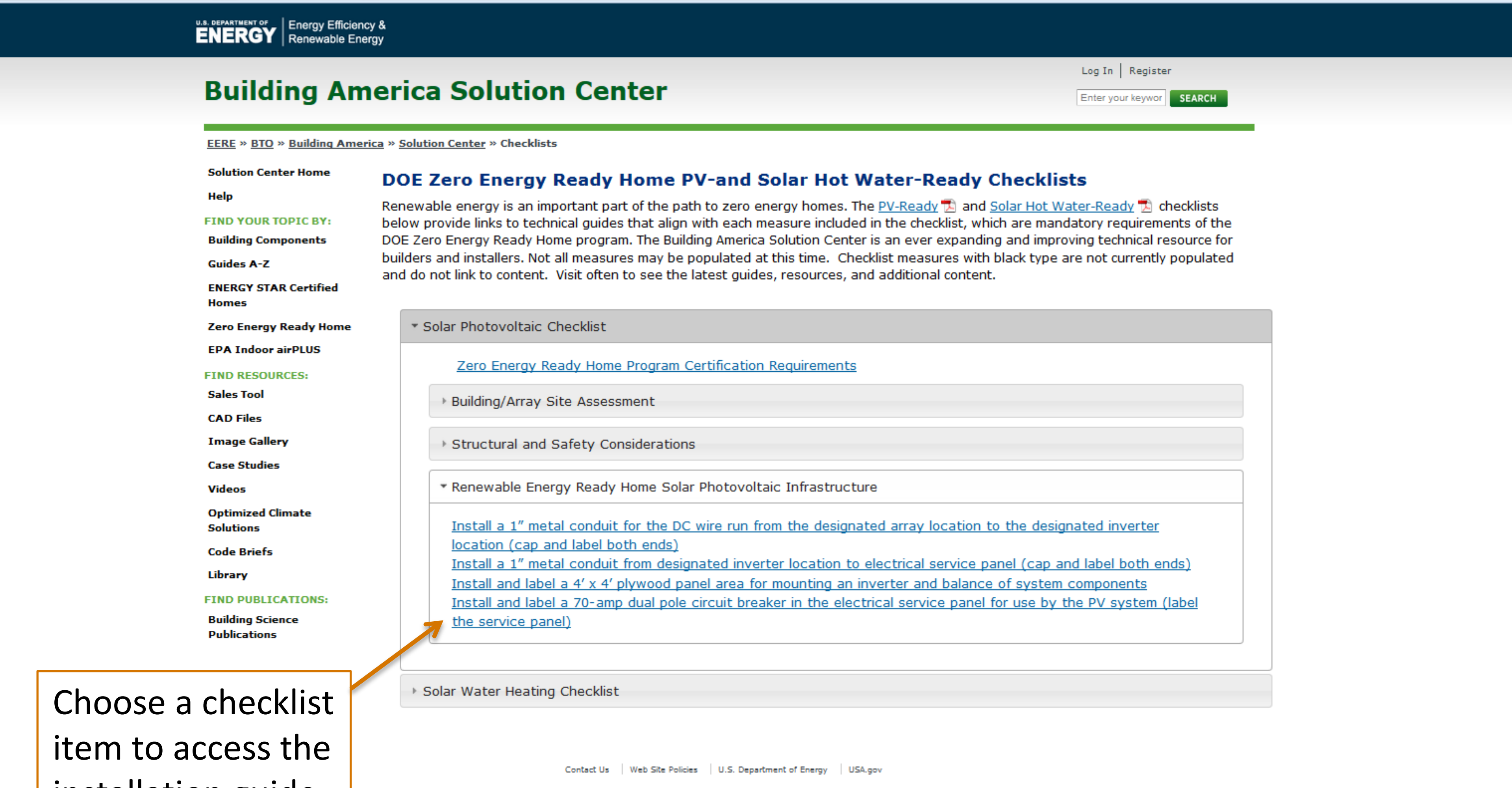

Choose a checklist item to access the installation guide

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70-Amp Dual-Pole Circuit Breaker for PV Systems

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Scope

Include a dedicated 70 amp dual-pole circuit breaker for a future solar photovoltaic (PV) system when building a Renewable Energy Ready Home (RERH). If possible, place the circuit breaker panel box near the future balance of system components for the PV. Space requirements and layout for solar photovoltaic system components should be taken into account early in the design process.

DOE Zero Energy Ready Home Notes

The U.S. Department of Energy (DOE) Zero Energy Ready Home National Program Requirements includes in Exhibit 1, Mandatory Requirements, Item 7 Renewable Ready, that all homes must meet the requirements in the Consolidated Renewable Energy Ready Home (RERH) Checklist.

The RERH Checklist requires builders to:

- Install a 70-amp dual pole circuit breaker in the electrical service panel for use by the PV system (label the service panel) (RERHPV Guide 3.4)

Alternative: Provide a labeled slot for a double-pole breaker in the electrical service.

Last Updated: 08/04/2014

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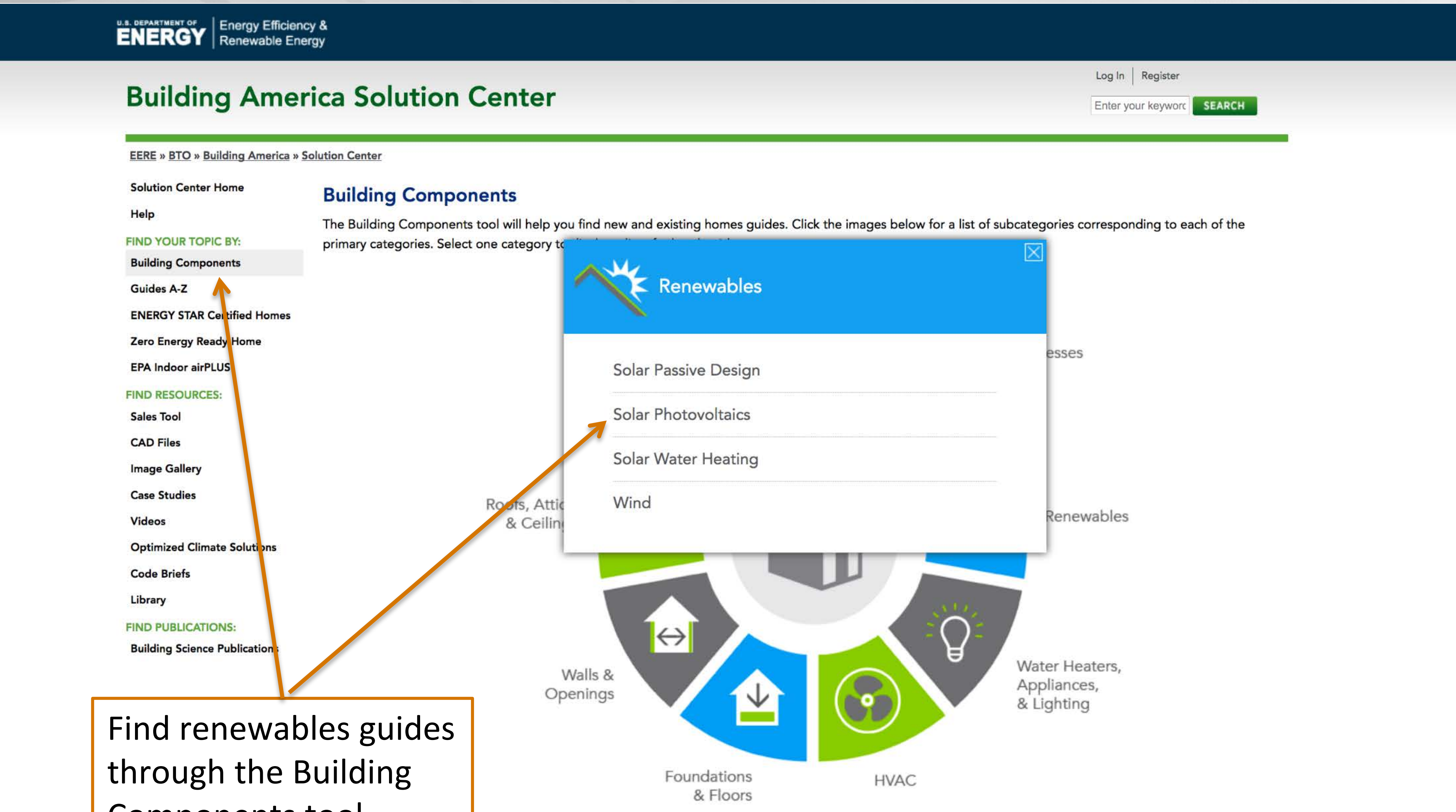

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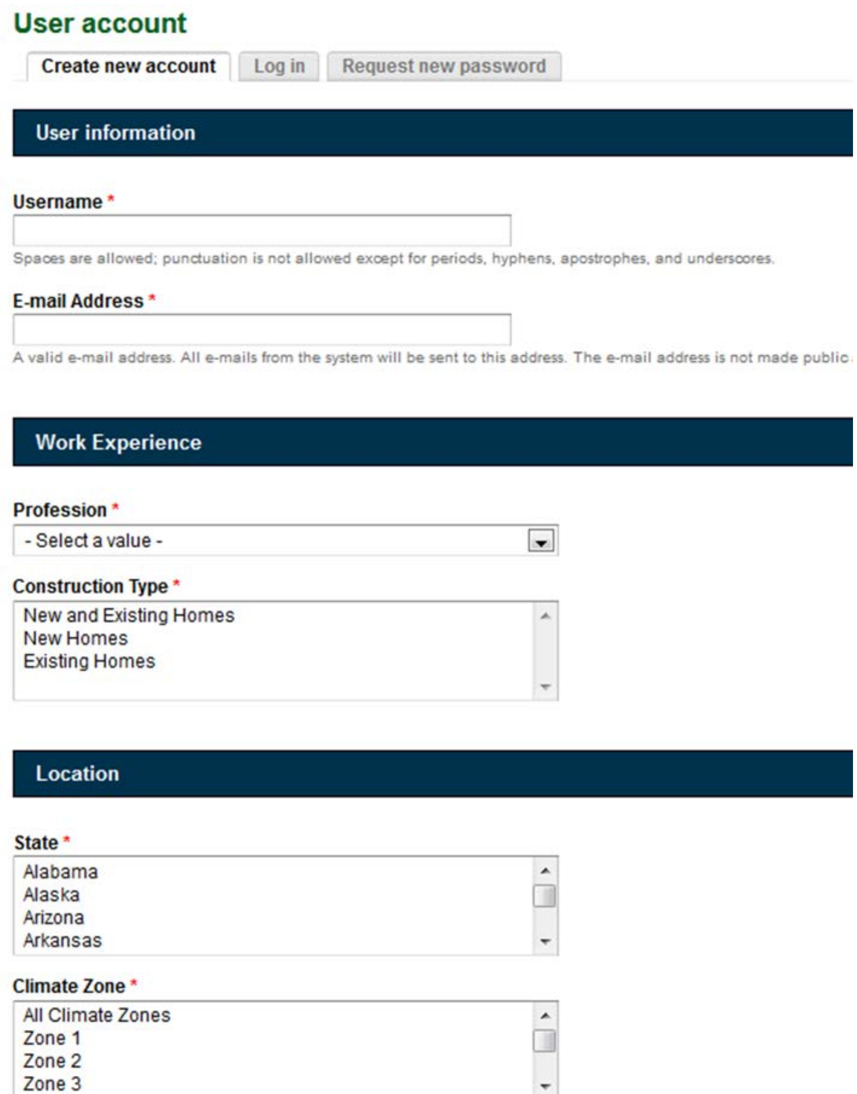

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