Fire Safety for Solar PV

March 20, 2019
Conshoshocken, PA
Delaware Valley Regional Planning Commission

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CADMUS

Reducing the cost of solar for 300 communities throughout the country

SOLSMART

NATIONALLY DISTINGUISHED. **LOCALLY POWERED.**

Technical Assistance

- Online, by phone, or in-person
- Opportunity to receive a fully-funded solar expert on staff for 6-months (SolSmart Advisor)
- Free of cost to participating communities!

Rewards and Recognition

- Nationally recognized award for leading solar communities
- Three levels: Bronze, Silver, Gold

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No-Cost Technical Assistance

- All communities pursuing SolSmart designation are eligible for no-cost technical assistance from national solar experts.
- Technical assistance helps governments reduce solar soft costs, spur the local solar market, and achieve SolSmart designation.

Technical Assistance Topics

Permitting	Solar Rights
Planning & Zoning	Utility Engagement
Inspections	Community Engagement
Construction Codes	Market Development & Finance

Egan Waggoner

- *Directed the technical training component of the New York State's PV Trainers Network, which includes building, electrical, and fire codes as they relate to Solar PV development.*
- *Provides solar policy trainings for the Network and Solar Ready Vets*
- *Leads the Massachusetts Commercial Solar + Storage program to provide education and technical assistance to commercial interested in solar + storage procurement and Cambridge's Building Energy Use Retrofit Program.*
- *Holds a Master of Science in Environmental Sciences with emphasis in Energy Systems and Water Resources from the SUNY College of Environmental Science & Forestry.*

Today's Agenda

- Introduction to solar technology [60 min]
- Identifying solar PV systems [45 min]
- Break [10min]
- Solar PV hazards and safety [30 min]
- Identifying and disabling solar PV systems [45 min]

Acknowledgements

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This presentation includes graphics, images, and schematics that have been take from a host of various sources as well as developed specifically by the author for this presentation.

We would like to acknowledge the use of materials from the NY-Sun PV Trainers Network (PVTN), Matt Piantedosi, Tony Granato, Interstate Renewable Energy Council (IREC), the National Electrical Code (NEC), Solar ABCs, the Department of Energy (DOE), and the International Association of Electrical Inspectors (IAEI).

Disclaimer

The views and opinions expressed in this presentation by the instructors are based upon their own experiences and understanding of the topic. They do not necessarily reflect the position of Cadmus, US DOE, or the participating states. Examples based on experiences are only examples. They should not be utilized in actual situations.

This presentation will provide an introduction solar photovoltaic technology, identifying different solar PV systems, common safety hazards and how to safely to disable a solar PV system. This course will not provide you with all the information you need to know.

Disclaimer – National Electrical Code

Pennsylvania adheres to the 2014 NEC. This presentation has been adapted to reflect the 2014 National Electrical Code cycle and best practices and highlights some of forthcoming changes in the 2017 version.

Many changes to the most current and future versions of the NEC (2014 and 2017) have occurred due to concerns expressed by the fire fighting community with regard to solar electric systems.

Disclaimer – PA Construction Codes

2015 Pennsylvania Uniform Construction Code

At the state level, the State Building Code is based on the 2015 International Codes. This presentation has been adapted to reflect the 2015 International Codes and recommended best practices. The Building Code Council adopted amendments that have been approved by the Rules Advisory Council are as follows:

The RAC voted to adopt Chapters 2—10, 12—29 and 31—35 of the IBC of 2015

http://www.dli.pa.gov/ucc/Pages/default.aspx

Workshop Learning Objectives

1. How to identify solar electric systems on-site

2. How to differentiate between common system types

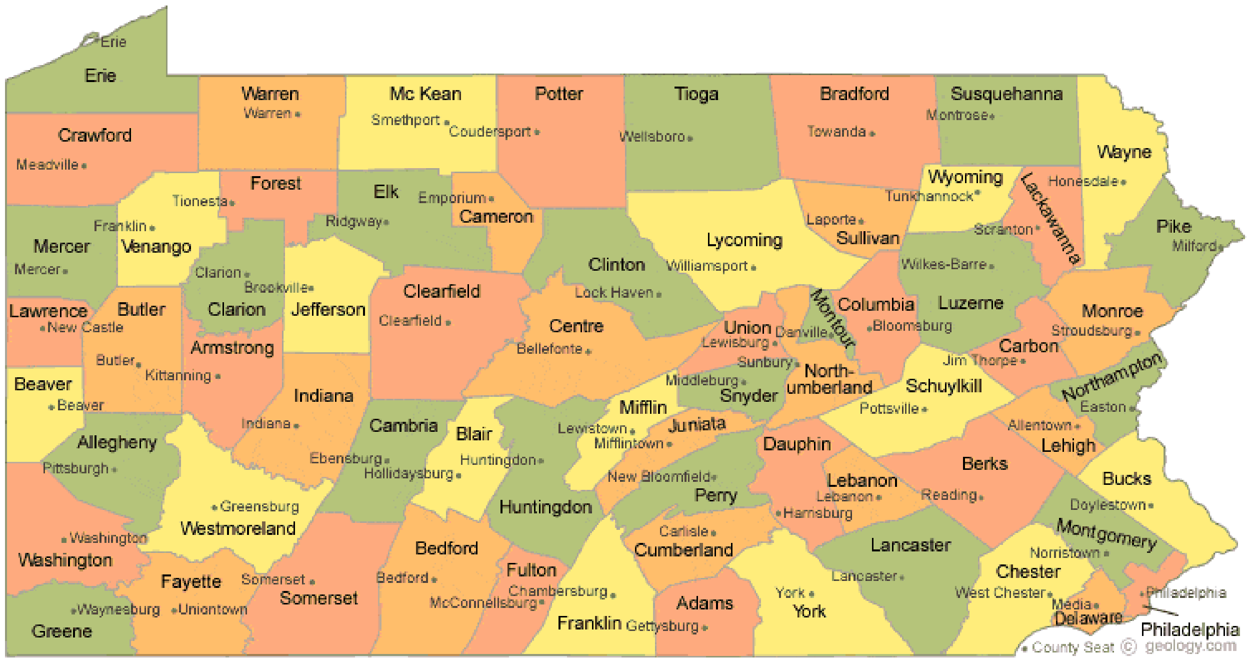
3. How to safely disable solar PV systems

Audience Introduction

- Who here is a fire fighter or first responder?

- Other attendees: CEO, solar installers, interested citizens?

- Does anyone have a solar electric system on their home?



Today's Agenda

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Introduction to Solar Technology

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Solar Photovoltaic (PV)

Solar Hot Water

Concentrated Solar Power

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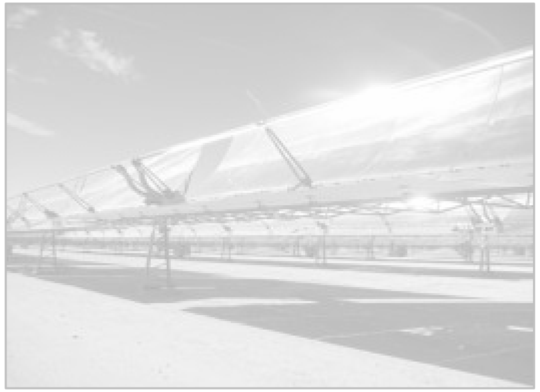
Introduction to Solar Technology

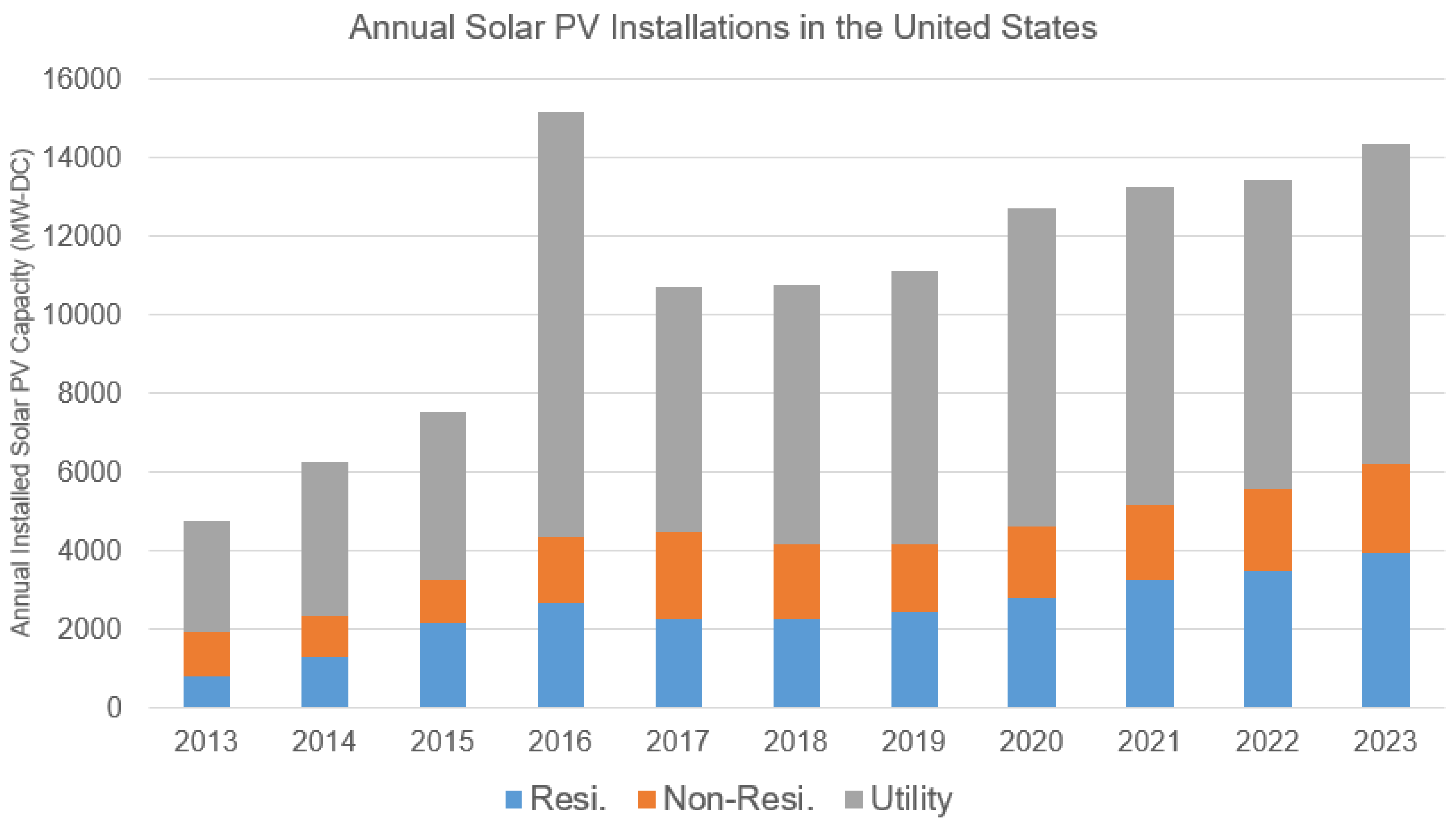
Solar Photovoltaic (PV)

Solar Hot Water

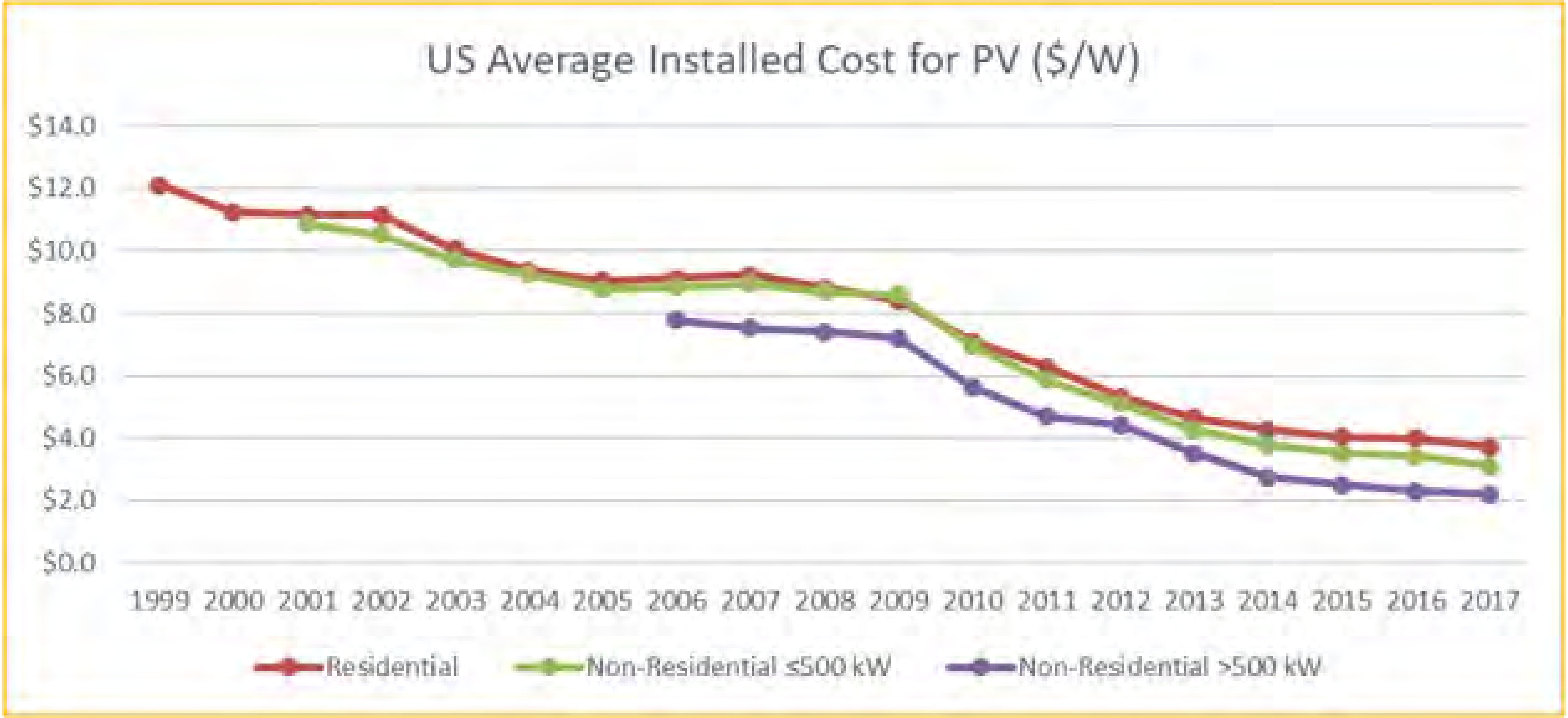


Concentrated Solar Power

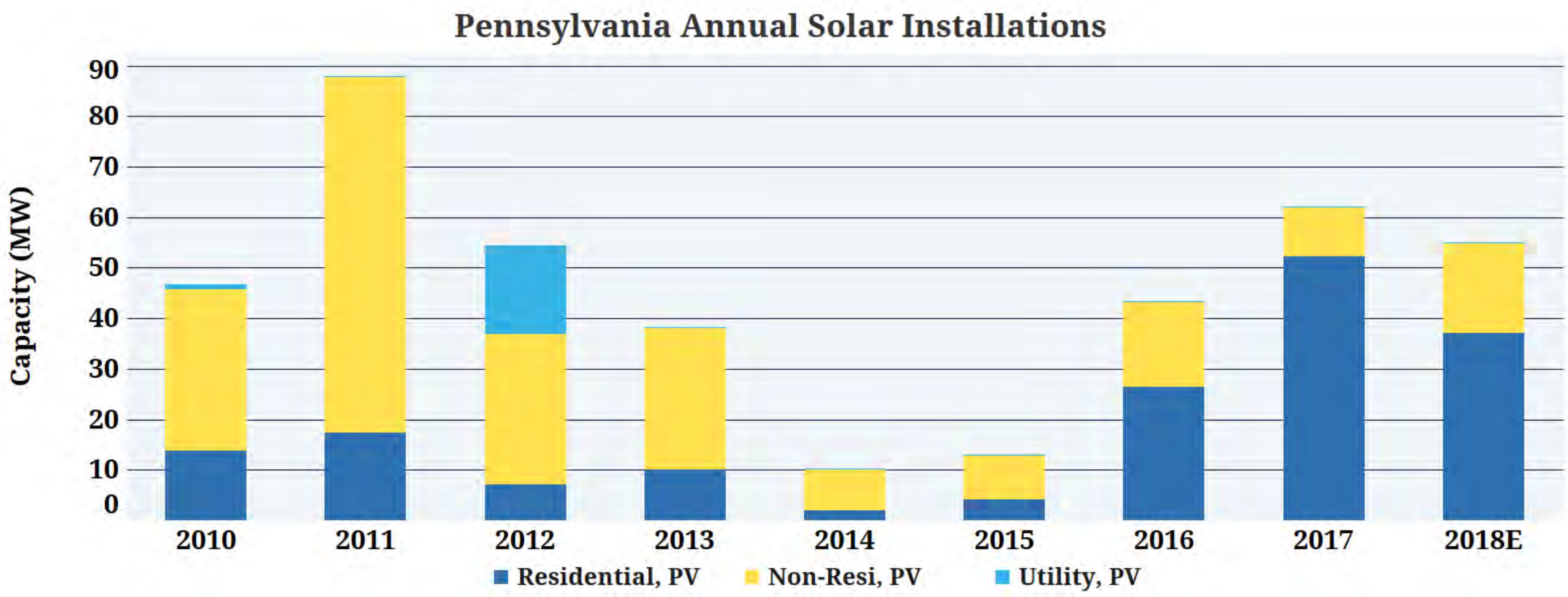
US Solar Market – annual installations



US Residential Solar PV Cost



Pennsylvania Solar Market



Source: SEIA/GTM Research U.S. Solar Market Insight, 2018: http://www.seia.org/state-solar-policy/pennsylvania

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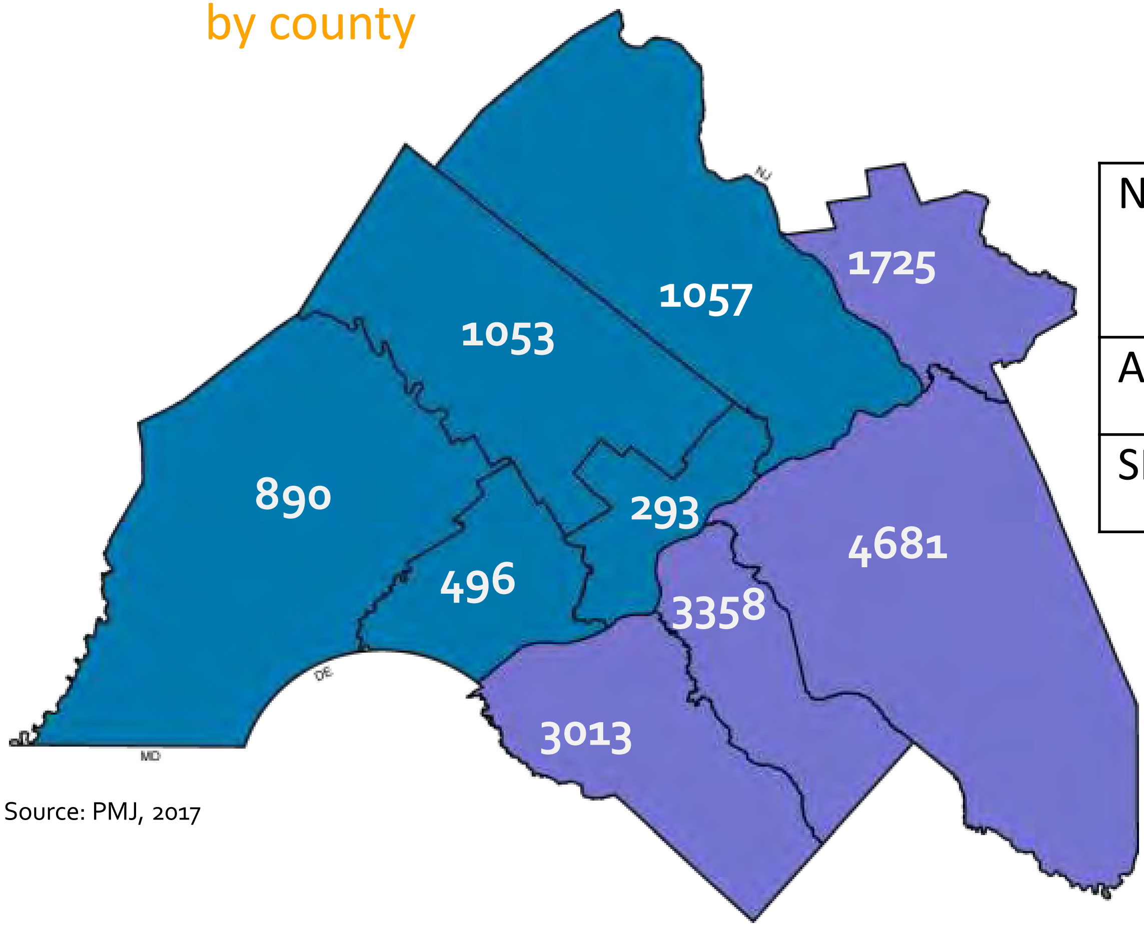
PV Installations in DVRPC Region

Count of solar PV systems installed by county

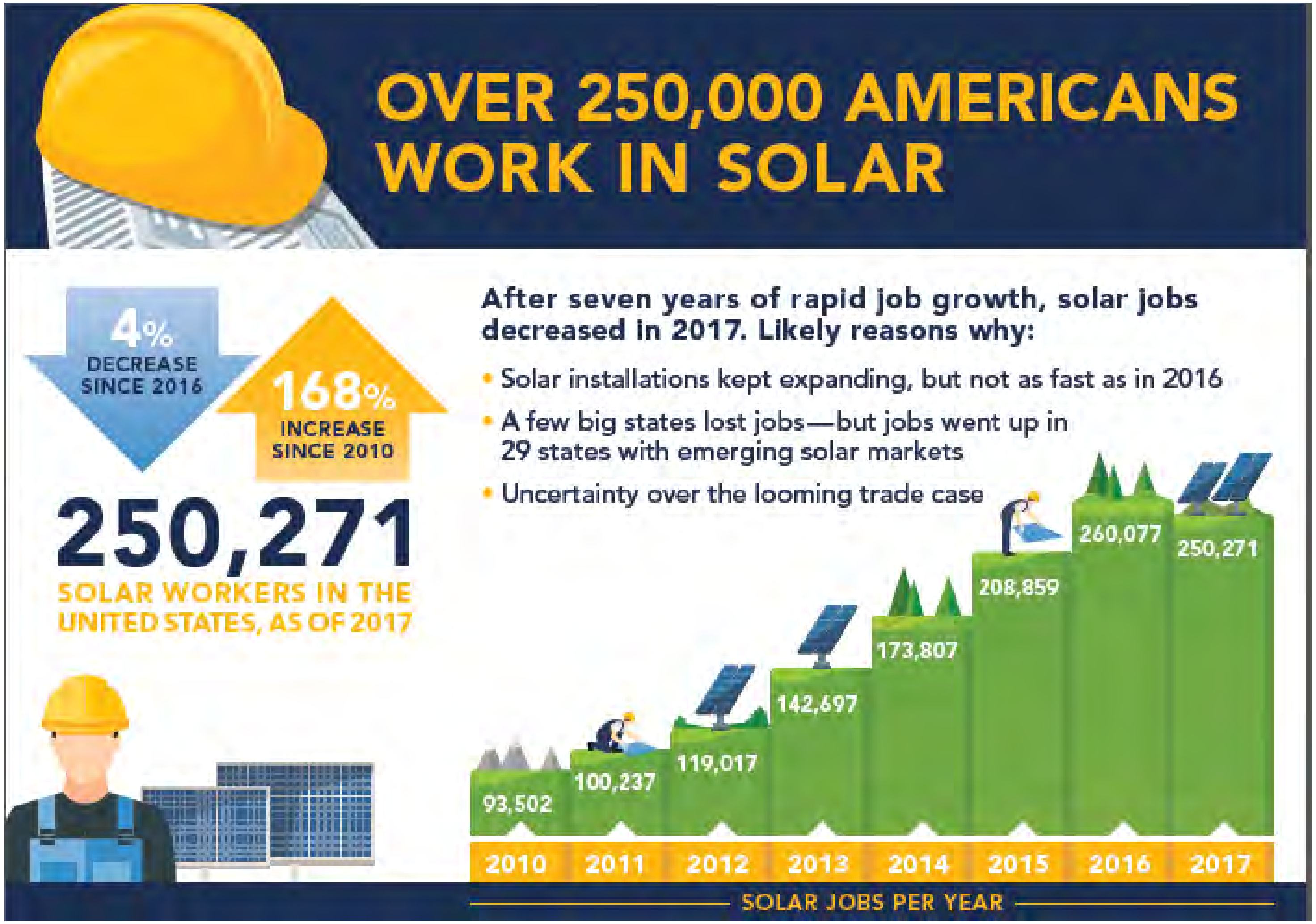


Source: PMJ, 2017

National Rank	PA	NJ
	16th	4th
Av. System Size	7.4 kW	7.8 kW
SREC Price	$3.00	$230.00

Source: SEIA, 2017; PJM, 2017; srectrade.com

Solar Job Growth in the US



Source: The Solar Foundation's National Solar Jobs Census 2017

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Solar Jobs in PA

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In 2017, Pennsylvania had

3,848 persons employed in solar jobs

across

534 different companies

The Solar Foundation – National Solar Jobs Census (2018)

Quick Facts on Pennsylvania Solar Market

39 in solar jobs per capita 2017

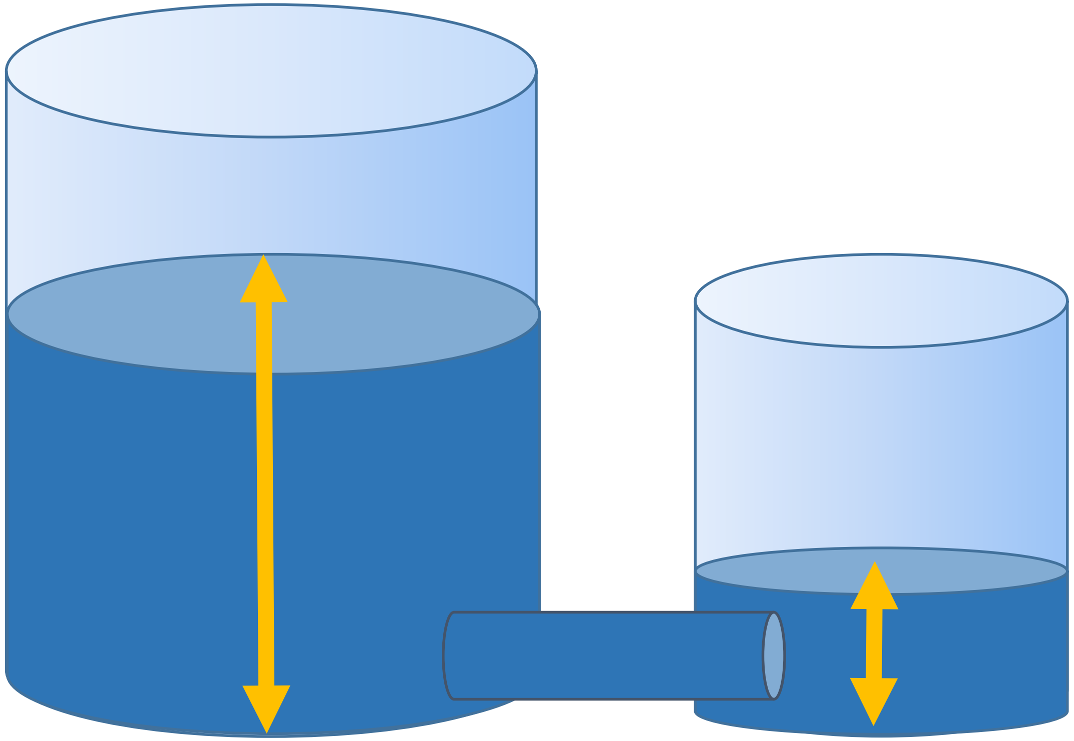
19 in solar jobs across US

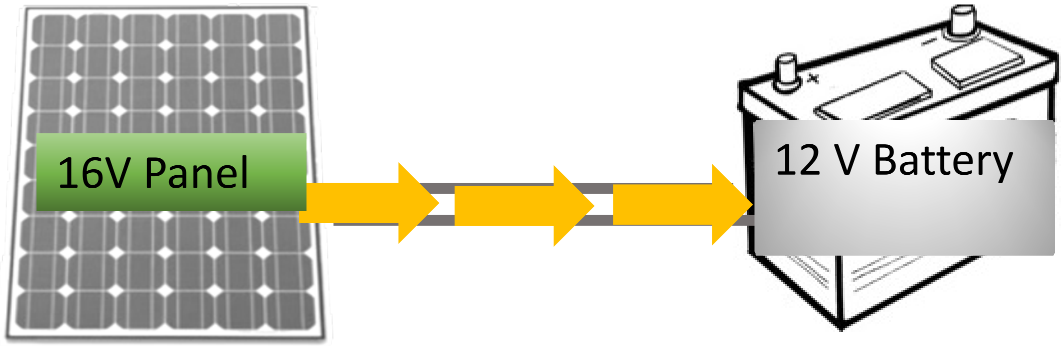
#22 cumulative installed solar capacity

Source: SEIA; The Solar Foundation;

Voltage

Water Analogy	Electrical Concept
Potential difference → Pressure	Potential difference → Voltage





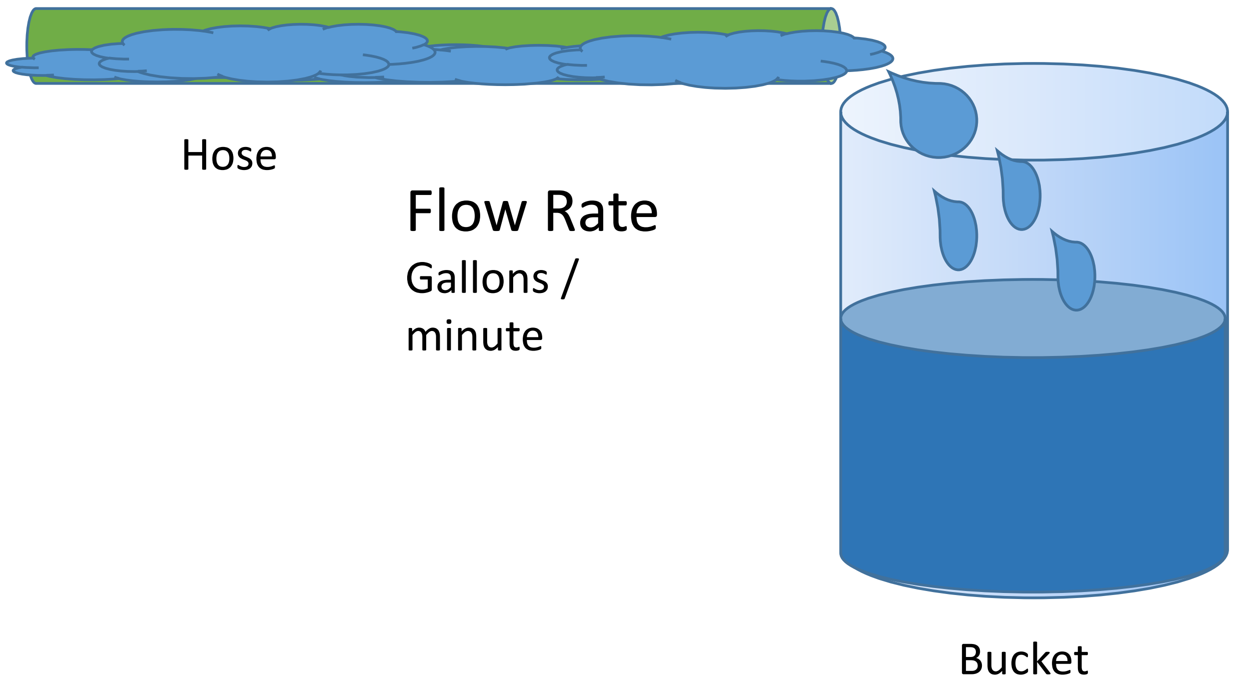
12 V Battery

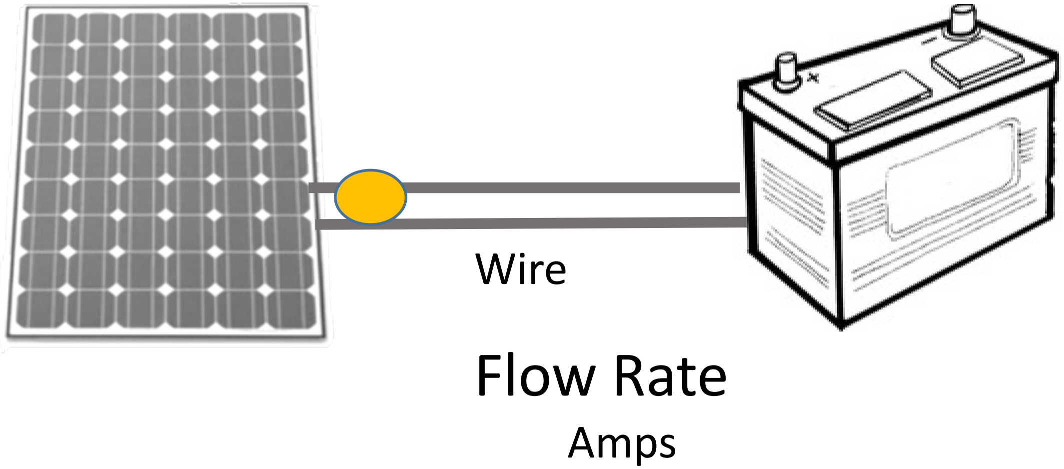
Graphics: Egan Waggoner

Concept source: Solar Energy International

Current or Amperage

Water Analogy	Electrical Concept
Water flow rate → gallons per minute	Electron flow rate → Amps





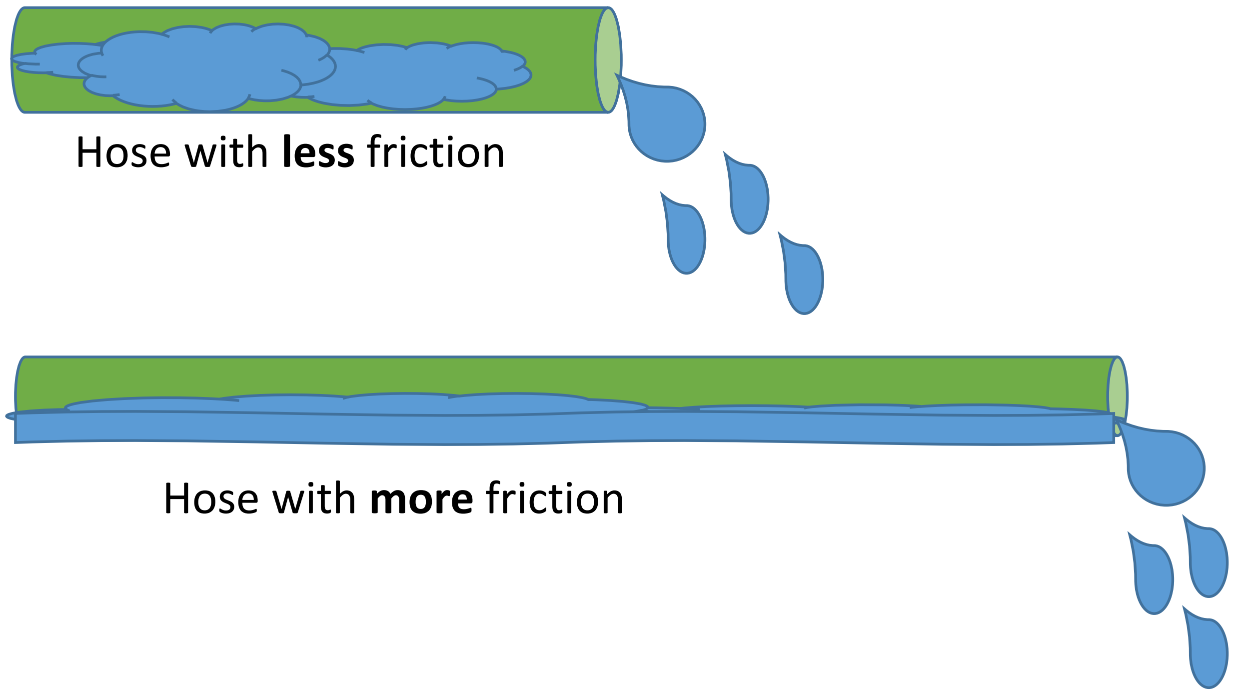
Graphics: Egan Waggoner

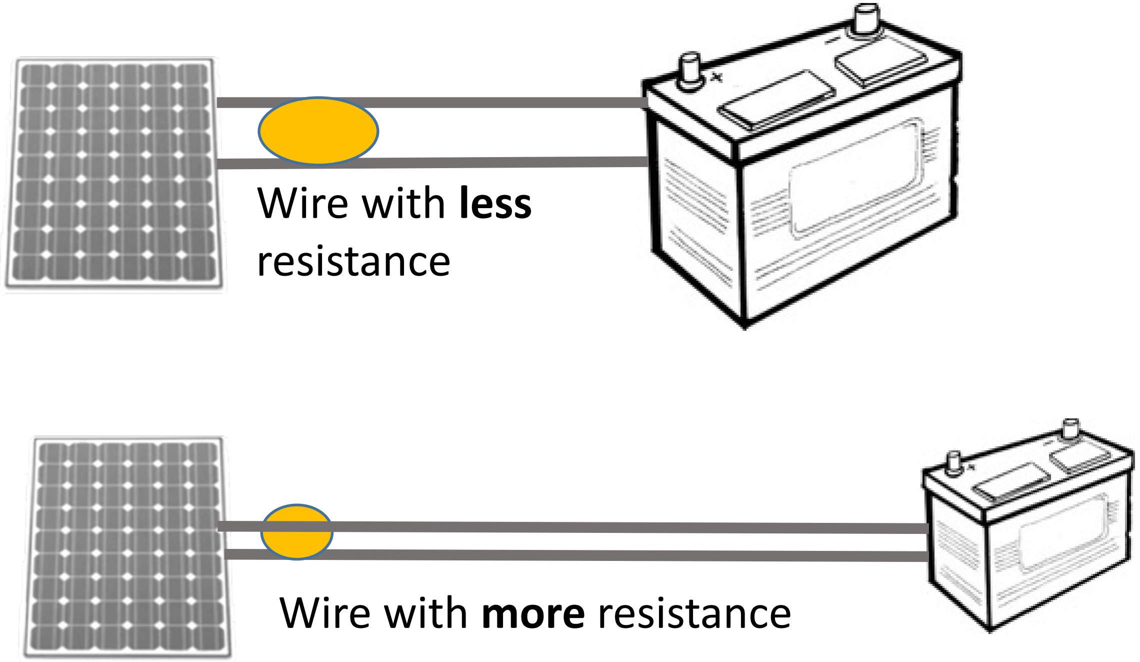
Concept source: Solar Energy International

Resistance

Water Analogy
Opposition to flow → friction in hoseline

Electrical Concept
Opposition to flow → Resistance





Graphics: Egan Waggoner

Concept source: Solar Energy International

Resistance

Water Analogy

PSI = GPM x FL

PSI = Pressure
GPM = Gallons per minute
FL = Friction loss in hoseline
Potential difference → Pressure

Energy Concept

V = I x R

V= Voltage
I = Current (Amps)
R =Resistance (Ohms)
Potential difference → Pressure

What is PV?

Photo = Light Voltage = Electricity

The “Photovoltaic effect” is the creation of voltage or electrical current in a material upon exposure to light

Photovoltaic Systems as defined by the National Electrical Code:
The total components and subsystems that, in combination, convert solar energy into electric energy suitable for connection to a utilization load [NEC 2014, 100]

NEC 690.4 General Requirement (A)
Photovoltaic systems shall be permitted to supply a building or other structure in addition to any other electrical supply system(s) [NEC 2014, 690.2].

NEC 2014, 100 & 690..2

How Do Solar PV Systems Work?

- Solar photovoltaics convert sunlight into electricity
- Amount of electricity directly dependent upon amount of sunlight striking the module

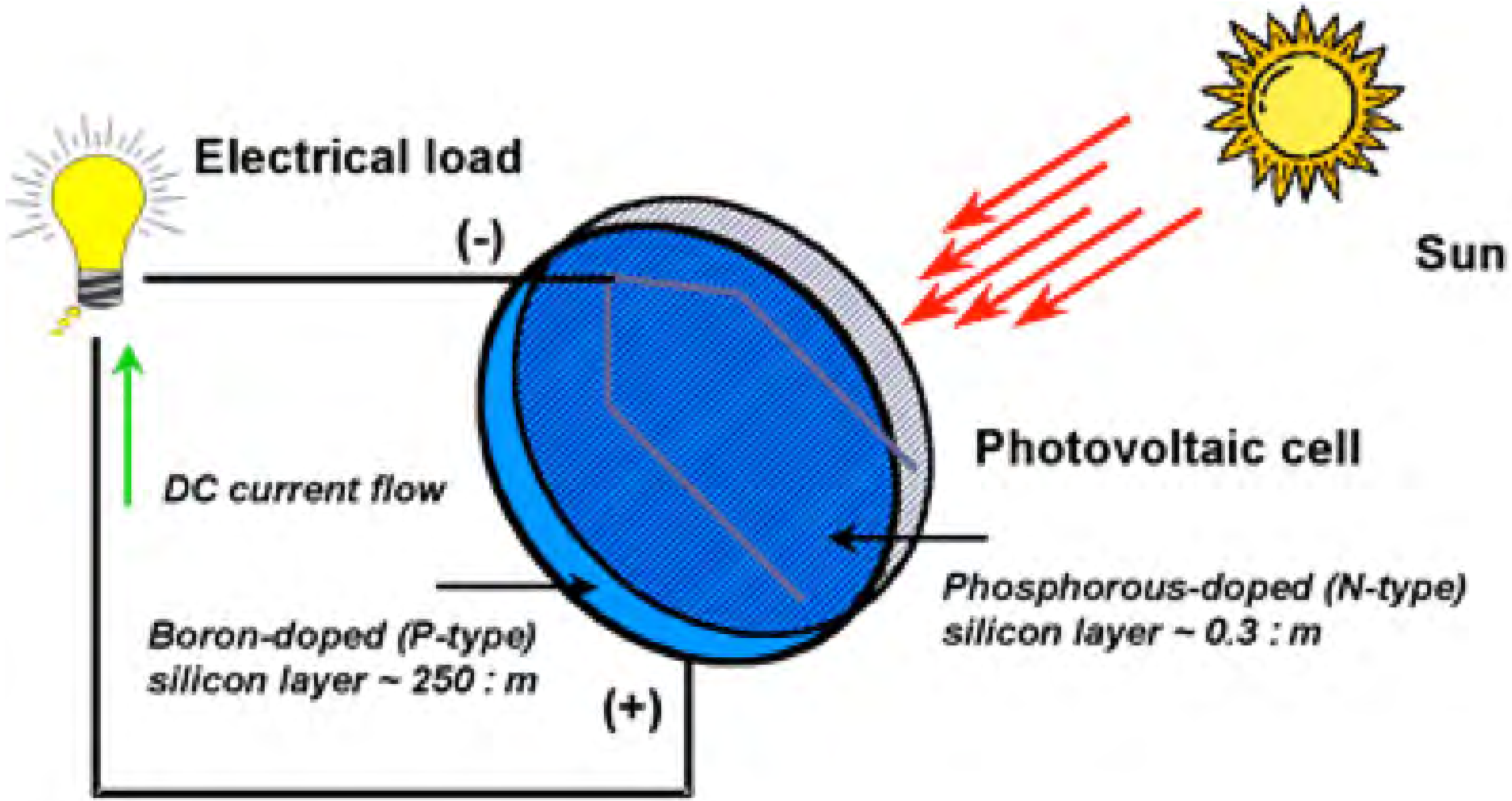
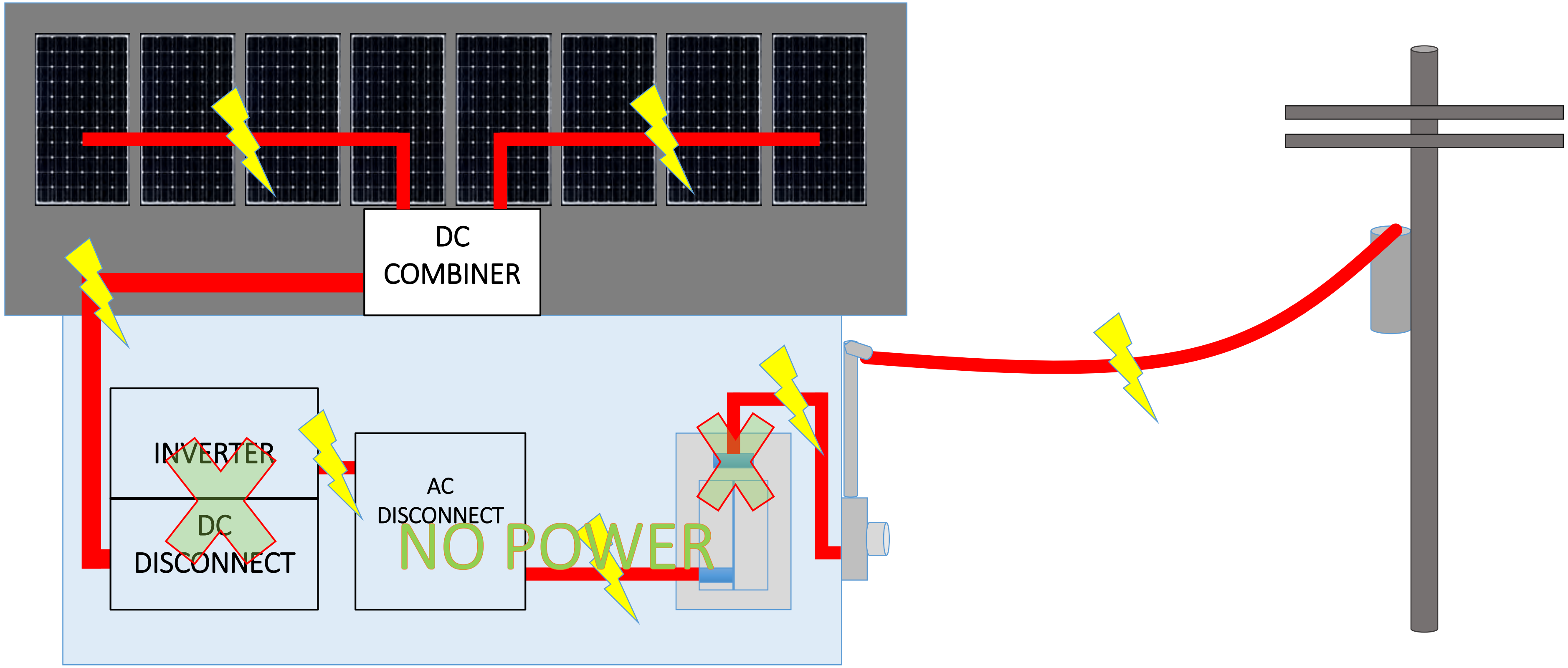


Image from MIT power supply presentation

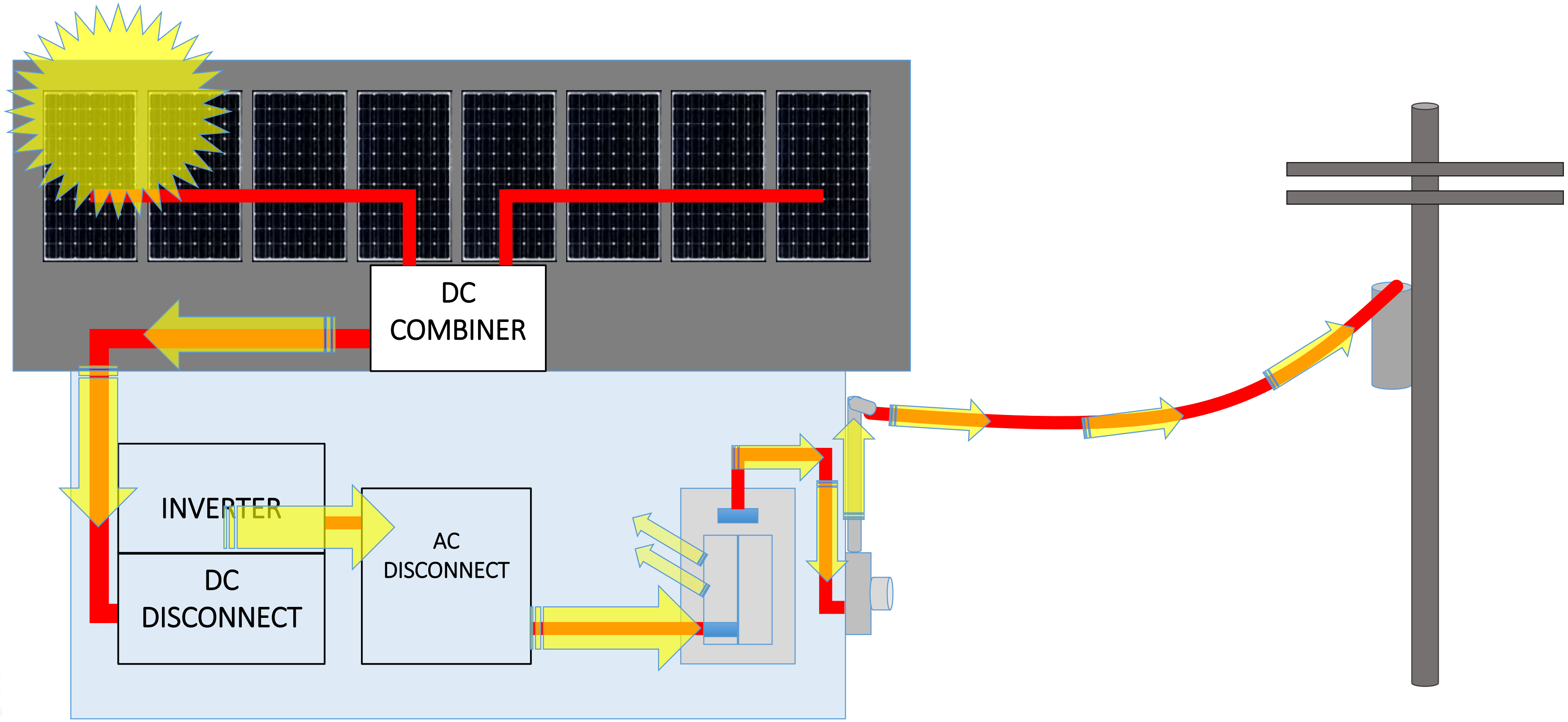
PV System Operation

- Inverter monitors grid voltage/power quality
  - UL 1741 requires inverter to shut off within fraction of a second if power goes out of range, or completely off
  - Inverter will remain off until it detects 5 minutes of continuous power
  - Most PV systems today **do not contain batteries or energy storage**



PV System Operation

- During production times, power goes to grid if not completely used behind the meter
  - Typically there is no onsite energy storage (today)



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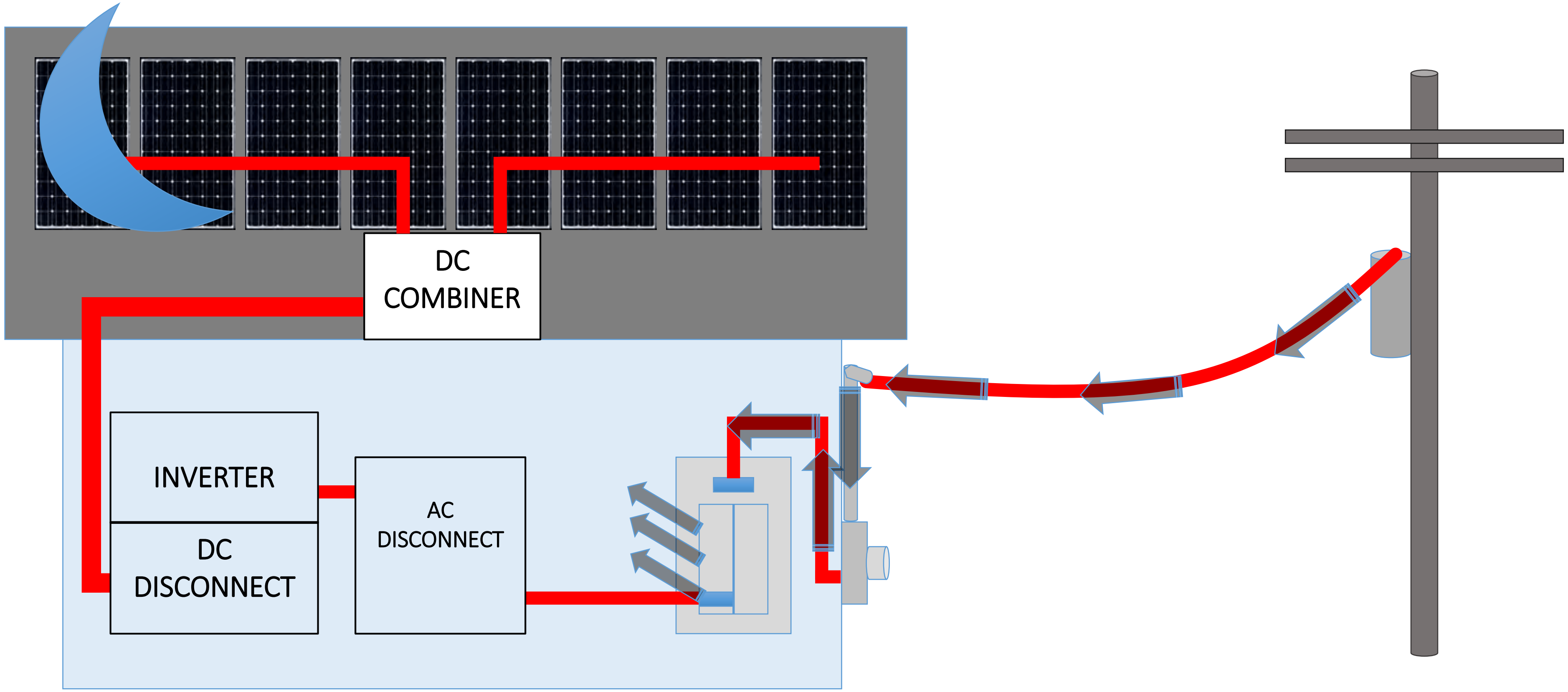
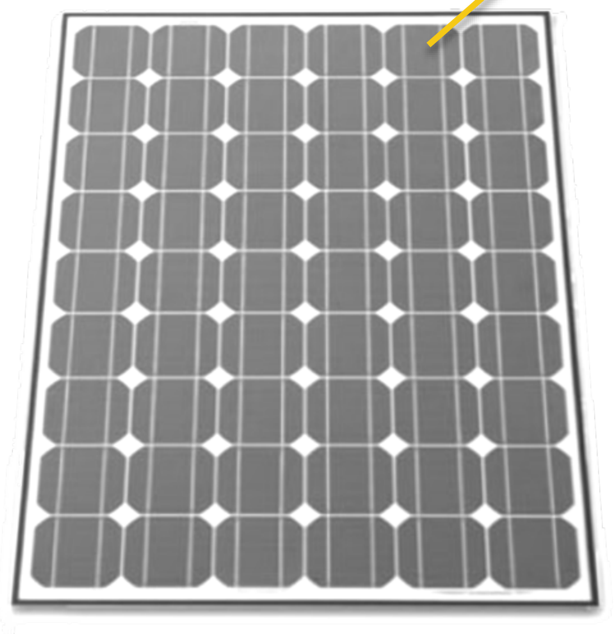
PV System Basics

- At night, electricity is supplied by grid



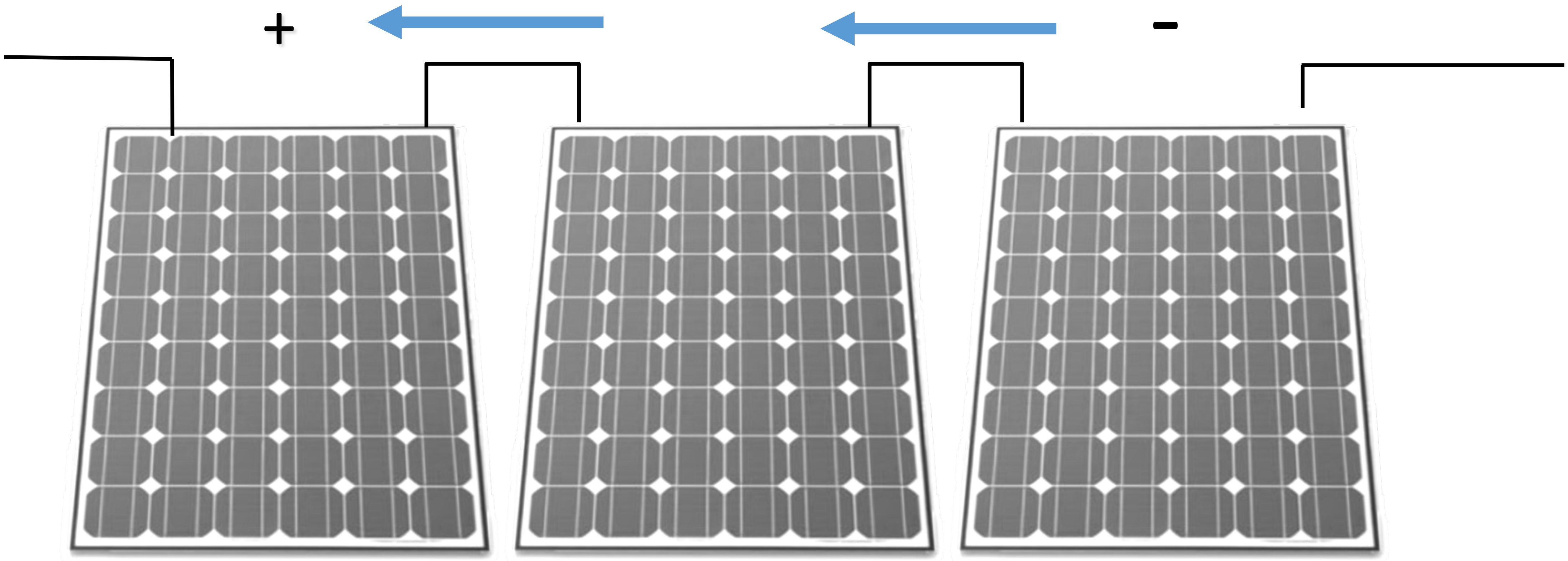
Some Basic Terminology

Cell



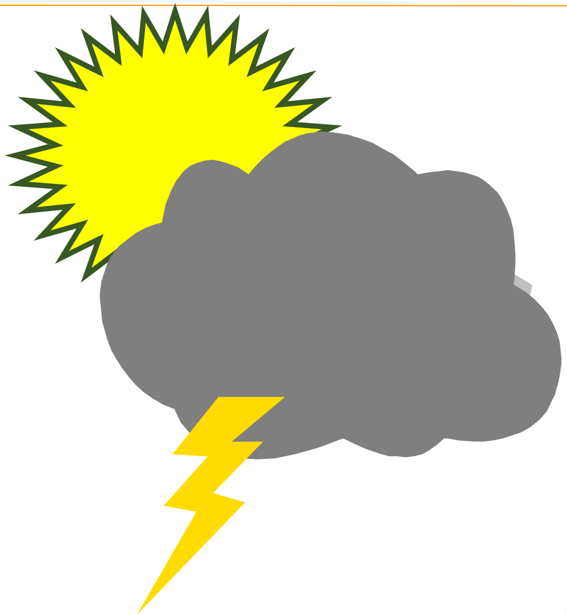
Panel / Module

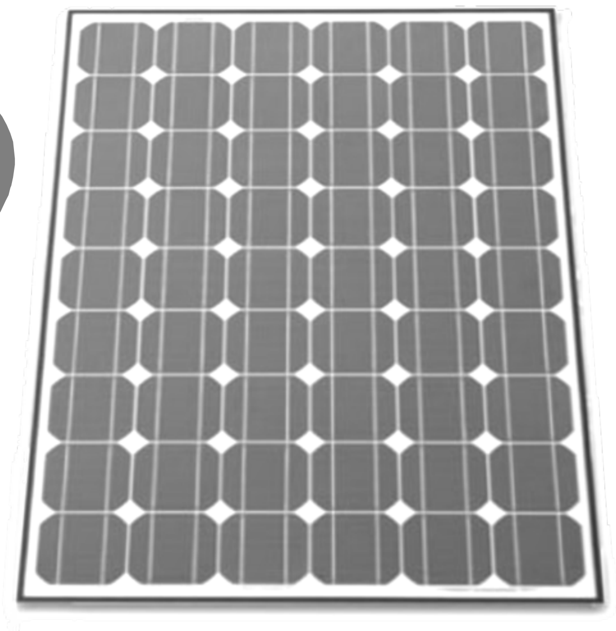
Some Basic Terminology



Array

Some Basic Terminology





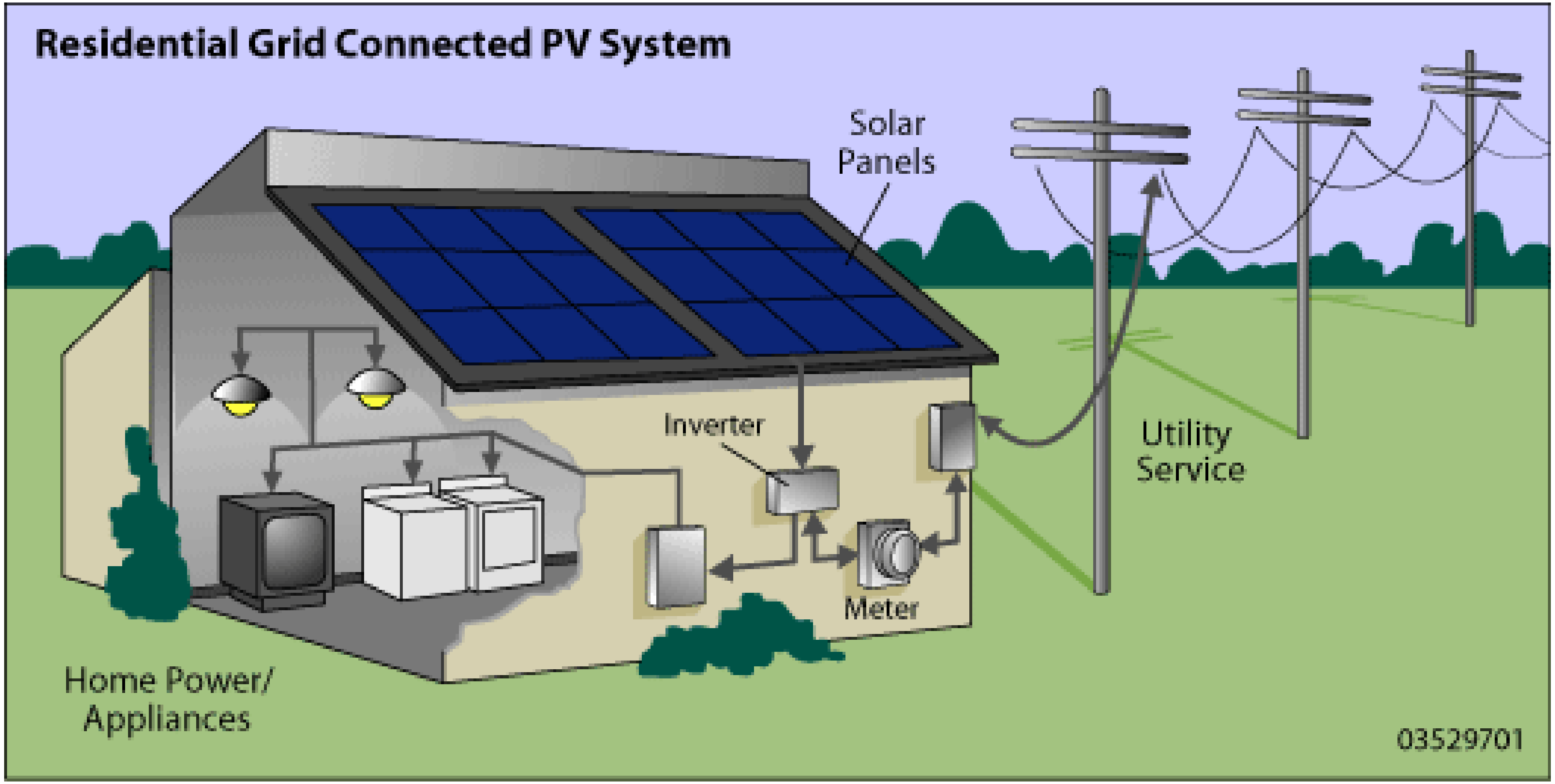
Production

Kilowatt-hour (kWh)

Capacity / Power

kilowatt (kW)

System Components



Scale of Solar PV Systems

Residence
5-10 kW

Factory
1 MW+

Office
50 – 500 kW

Utility
2 MW+

Modules

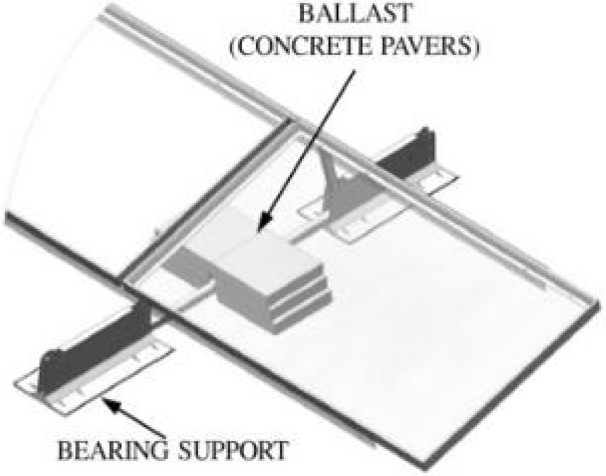
Typical pitched-roof mounting

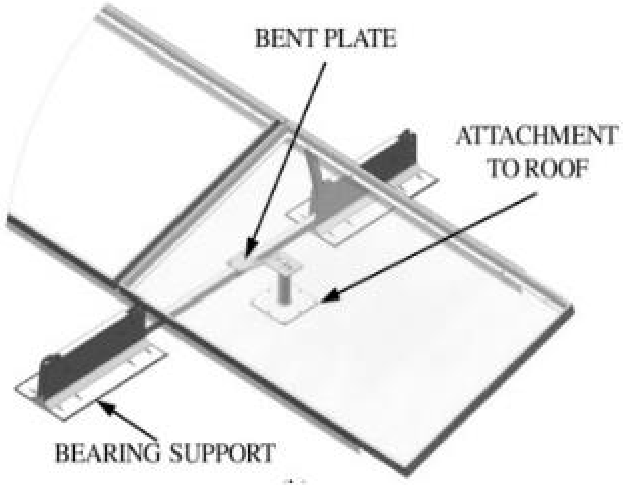
Panels are secured using an aluminum racking system

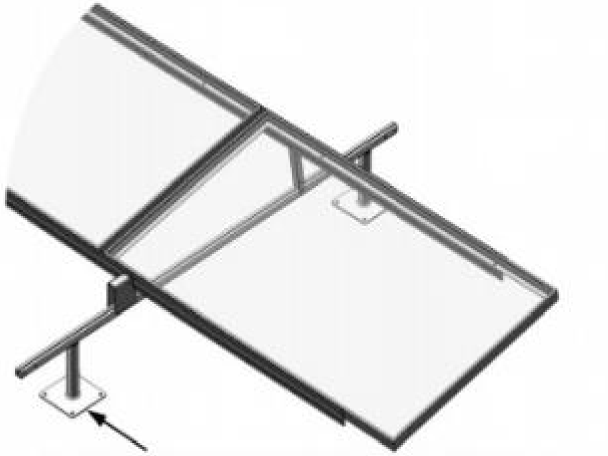
Racking is secured to roof with lag screws drilled into structural rafters

Mounting is designed to withstand wind loads for installation area requirements – making them very difficult to remove

Typical flat-roof mounting







Solar PV System Types

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Roof Mount

Ground Mount

Parking Canopy

Solar PV System Types

Roof Mount Commercial

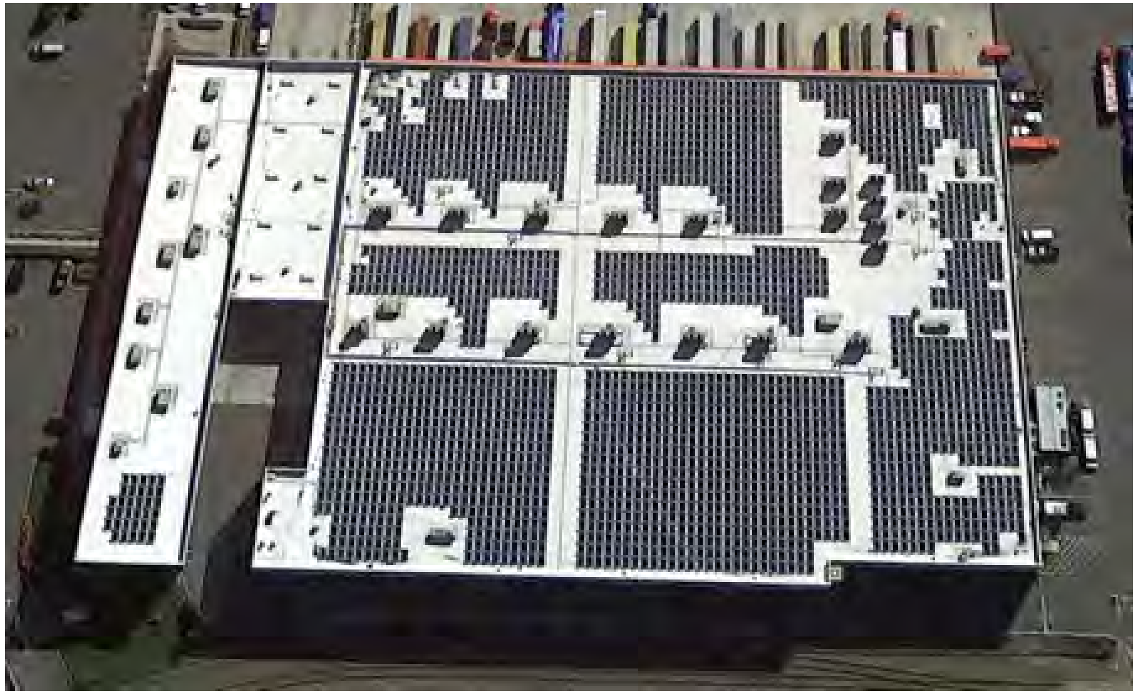
Shingles

Ground Mount

Residential Rooftops

Source: Atomic Solar (North Carolina); Egan Waggoner (Lincoln, MA)

Commercial Rooftops



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Commercial Rooftops

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Commercial Rooftops

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Shading Structures or Canopies

Ground Mount Systems

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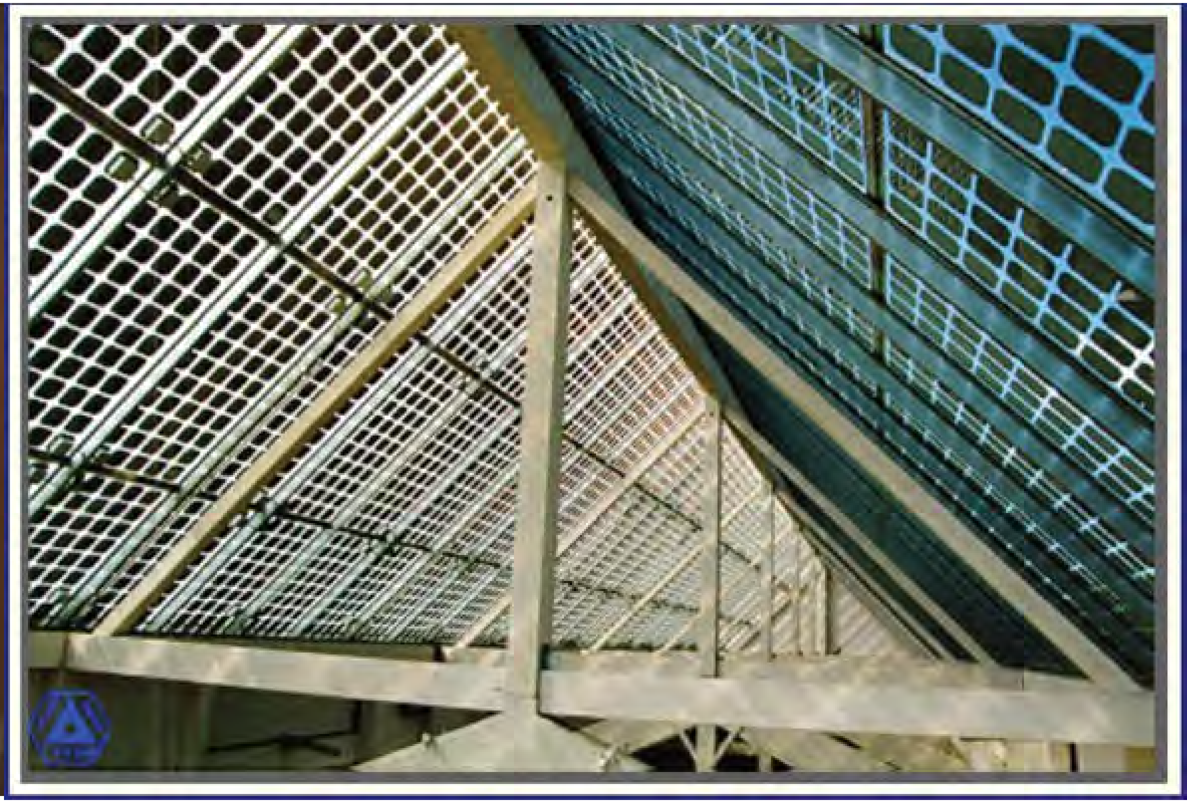
Rooftop Canopies

Pole Top Mounts

Solar Skylights



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Solar Shingles

Image from PV Magazine

No guarantee you're walking on an asphalt shingle roof

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Solar Shingles

Solar Shingles

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Solar Shingles

Combinations of different systems

Solar PV and
Thermal Systems

Solar Thermal System

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Typically 2-6 panels

Insulated piping coming from panels (as opposed to wiring) – typically copper

Solar thermal systems do not pose the same risk as solar photovoltaic systems.
They typically contain a loop of water/glycol in the rooftop collectors, however there may be a scalding hazard.

Solar Thermal System

Thermal piping can be wrapped with insulation

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Solar Thermal System

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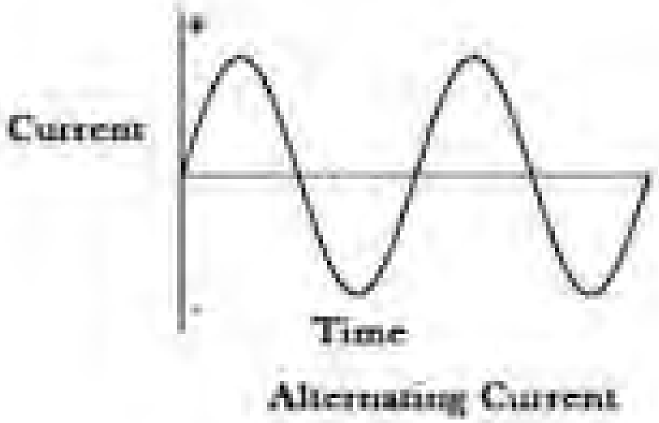
Building Integrated

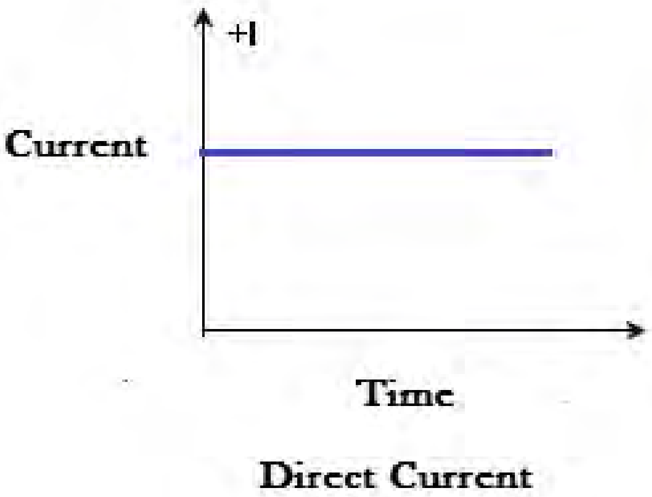
Types of Electrical Current

Alternating Current



- Utility Power
- Generators

Direct Current



- PV Cells
- Batteries

Images courtesy of Durofy

Pop quiz

1. Name three different types of solar technology
2. What's the difference between AC and DC Current?
3. Name three locations where solar PV systems can be installed?
4. Do solar PV systems produce AC or DC electricity?

Today's Agenda

- Introduction to solar technology [60 min]
- Identifying solar PV systems [45 min]
- Break [10min]
- Solar PV hazards and safety [45 min]
- Identifying and disabling solar PV systems [45 min]

» **Identifying solar PV systems**

- › System Components
- › Understanding Schematic Drawings
  - › Micro and string inverters
  - › Battery back up
- › Design documentation

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System Components: Modules

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch

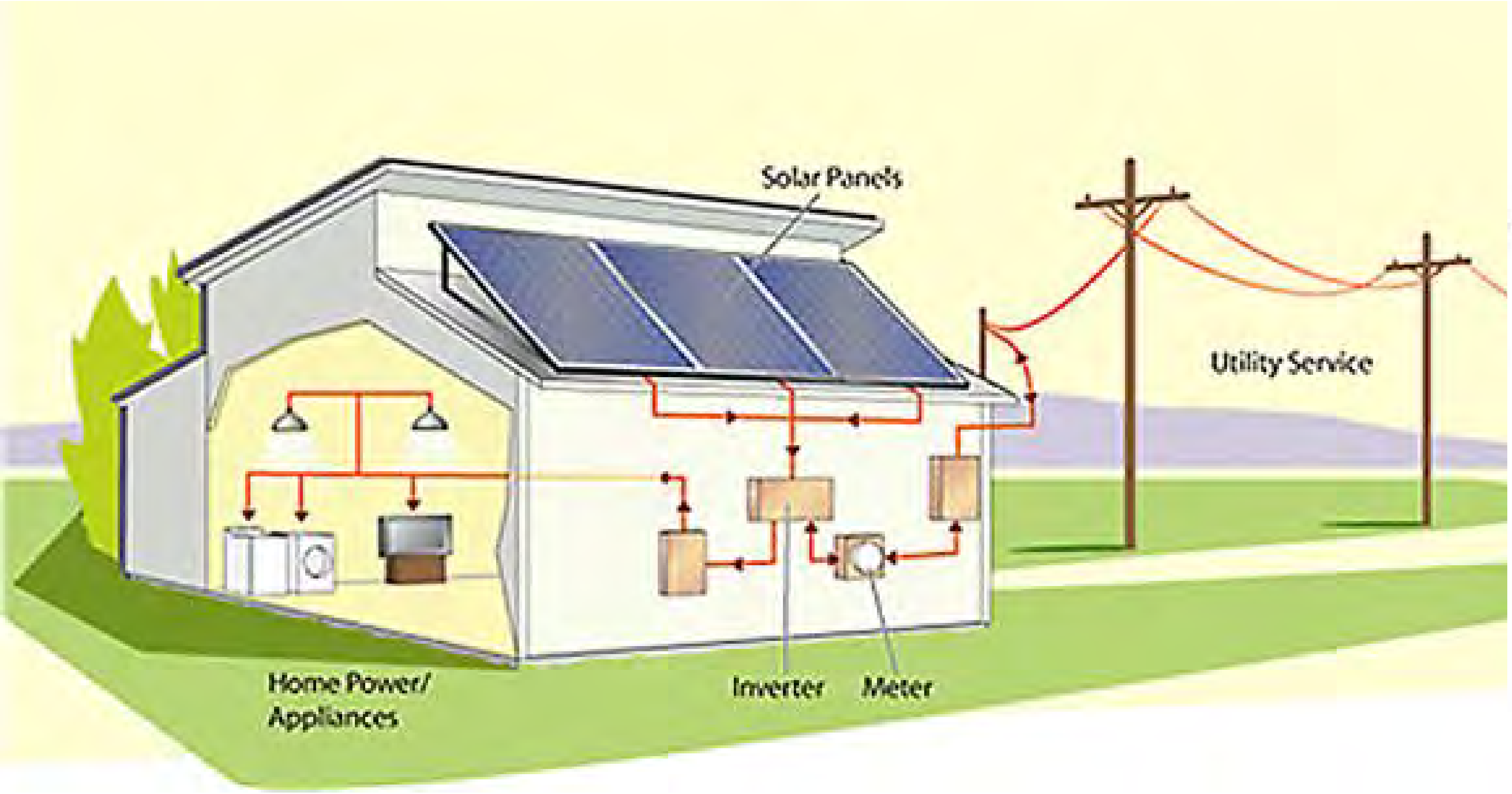
4 Inverter

5 AC Disconnect Switch

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

Solar Electric System Components



System Components: Modules

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1

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System Components: Modules

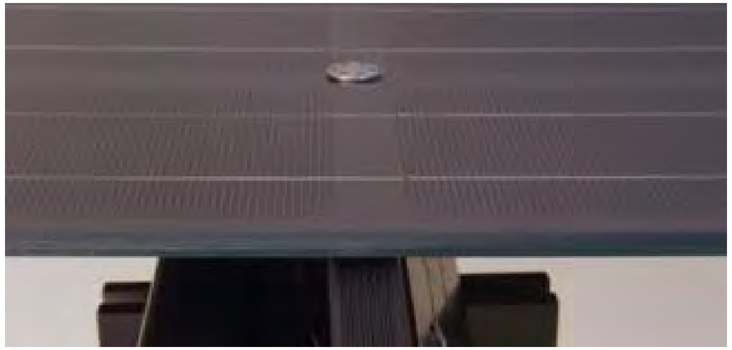
1 Poly

Mono

Thin film

Solar Laminate

Frameless



System Components: Modules

1

Module Specifications Sheet:

- Performance
- System Integration
- Component Materials
- Thermal Characteristics
- Warranties


Sunmodule Plus
SW 285 - 290 MONO BLACK


Sunmodule Plus
SW 285 - 290 MONO BLACK
SOLARWORLD
REAL VALUE
Data sheet

QUALITY BY SOLARWORLD

SolarWorld's foundation is built on more than 40 years of ongoing innovation, continuous optimization and technology expertise. All production steps from silicon to module are established at our production sites ensuring the highest possible quality for our customers. Our modules come in a variety of different sizes and power, making them suitable for all global applications – from residential solar systems to large-scale power plants.

- Elegant aesthetic design–entirely black solar module, from the cells and frame to the module corners
- Extremely tough and stable, despite its light weight – able to handle loads up to 178 psf (8.5 kN/m²)
- Tested in extreme weather conditions – hail impact tested and resistant to salt spray, frost, ammonia, dust and sand
- Proven guarantee against hotspots and PID-free to IEC 62804-1
- SolarWorld Efficells™ for the highest possible energy yields
- Patented corner design with integrated drainage for optimized self-cleaning
- High-transmissive glass with anti-reflective coating
- Long-term safety and guaranteed top performance – 25-year linear performance warranty, 20-year product warranty

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System Components: Modules

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1

DC Electricity

		SW 285
Maximum power	P_{max}	285 Wp
Open circuit voltage	V_{oc}	39.2 V
Maximum power point voltage	V_{mpp}	32.0 V
Short circuit current	I_{sc}	9.52 A
Maximum power point current	I_{mpp}	9.00 A
Module efficiency	η_m	17.0 %

Measuring tolerance (P_{max}) traceable to TUV Rheinland: +/- 2% (TUV Power controlled, ID 000039351)

Measuring tolerance (P_{max}) traceable to TUV Rheinland: +/- 2% (TUV Power controlled, ID 000039351)

DIMENSIONS / WEIGHT

Length	65.95 in (1675 mm)
Width	39.40 in (1001 mm)
Height	1.30 in (33 mm)
Weight	39.7 lb (18.0 kg)

CERTIFICATES AND WARRANTIES

Certificates	IEC 61730	IEC 61215	UL 1703
	IEC 62716	IEC 60068-2-68	IEC 61701
Warranties	Product Warranty		20 years
	Linear Performance Guarantee		25 years

Module Specifications Example

Specifications unique to make/model

Current-limiting power source

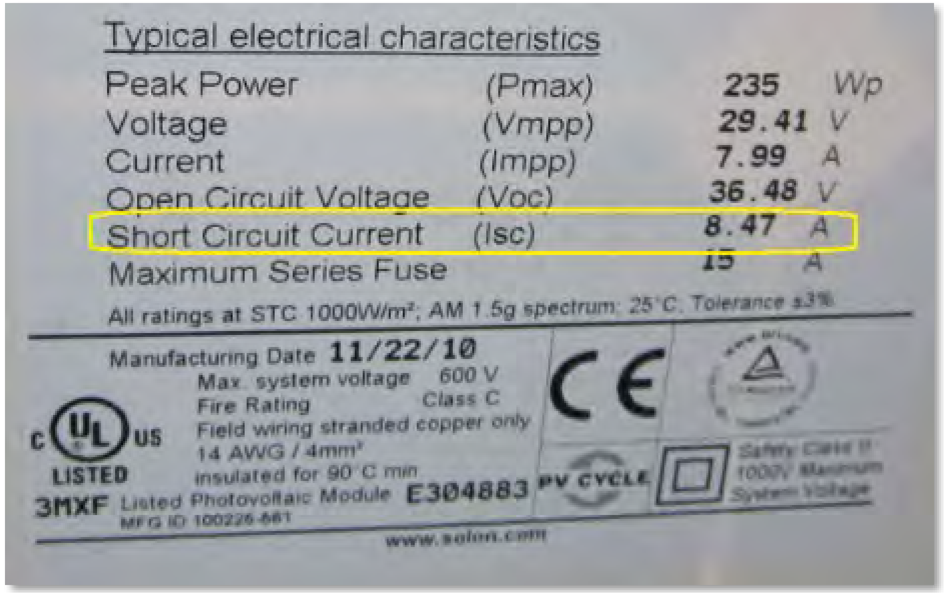
- Will <u>never</u> produce more current than their short-circuit current (Isc) rating

Strung together in series to produce greater voltage

- Similar to a DC battery

Power depends on ***sun exposure*** and ***temperature***

<u>Lower</u> temperature, <u>higher</u> voltage



Nameplate rating on a typical PV module.

System Components: Combiner Boxes

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch

4 Inverter

5 AC Disconnect Switch

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

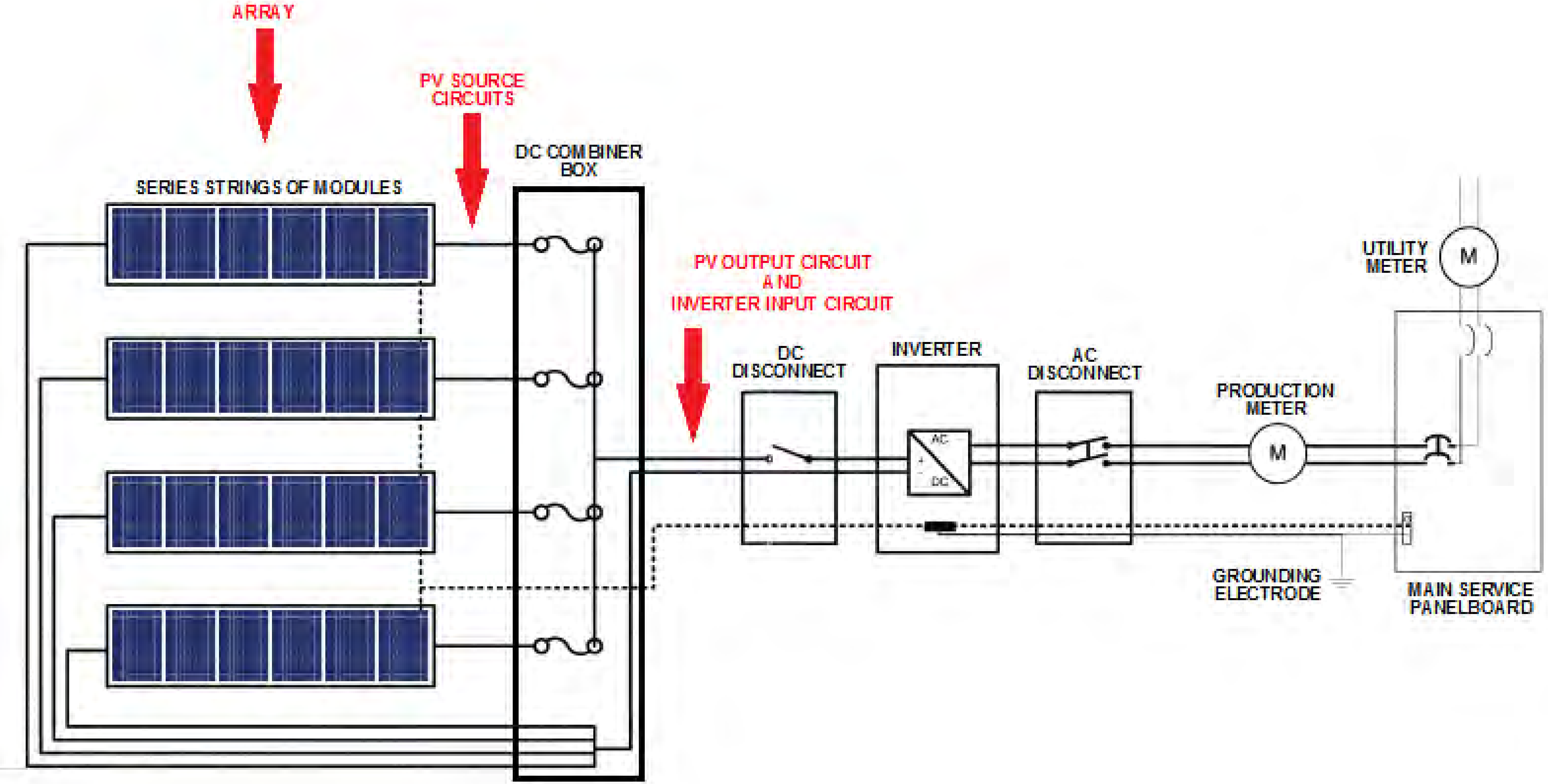
String Combiners

2

Left: Typical Residential Combiner, Right: Typical Commercial Combiner

System Components: Combiner Boxes

2



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System Components: DC Disconnect Switches

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch

4 Inverter

5 AC Disconnect Switch

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

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System Components: DC Disconnect Switches

3

Large Commercial or Industrial Systems have DC Disconnect Switches located on the roof top or on the side of building at ground level.

Disconnects

Disconnect switches can be integral to inverters or located remotely.

System Components: DC Disconnect Switches

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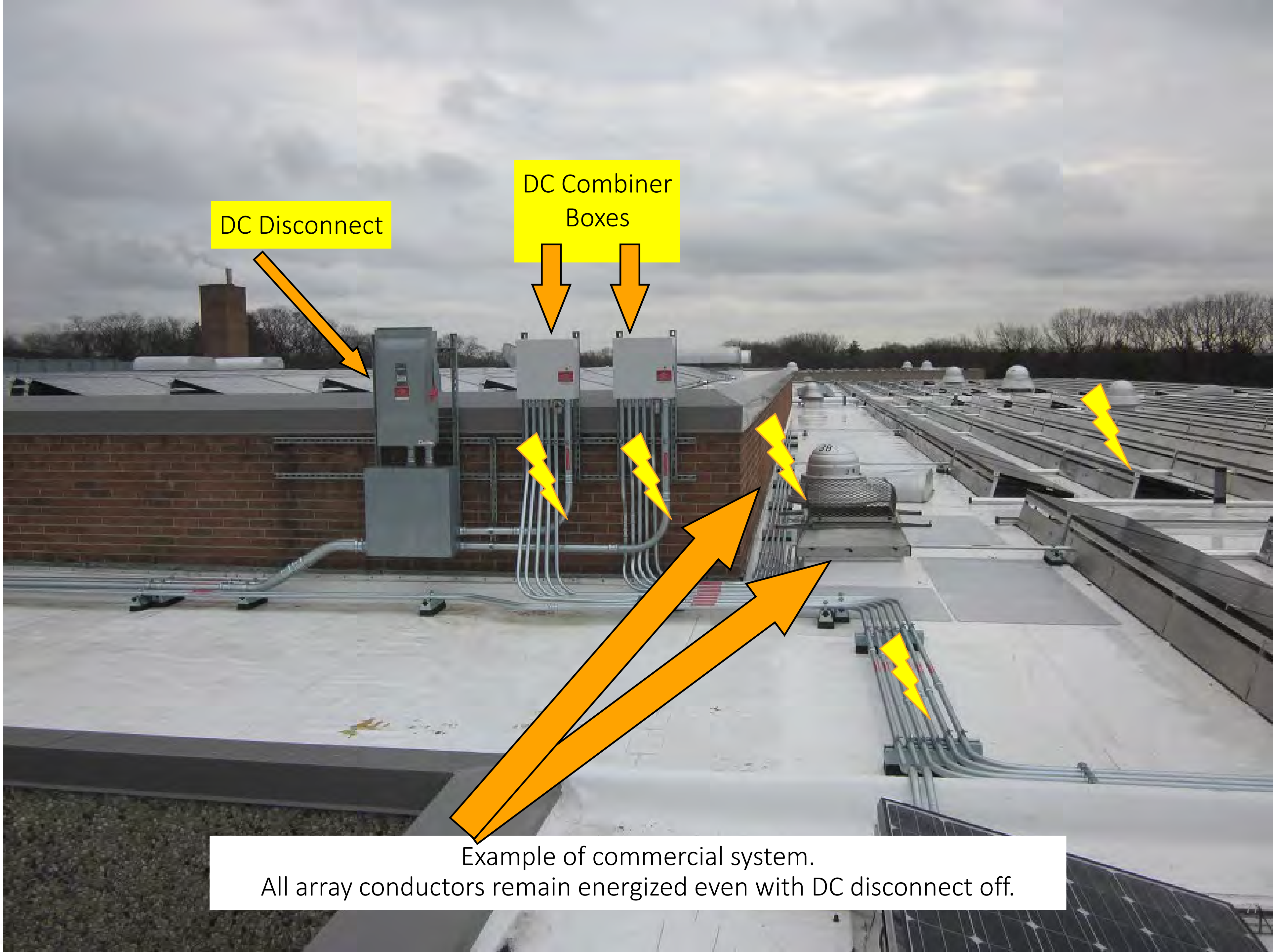
Five pieces of information:

Voltage
- *Vmax* or *Voc* (maximum system voltage)
- *Vmp* (maximum power point voltage)

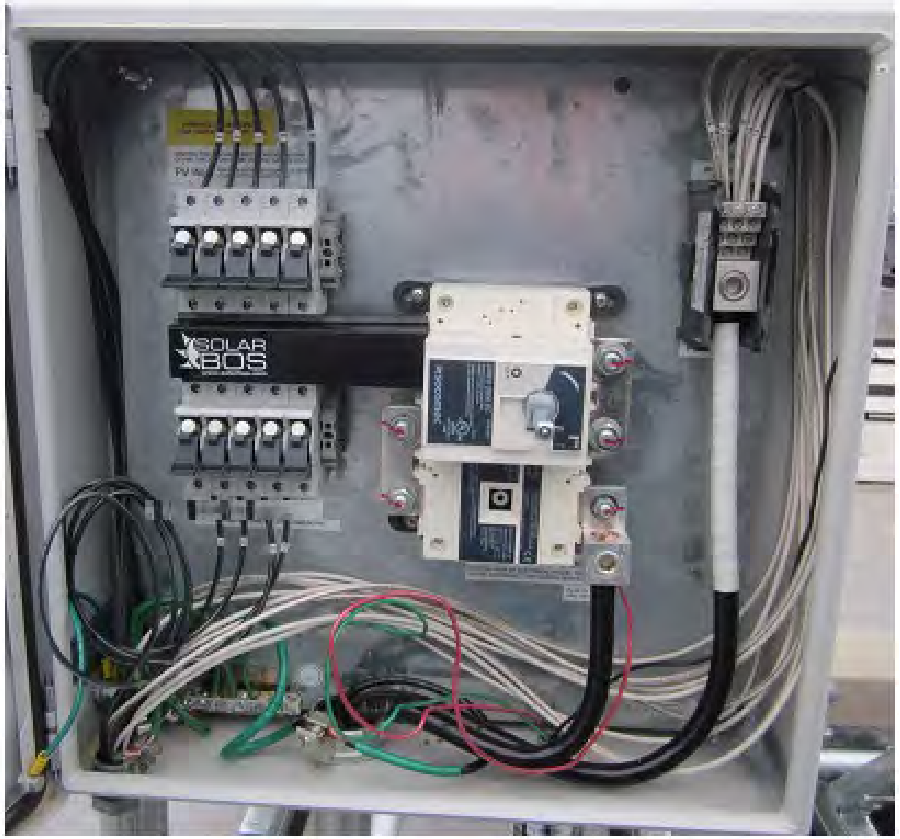
Current
- *Isc* (short circuit current)
- *Imp* (maximum power point current)

Current
- Presence of *charge controller*



Example of commercial system.
All array conductors remain energized even with DC disconnect off.

Combiner Box with DC Disconnect



System Components: DC Disconnect Switches

3

Large Commercial or Industrial Systems typically have DC Disconnect Switches located on the roof top or on the side of building at ground level.

Example of commercial system.
DC combiner contains disconnect, array will remain energized.

System Components: Inverter

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1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch

4 Inverter

5 AC Disconnect Switch

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

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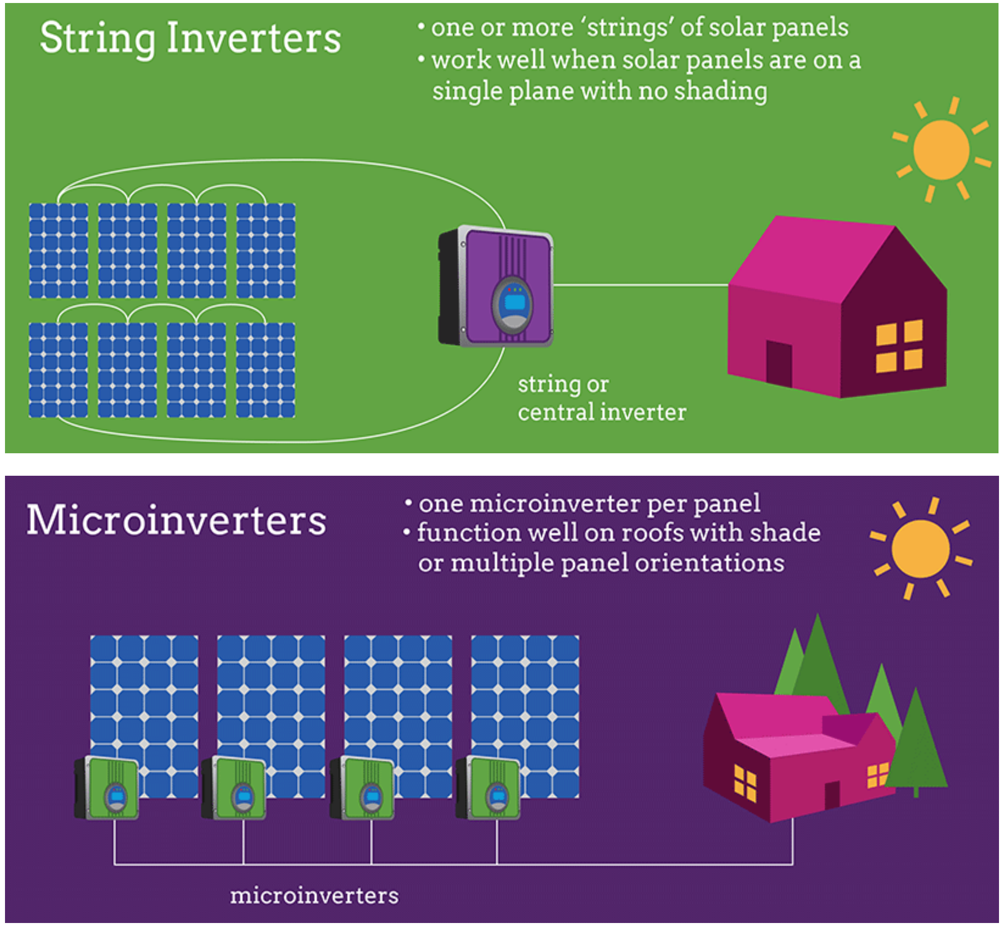
System Components: Inverters

4



- Inverters (non-battery) convert DC power from the PV modules to AC power to match the building/grid electrical system
- Disconnecting the AC utility power sources turns off the inverter, but DOES NOT disable the DC solar module circuit.
- 3 types of inverters:

  Central Inverter

  String Inverter

  Microinverters
- <u>All types stop converting power when utility power shuts down</u>

Central Inverter System

4

- Larger inverters
- Typically located remotely from array
- Most-common for large-scale ground-mount or commercial rooftop systems

4

String Inverter System

4

- Mid-sized inverters
- Typically located adjacent to array on commercial rooftop systems
- Most-common type for residential rooftop systems, inverter will typically be located in basement or outside

4

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4

PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN
DC PHOTOVOLTAIC DISCONNECT
AC PHOTOVOLTAIC DISCONNECT
NSTAR UTILITY DISCONNECT
WARNING

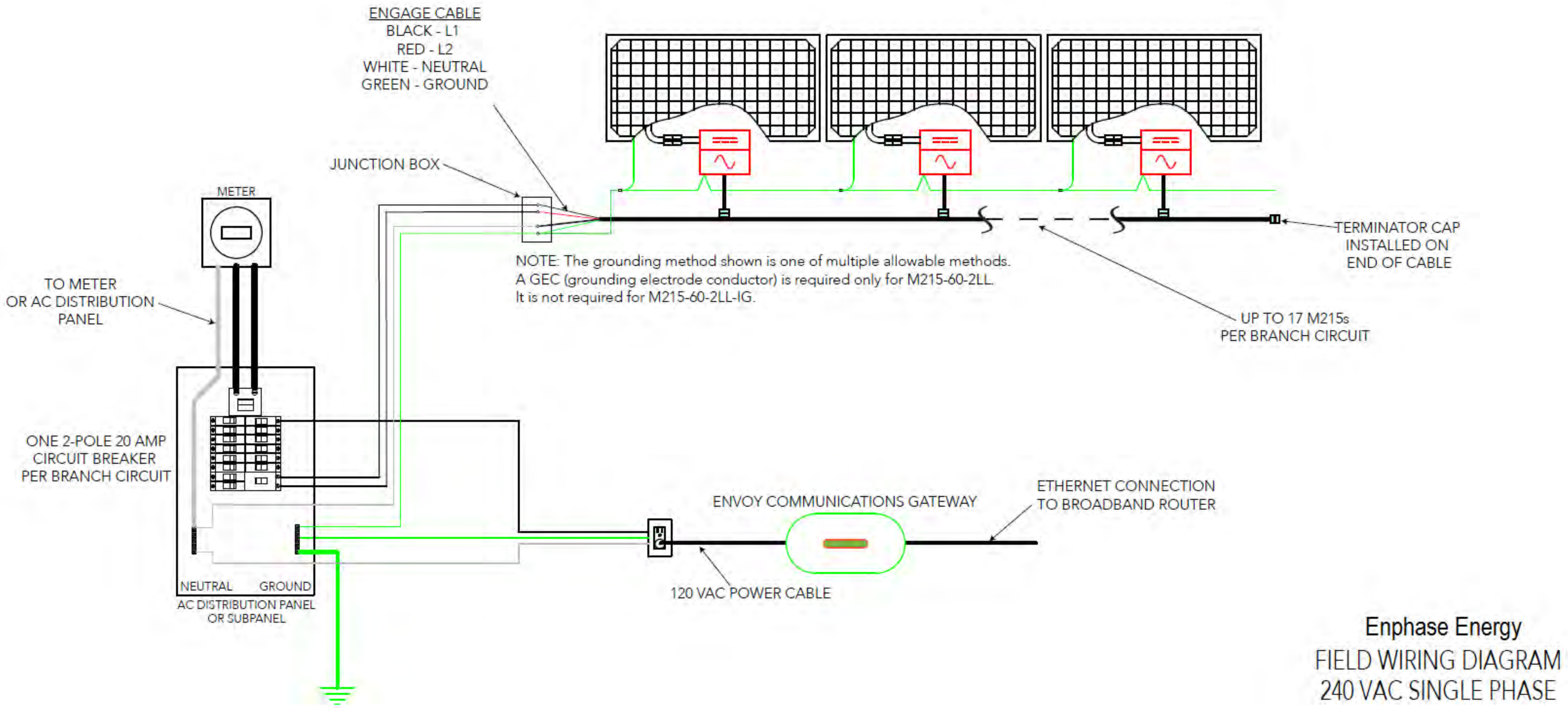
Microinverter System

4

- Mini inverter under each module
- Most-common type for residential rooftop systems
- Typically not found on large commercial systems
- Minimum DC exposure

Utility-Interactive AC (Microinverter) System

4



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4

4

System Components: Battery String of Central Inverters

4

Battery Inverters convert DC power into AC power matching utility voltage and frequency to generate utility quality power. Disconnecting AC utility power turns off the inverter, but does not disable the DC solar circuit.

Images courtesy of the NY-Sun PV Trainers Network

System Components: AC Disconnect

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch

4 Inverter

5 AC Disconnect Switch

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

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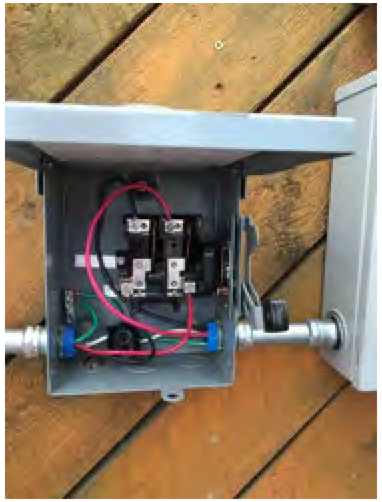
System Components: AC Disconnects

5

AC Disconnects must in or within sight of the inverter and be marked with the following:

- Rated AC output current (Amps)
- Nominal AC voltage (Volts)



Photos courtesy of Chad Laurent and author

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System Components: Utility Interconnection

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch

4 Inverter

5 AC Disconnect Switch

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

System Components: Utility Interconnection

6

Photo courtesy of Chad Laurent

At the location of the ground-fault protection, normally at the inverter, warning of a shock hazard (*NEC* 690.5[C]).

4 Main Service Disconnect

MAIN PV SYSTEM DISCONNECT

Per NEC690.14(2)

CAUTION: SOLAR ELECTRIC SYSTEM CONNECTED

SOLAR DISCONNECT

4 Breaker Panel/ Pull Boxes

WARNING DUAL POWER SOURCE SECOND SOURCE IS PV SYSTEM

CAUTION PHOTOVOLTAIC SYSTEM CIRCUIT IS BACKFED

Per NEC 705.12(D)(4) & NEC 690.64

DO NOT DISCONNECT UNDER LOAD

Per NEC690.33(E)(2)

Conductors at switch or circuit breakers (pull boxes) per NEC 690.4 Main circuit breaker panel and meter per NEC 690.17, Dual power source NEC 705.12(D)(4) and Back-Fed Breakers per NEC705.22 and NEC690.64.

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System Components: Understanding Schematic Drawings

SOLSMART

1 Modules

2 Combiner Boxes/Overcurrent Protection

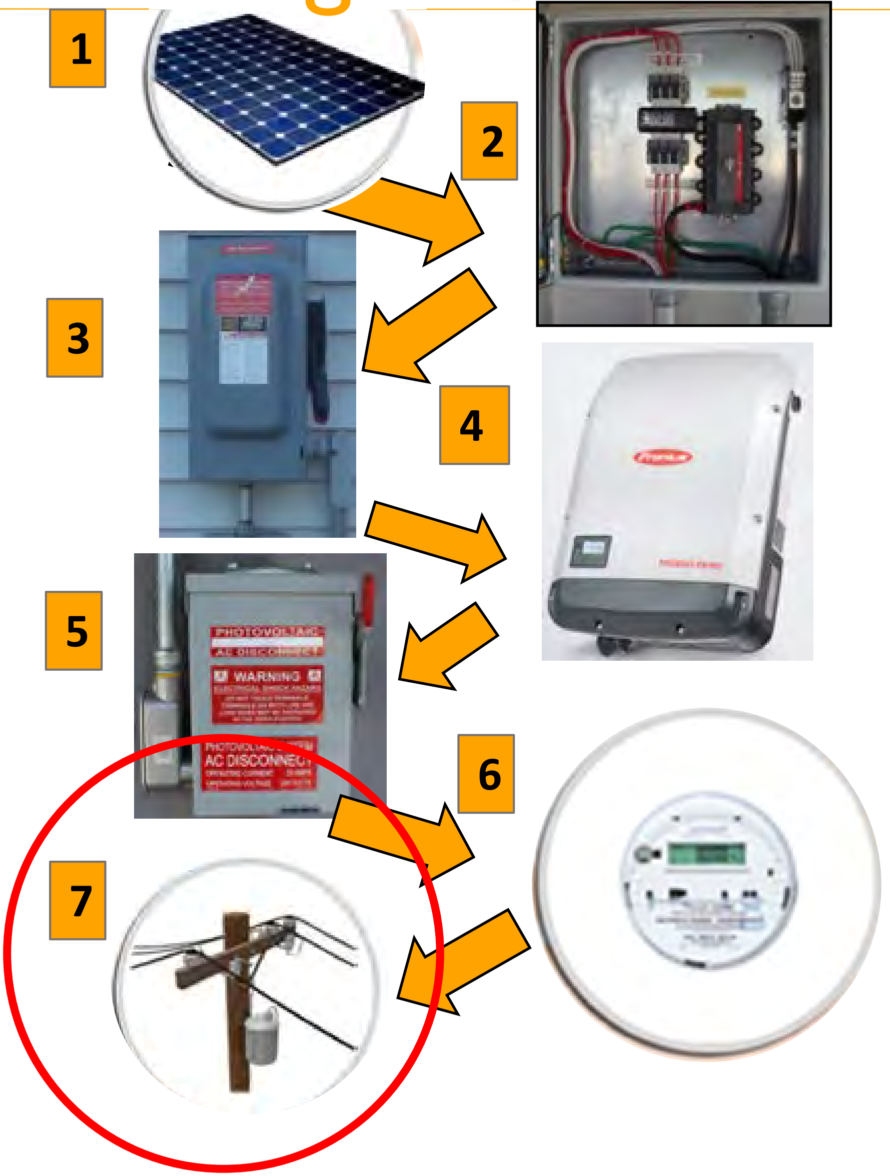
3 DC Disconnect Switch

4 Inverter

5 AC Disconnect Switch

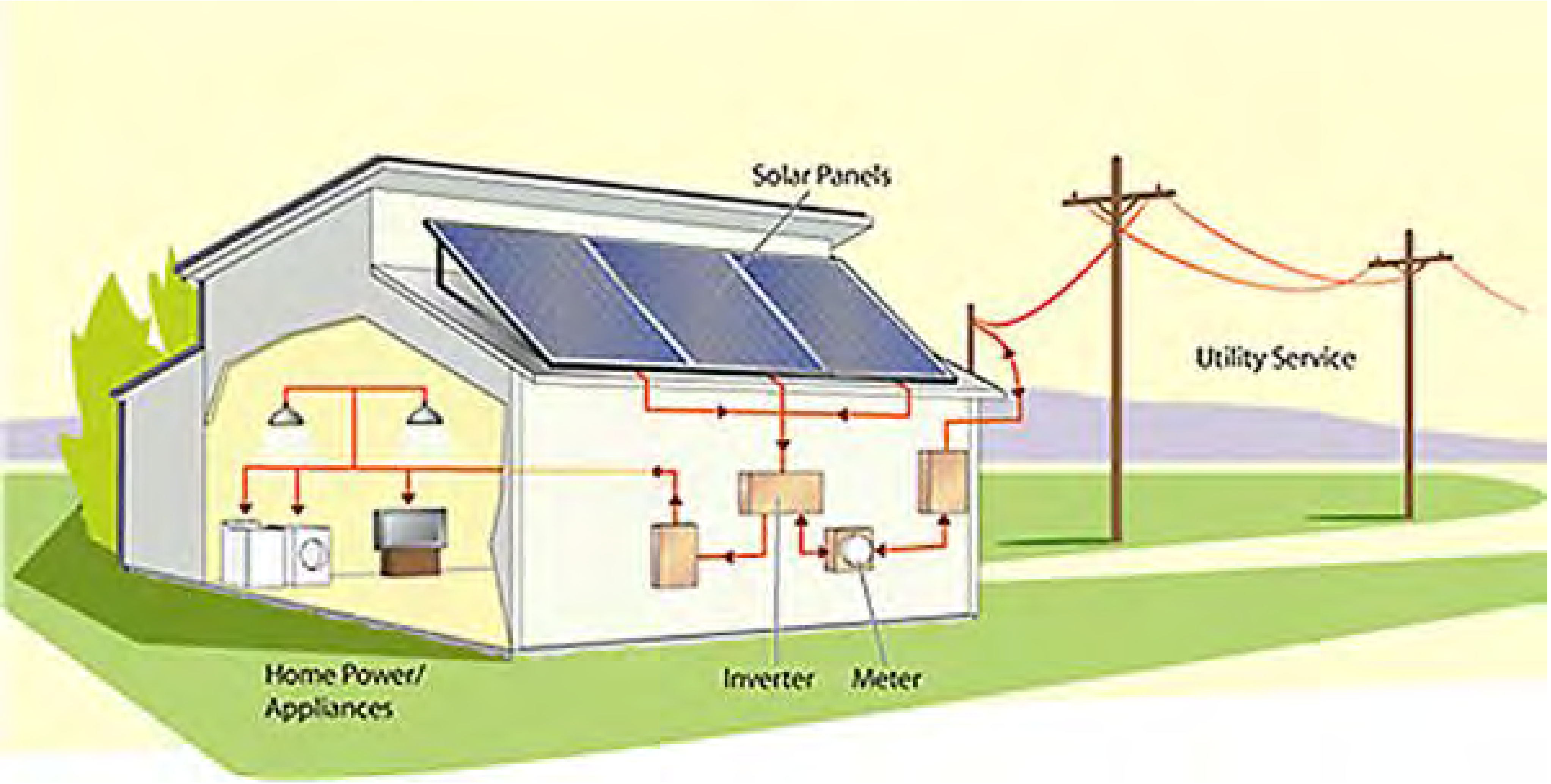
6 Utility Interconnection/Overcurrent Protection

7 Utility Grid



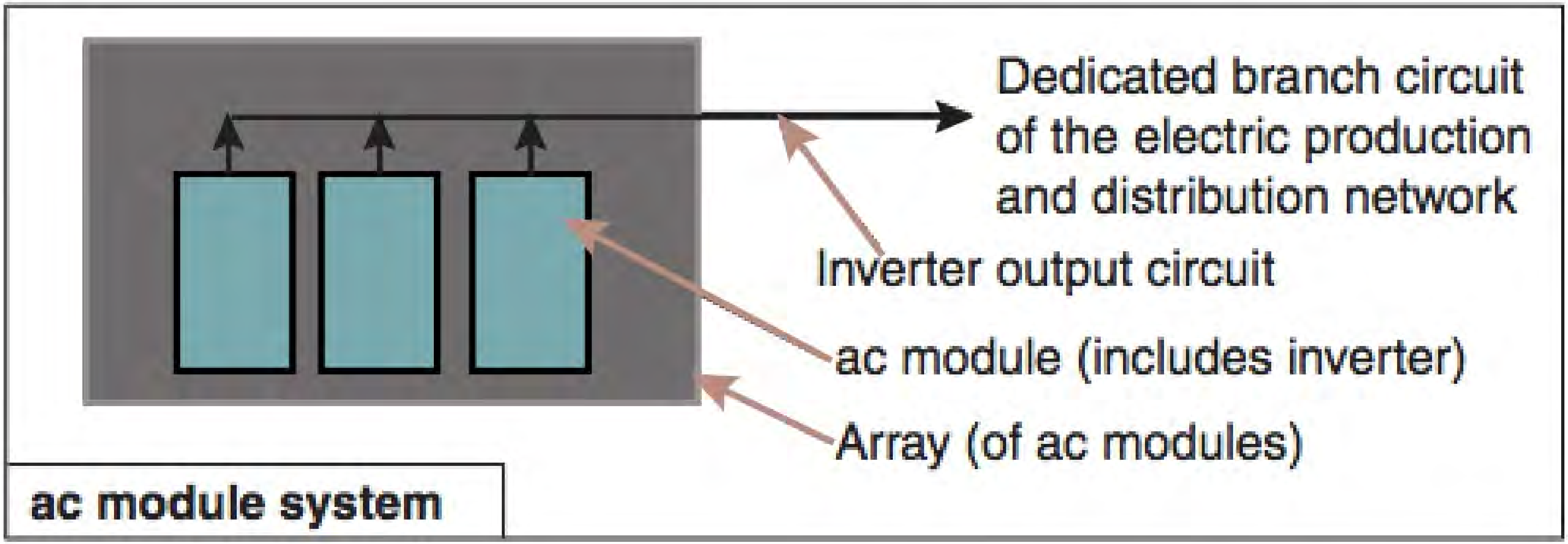
Solar Electric System Components

7



Understanding Schematic Drawings: Micro Inverter or AC Module System

7



NEC 2014, Figure 690.1 (c)

7

Understanding Schematic drawings: String tied inverter systems

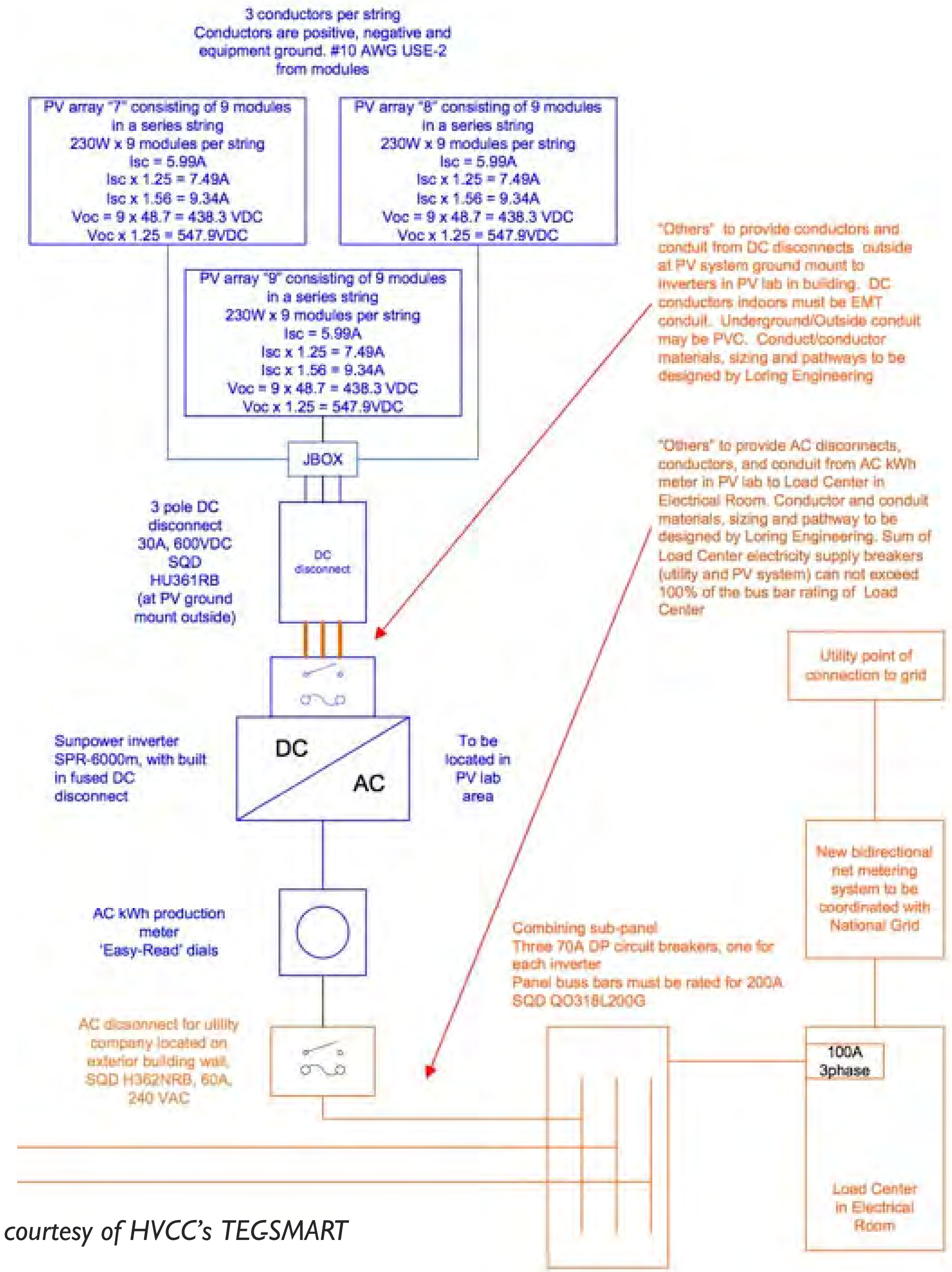


Image courtesy of HVCC's TEGSMART

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Understanding Schematic drawings: String tied inverter systems

7

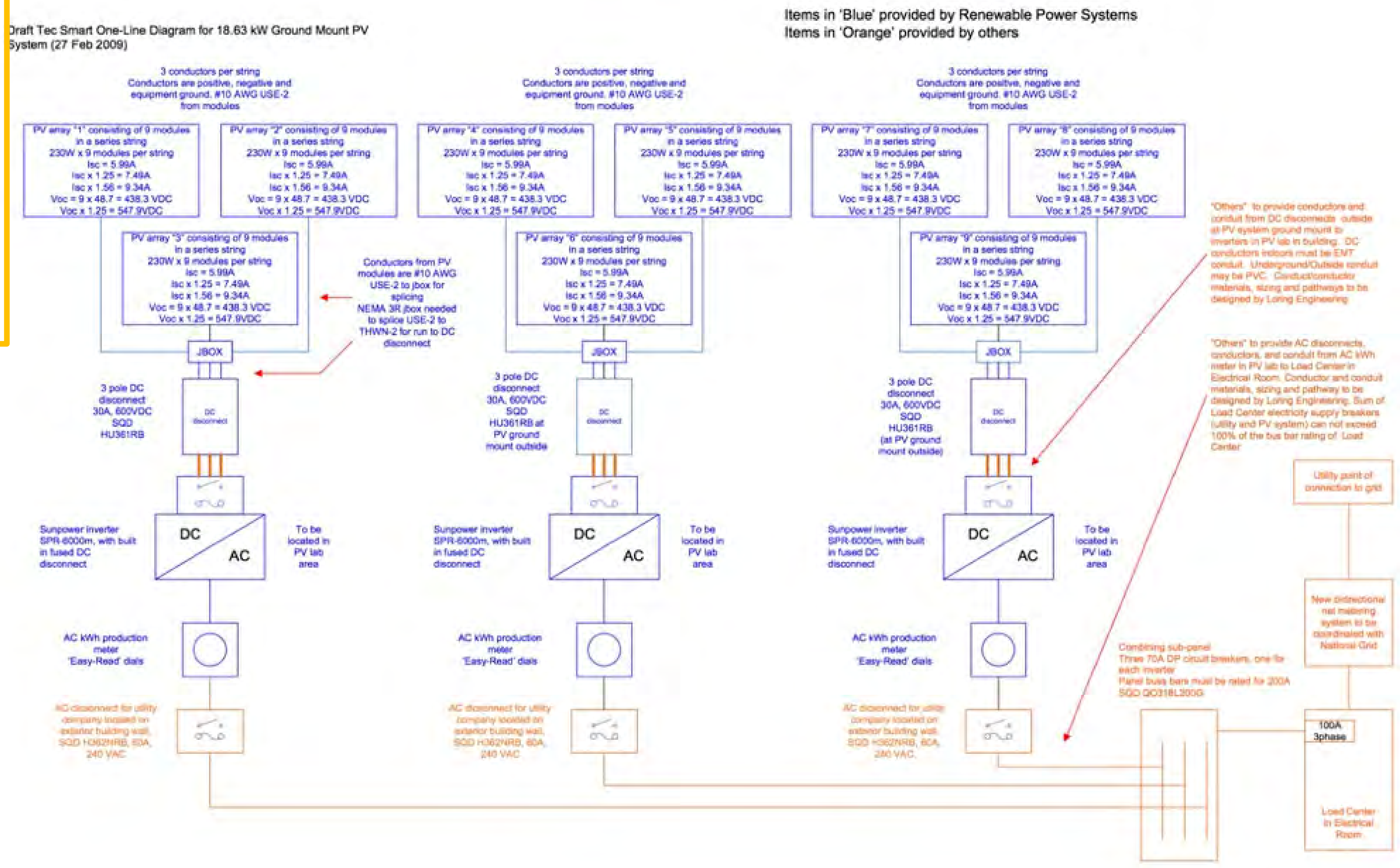

Image courtesy of HVCC's TEGSMART

System Components: Battery Backed up

SOLSMART

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch

4 Inverter

5 AC Disconnect Switch

6 Utility Interconnection/Overcurrent Protection

7 Batteries and Utility Grid

Pop quiz

1. What’s the role of the inverter?

2. Name one difference between systems with storage (batteries) and those without.

3. What are the different inverter types?

4. Identify the components!

Pop quiz

3. What are the different inverter types?

Pop quiz

3. What are the different inverter types?

Non Battery
String Inverter

Microinverter

Battery String Inverter

NICK FOLES

Pop quiz

4. What are these system components?

Bonus: what type?

Pop quiz

4. What are these system components?

AC Disconnect
Switch

Solar PV Panel
Bonus: thin film

Combiner Box

The Process

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Today's Agenda

- Introduction to solar technology [60 min]
- Identifying solar PV systems [45 min]
- Break [10 min]
- Solar PV hazards and safety [45 min]
- Identifying and disabling solar PV systems [45 min]

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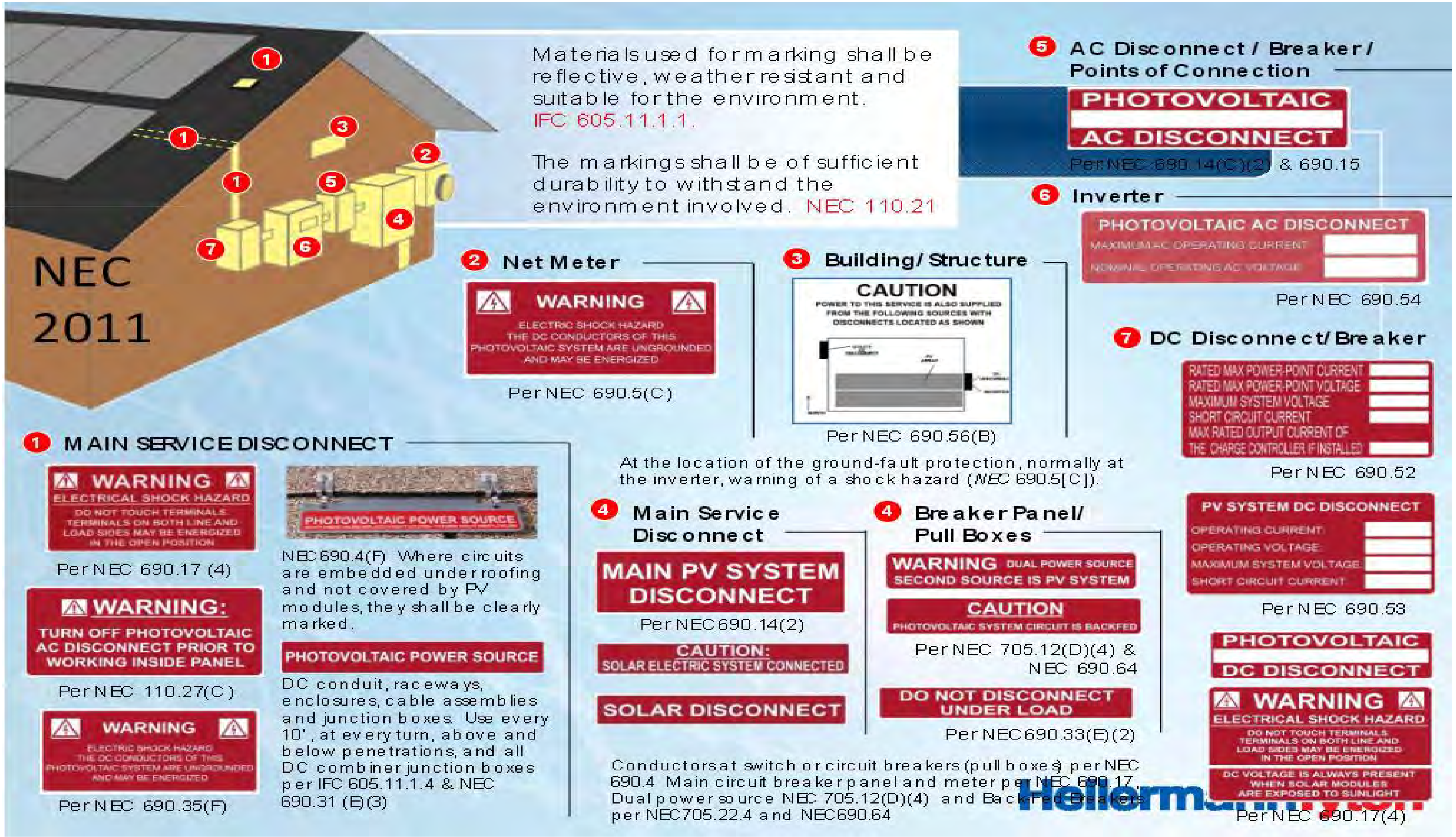
» **Solar PV Hazards & Safety**

- › **Hazard overview/labeling**
- › Site assessment
- › Protecting yourself
- › PA Code and safety recommendations

Hazard Overview & Labeling

PV System Labeling



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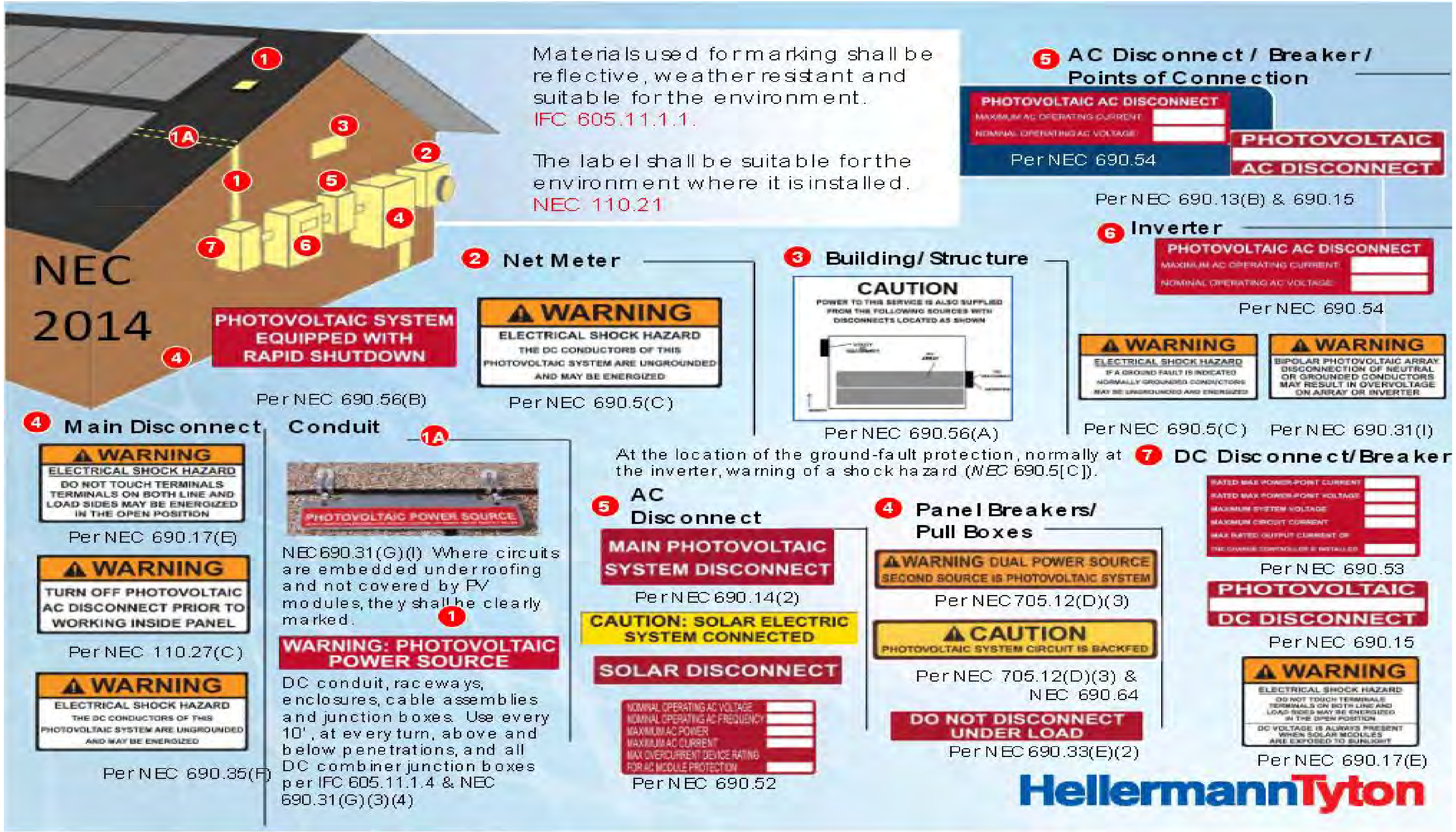
Hazard Overview & Labeling

PV System Labeling



Hazard Overview & Labeling

DC Raceway Label: NEC Article 690.31(G)(3)

On or inside a building

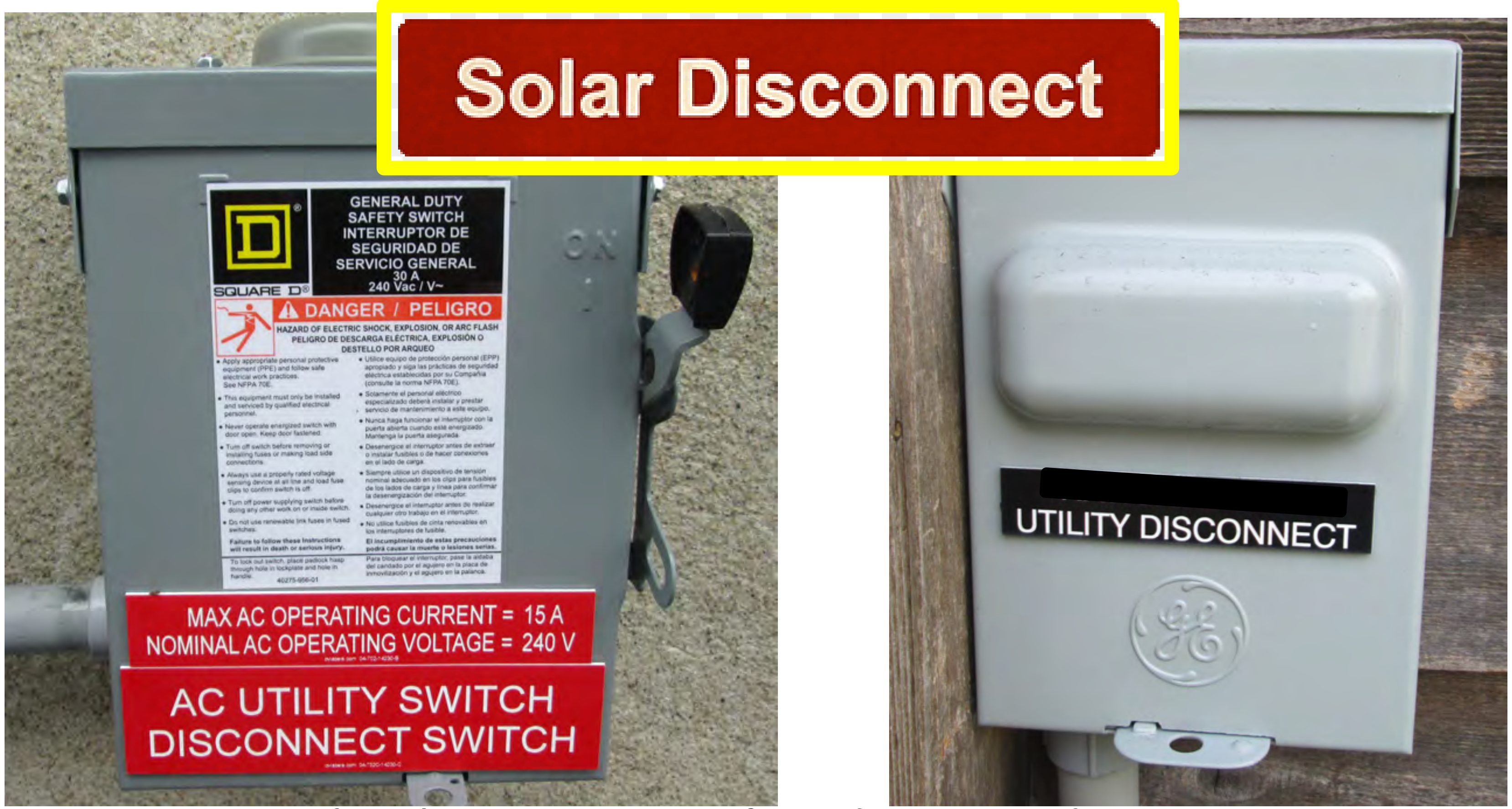
WARNING:
PHOTOVOLTAIC POWER SOURCE

Minimum 3/8” CAPS
White on **Red**
Reflective

Required on all DC raceways, every 10 feet.

Hazard Overview & Labeling

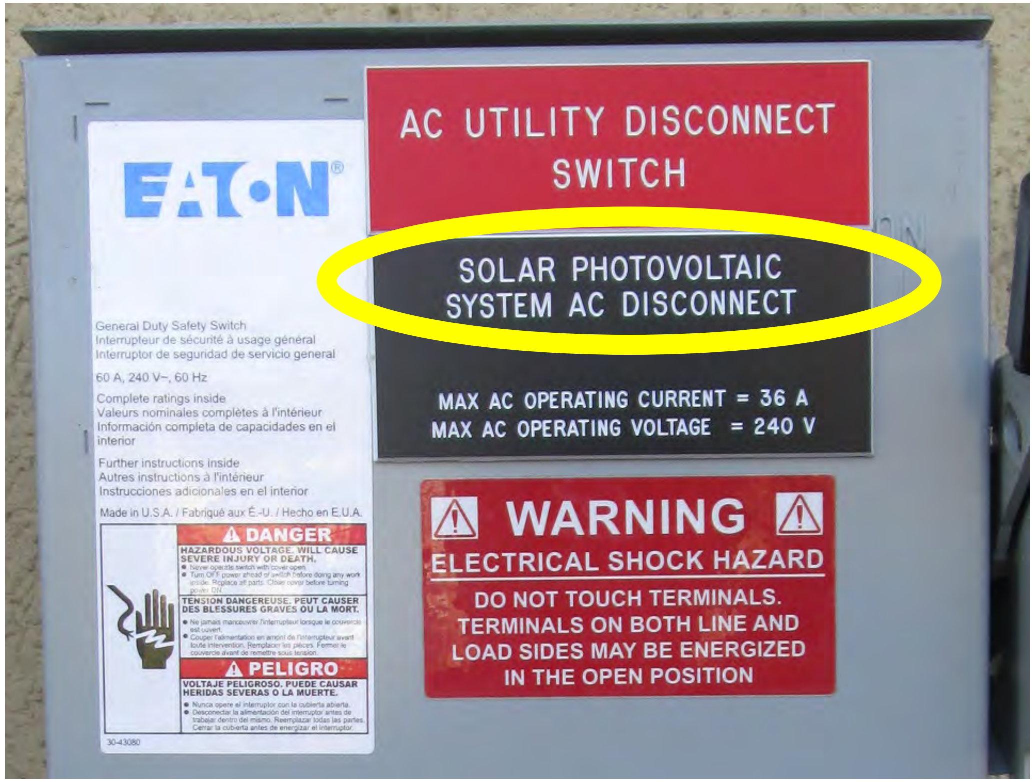
PV System Disconnect: NEC Article 690.13(B)



The utility may require specific wording on an AC disconnect.
Article 690.13(B) still applies. It is important that this is not confused with the Service Disconnect.

Hazard Overview & Labeling

PV System Disconnect NEC Article 690.13(B)



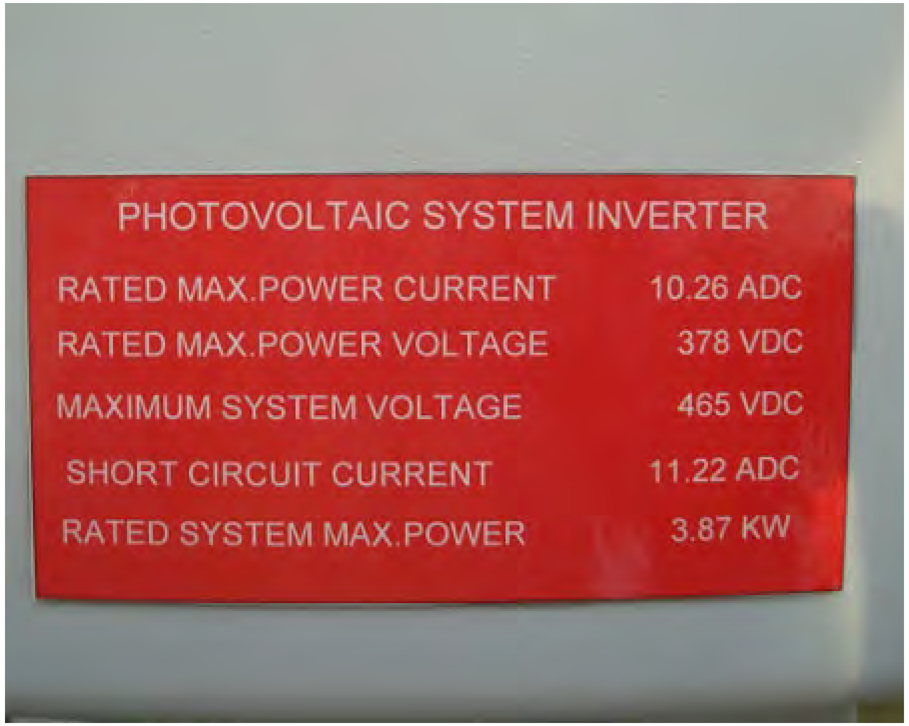
The correct way: Label identifying disconnect as Solar PV disconnect.

Hazard Overview & Labeling

Disconnect Line/Load Energized NEC Article 690.17(E)

Hazard Overview & Labeling

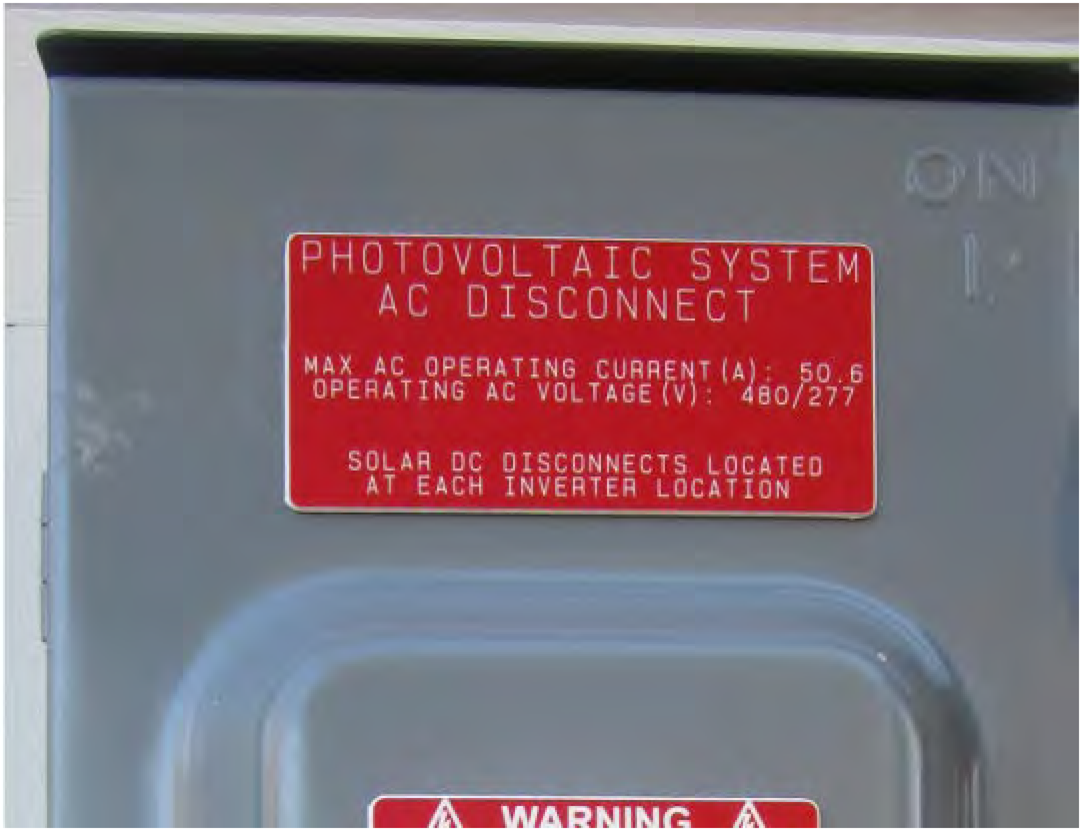
DC Power Source NEC Article 690.53



Maintenance label showing DC system properties.

Hazard Overview & Labeling

AC Power Source NEC Article 690.54



Maintenance label showing AC system properties.

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Hazard Overview & Labeling

Dual Power Sources NEC Article 705.12(D)(3)

Warning label indicating multiple sources of power present.

Hazard Overview & Labeling

"Do Not Relocate" NEC Article 705.12(D)(2)(3)(b)

Maintenance label for electrical connection in panelboard.

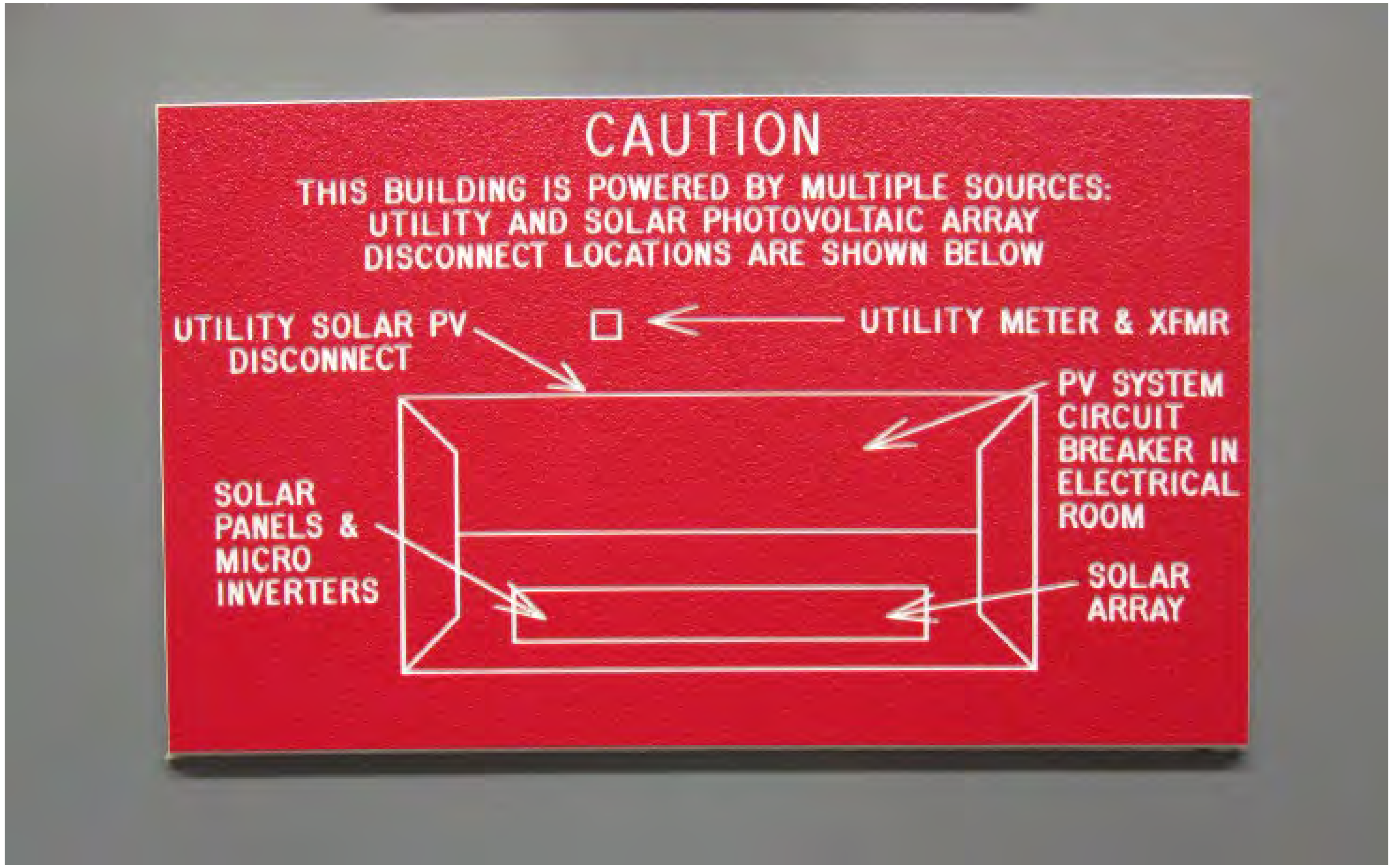
Hazard Overview & Labeling

AC Combiner Panel NEC Article 705.12(D)(2)(3)(c)

Maintenance label for electrical connection in panelboard.

Hazard Overview & Labeling

Service Disconnect Directory NEC Article 690.56(B)



Hazard Overview & Labeling

Inverter Directory NEC Articles 690.15(A)(4)/705.10

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» **Solar PV Hazards & Safety**
  - Hazard overview/labeling
  - **Site assessment**
  - Protecting yourself
  - PA Code and safety recommendations

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Site Assessment

Planning, Size Up, and Tactical Considerations

Pre-plan development considerations:

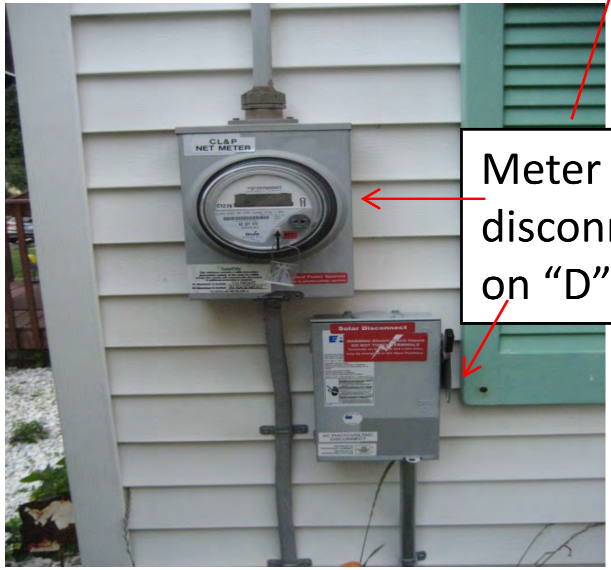
- Buildings with installed solar PV systems
- Coordination with building department
- FMO Involvement in permit process?
- Maintain a record of buildings containing PV?
- Company training and walk through
- Dispatch center CAD entries

Site Assessment

- After the initial size up, consider the following
  - Is there a PV system present on the structure/property?
  - A complete 360 is important to get a look at all sides and roof
- What type of system is it?
  - PV, Thermal, integrated

Site Assessment

Sample House



Meter and AC disconnect located on “D” side

Array installed right up to ridge line with no setbacks, will not allow roof ladder hooks to sit on roof

Site Assessment

Is the system involved in a fire? If yes, what are the appropriate actions?

- Proper hose stream selection and safe distances for applying water to burning PV systems

Site Assessment

Roof Access

What do we have for roof access?

Aerial or ground ladder operations (setbacks at ridge)

Site Assessment

Ventilation

- Vertical ventilation might not be an option depending on PV system location
- Horizontal Ventilation might be the best and only choice

Site Assessment

Disconnect Location

- Where are the disconnects located?
  - Interior (garage/basement) or exterior

- Do we have access to secure the disconnects?

This is <u>NOT</u> DIY work!

Consider notification to Solar contractor for assistance

- Look for labeling
- Information will also be on electrical/building permit

Labeling may or may not be present or legible

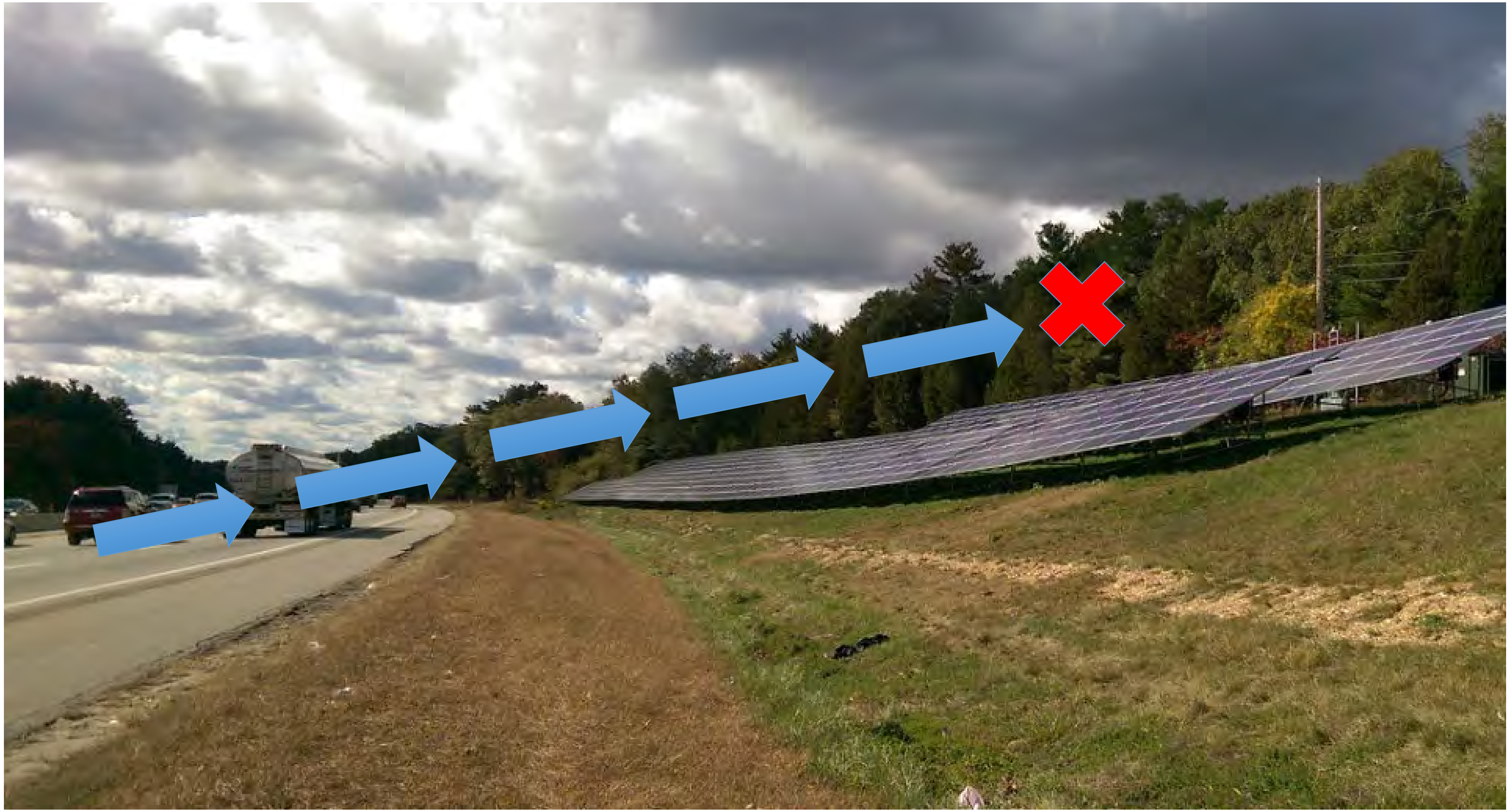
Site Assessment

Remote Inverter & Disconnects

- Ground-mount array, large inverter and disconnected located remotely

Site Assessment

Ground-Mount Array Near Highway



Ground-mount array near highway.

Today's Agenda

SOLSMART

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» **Solar PV Hazards & Safety**

› Hazard overview/labeling

› Site assessment

› **Protecting yourself**

› PA Code and safety recommendations

Protecting Yourself

SOLSMART

- Cover panels with tarps
  - May work on small residential systems
  - Not practical for large PV systems
- Shut off all available disconnects
- Foam is not effective
- Lock Out Tag Out (LOTO) main electrical panel & system disconnects

Disconnects

<u>May</u> be effective method to de-energize system

Various system types

- Some disconnects DO NOTHING
- Can be in multiple locations

AC Microinverter System

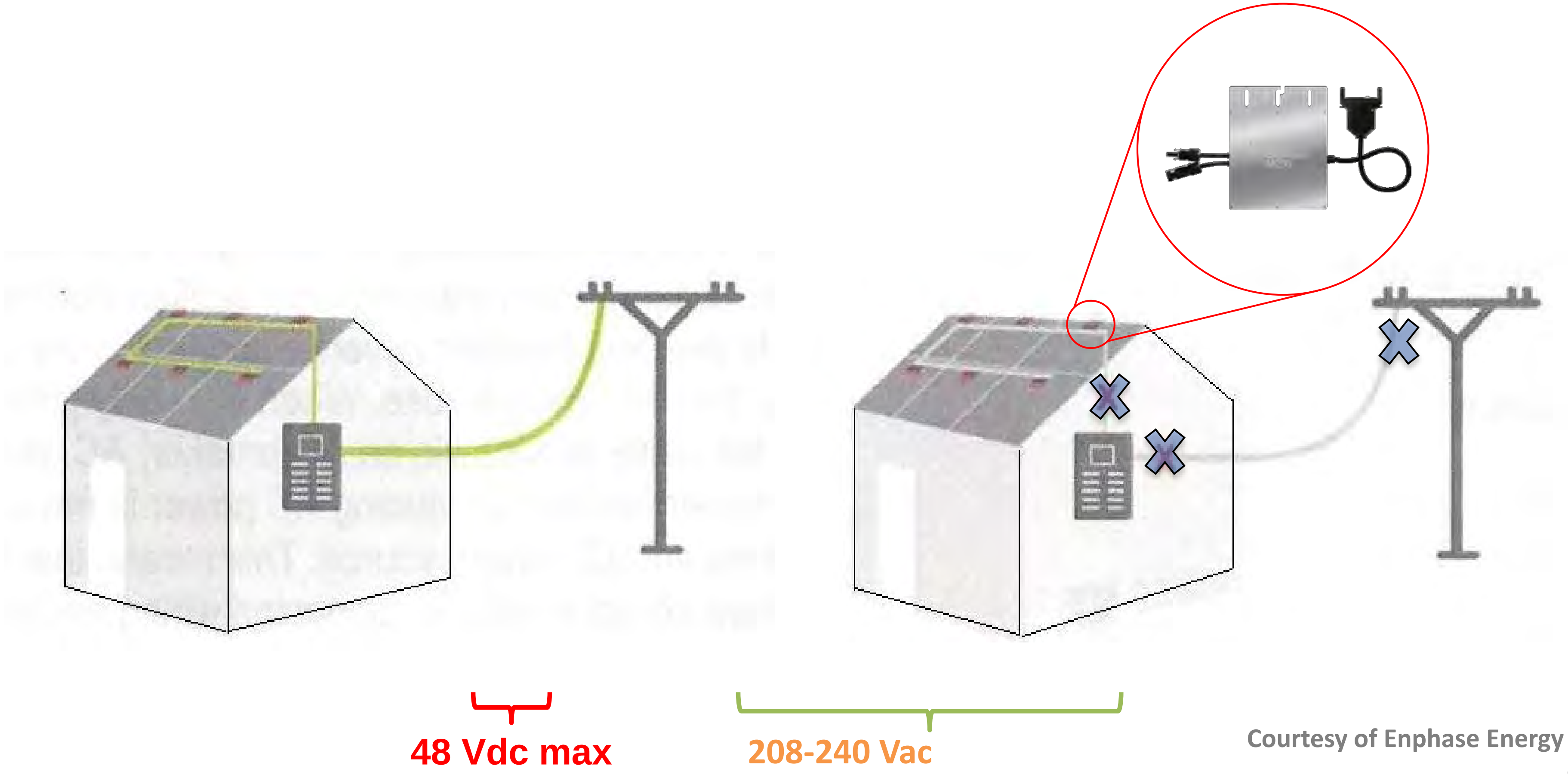
What will happen if I shut off the main disconnect?

- Conductors will be energized only under modules
- All AC electrical circuits/devices will be de-energized

AC Microinverter System

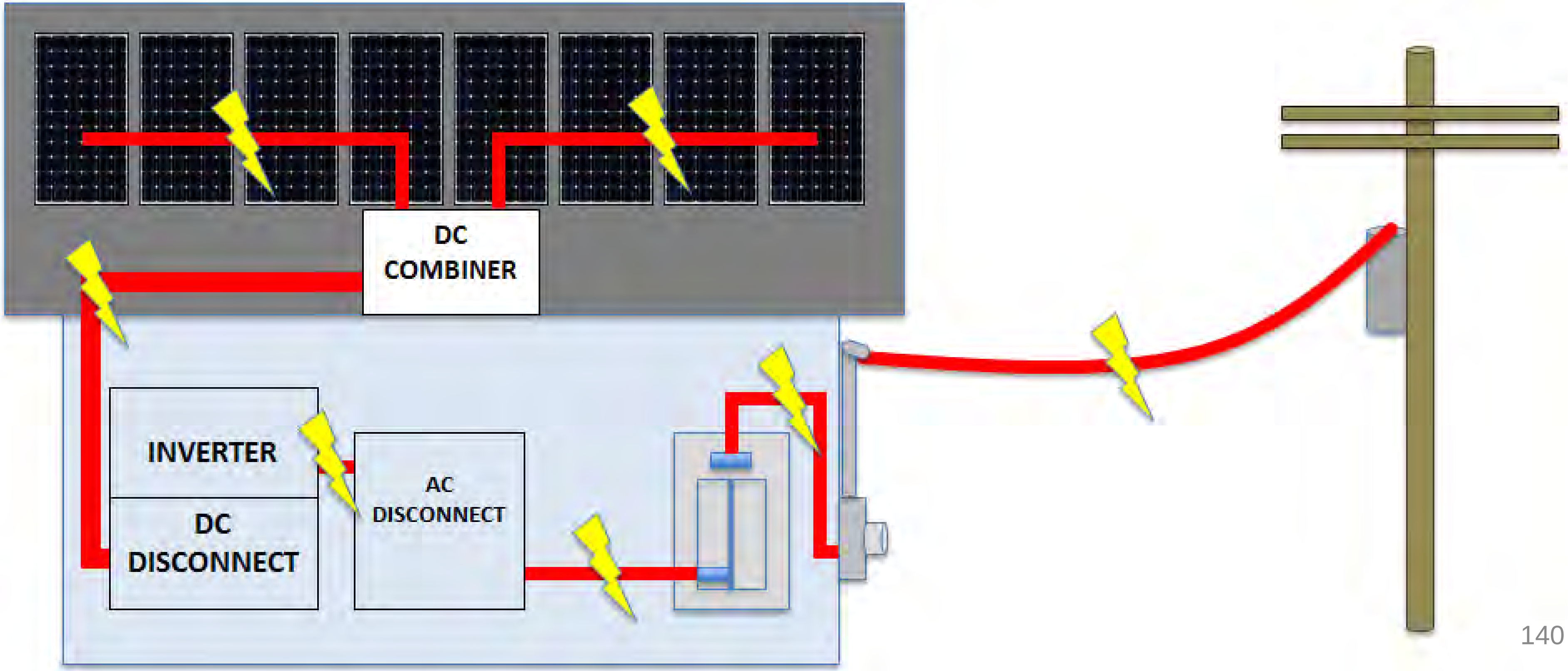
SOLSMART

What will happen if I shut off the main?



Courtesy of Enphase Energy

Central Inverter System
(Most Common)



Central Inverter System
(Most Common)

What will happen if I shut off the main?

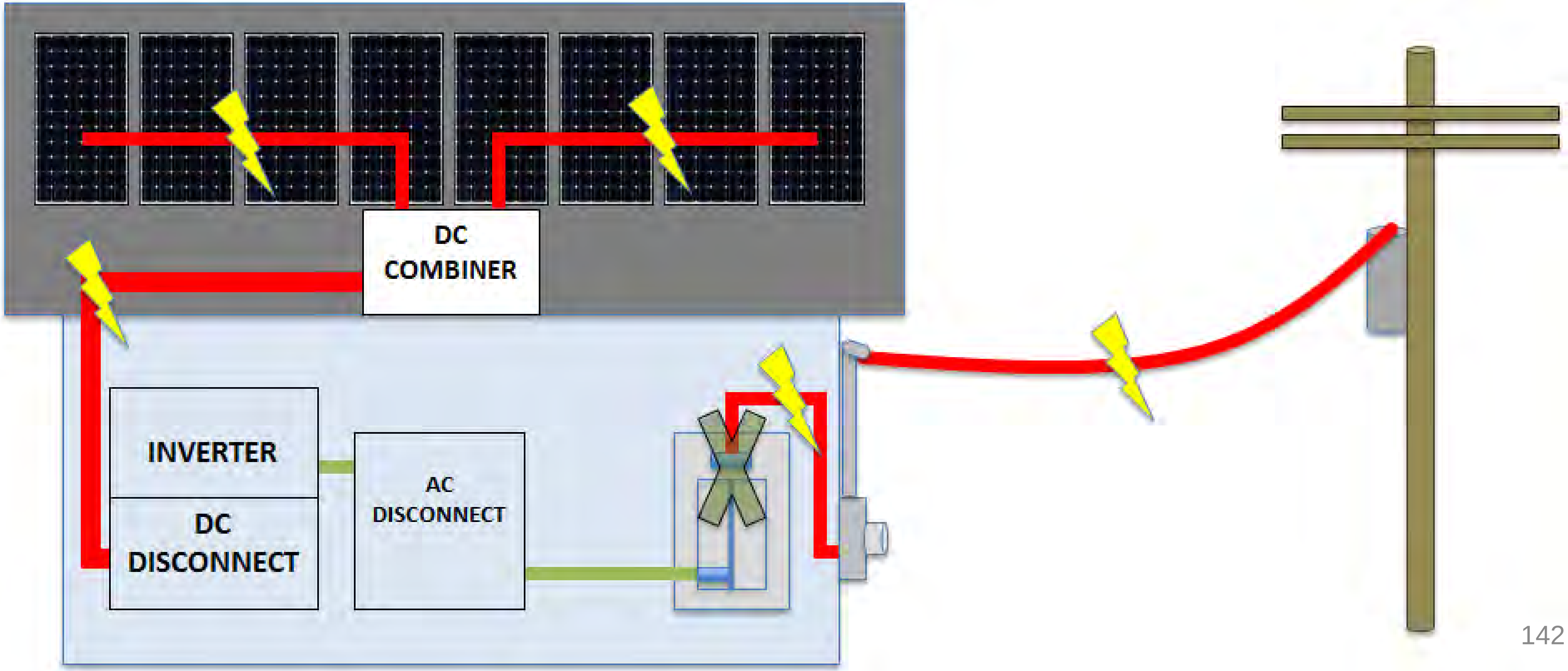
- All AC electrical circuits/devices **de-energized**
- AC conductors up to inverter **de-energized**
- DC conduit inside building **still energized**
- Rooftop DC conduit **still energized**

The following example assumes the PV system is connected to the main panelboard. Care should be taken, as this is not always the case and the PV system may have its own disconnect located remotely from the main breaker.

Central Inverter System
(Most Common)

What will happen if I shut off the main?

AC circuits throughout building will be de-energized if PV breaker is in main panelboard



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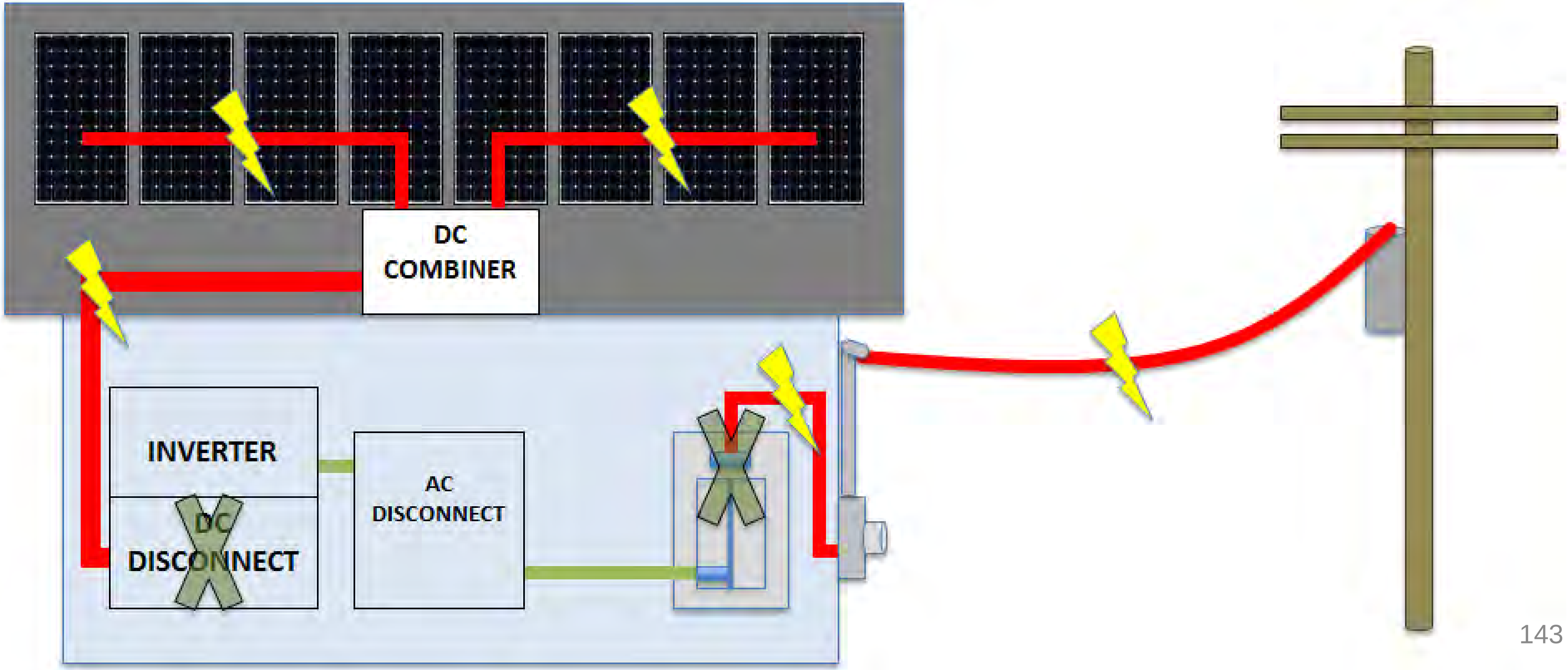
Central Inverter System
(Most Common)

What will happen if I shut off the main and DC disconnect?

AC circuits throughout building will be de-energized if PV breaker is in main panelboard

DC will still be energized between inverter and array



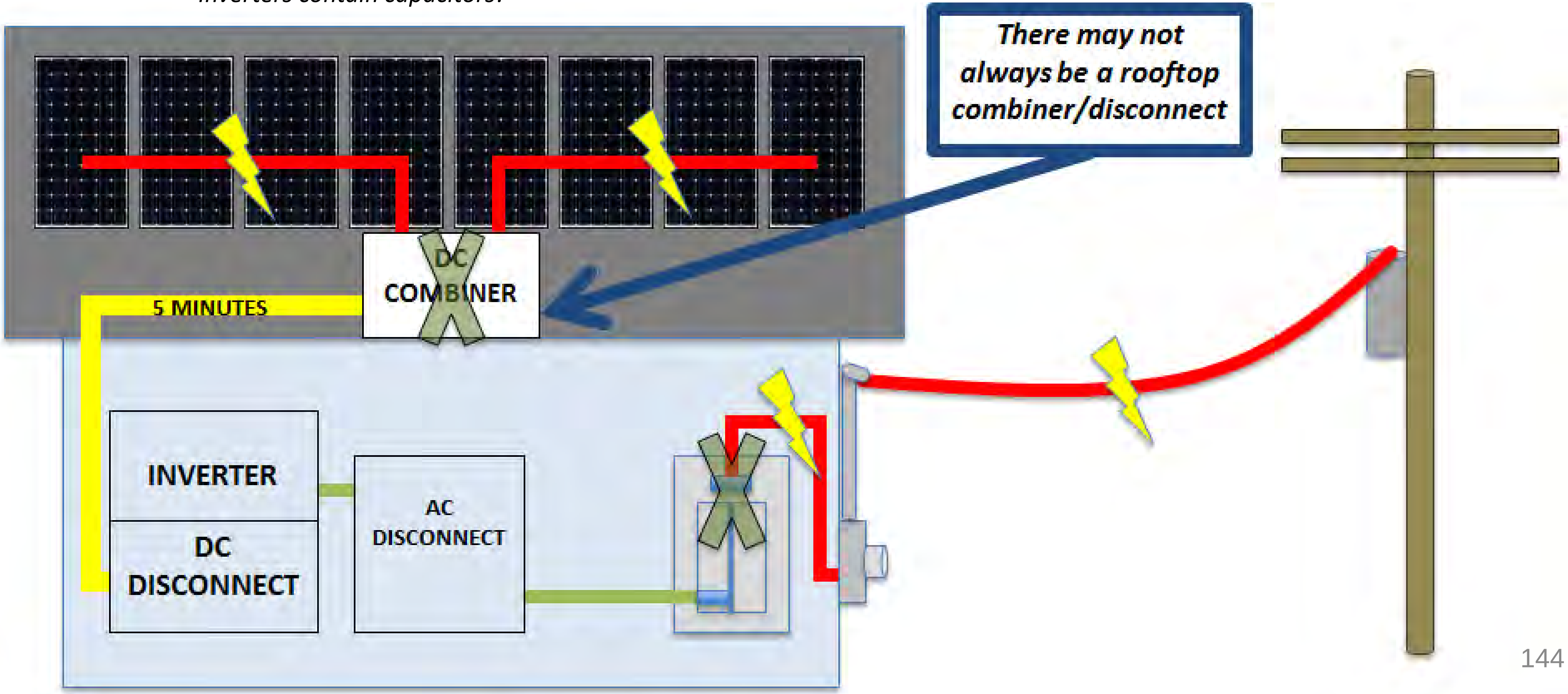
Central Inverter System
(Most Common)

What will happen if I shut off the main and DC combiner disconnect?

AC circuits throughout building will be de-energized if PV breaker is in main panelboard

DC between inverter and combiner may be de-energized in 5 minutes

Inverters contain capacitors!



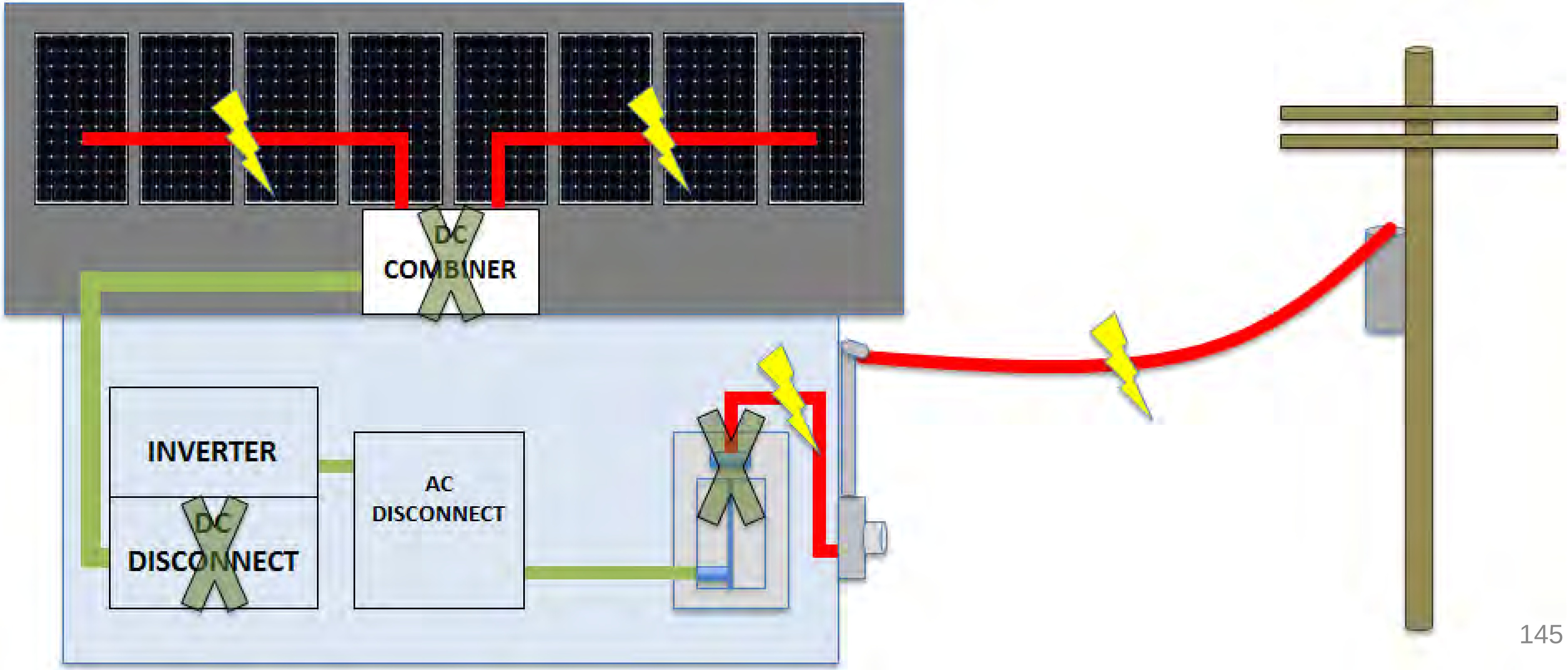
Central Inverter System
(Most Common)

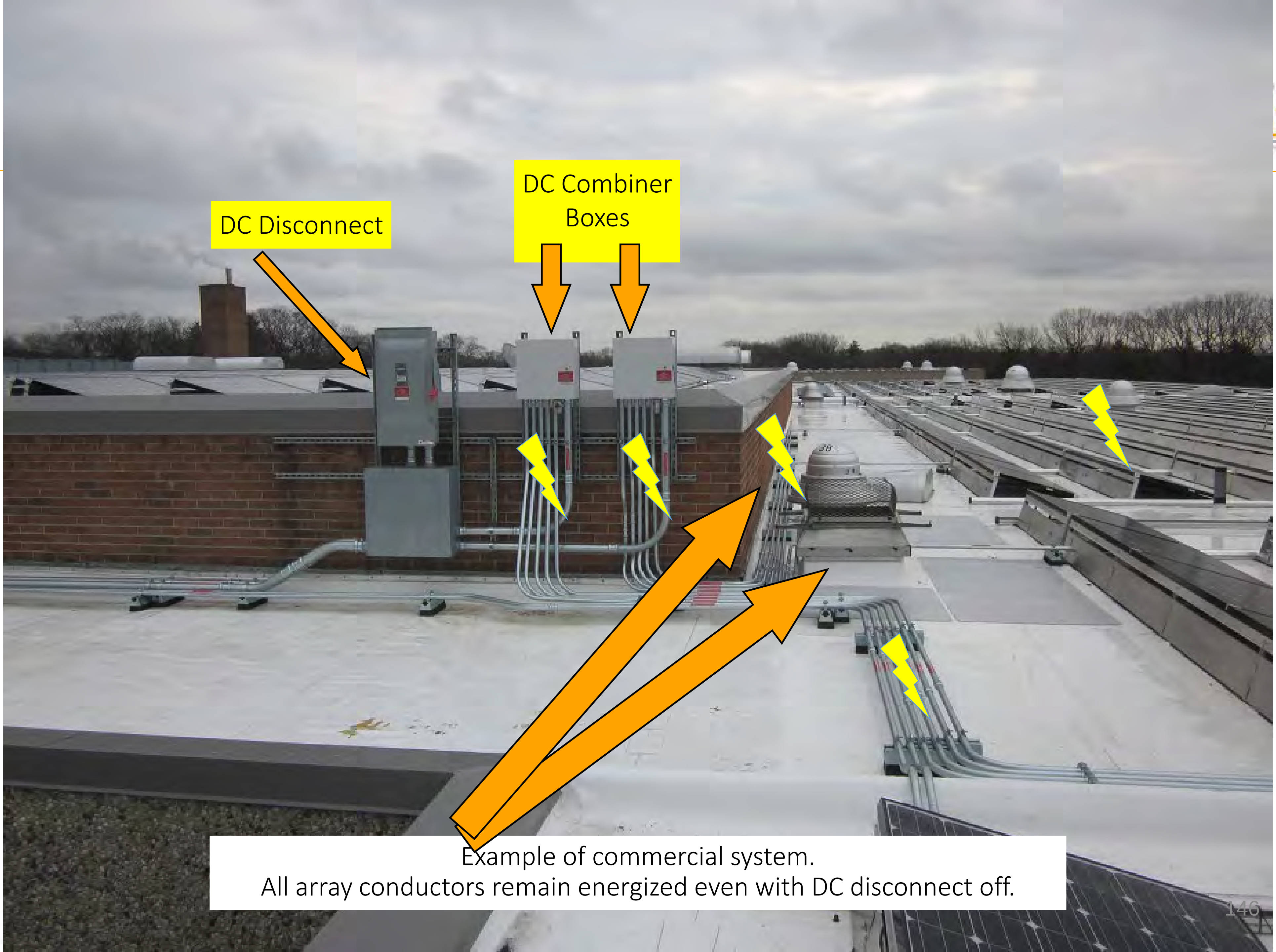
What will happen if I shut off the main, DC, and DC combiner disconnects?

AC circuits throughout building will be de-energized if PV breaker is in main panelboard

All DC conductors between inverter and DC combiner will be de-energized

Array conductors still energized

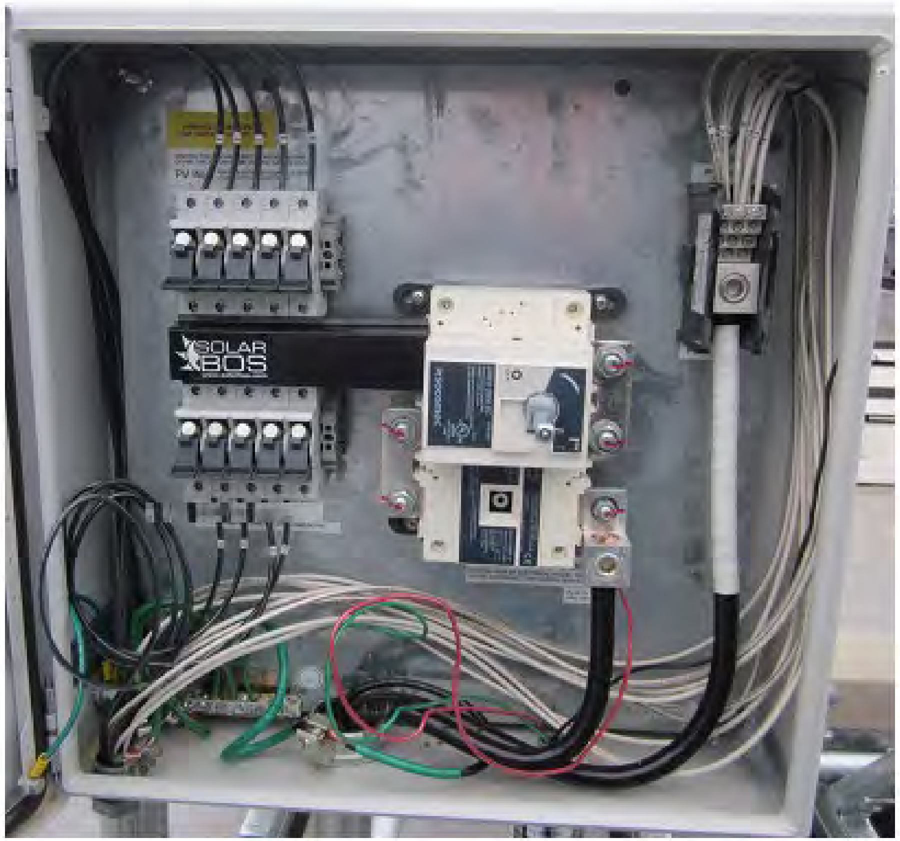




Example of commercial system.
All array conductors remain energized even with DC disconnect off.

Combiner Box with DC Disconnect

SOLSMART



Combiner Boxes with DC Disconnects

At Watertown DPW

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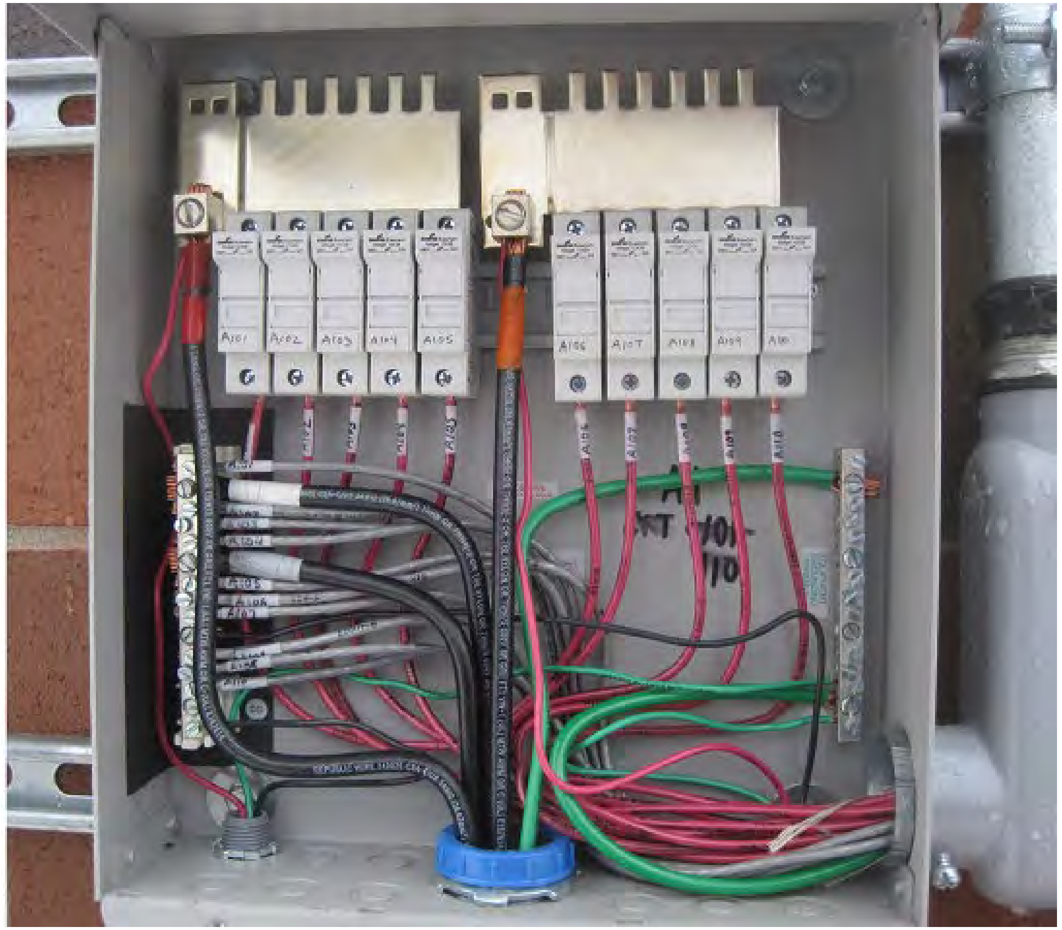
Combiner Boxes, No Disconnects

Prior to the 2011 National Electrical Code



Prior to the 2011 Code, combiner boxes were not required to have disconnects.

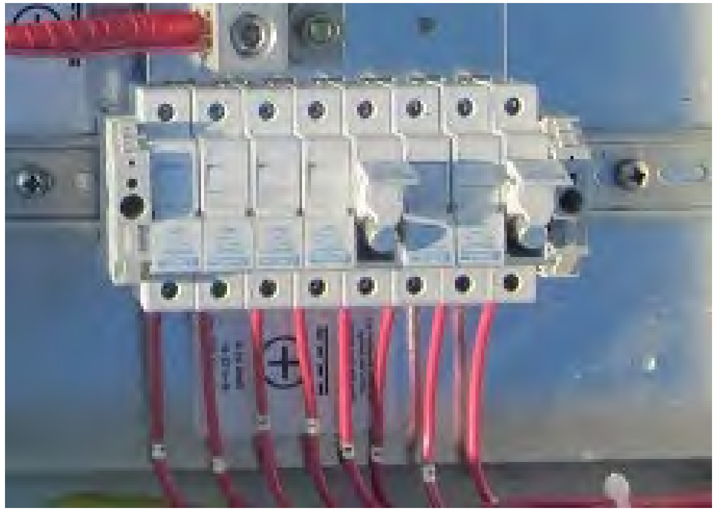
Combiner Boxes

Opening fuseholders under load is dangerous

- Arcing hazard

Inverter or DC disconnect MUST be shut down before fuseholders are opened

- Inverter will shut down automatically if main breaker is off
- If there is a fault in the DC wiring (modules burning, etc.), current will still flow to ground and a hazard may still exist when opening fuseholders



Example of commercial system.
No rooftop DC disconnects, array conductors remain energized.

Example of commercial system.
DC combiner contains disconnect, array will remain energized.

Ground-mount array with DC combiner/disconnect. Array conductors remain energized of disconnect is opened “off.”

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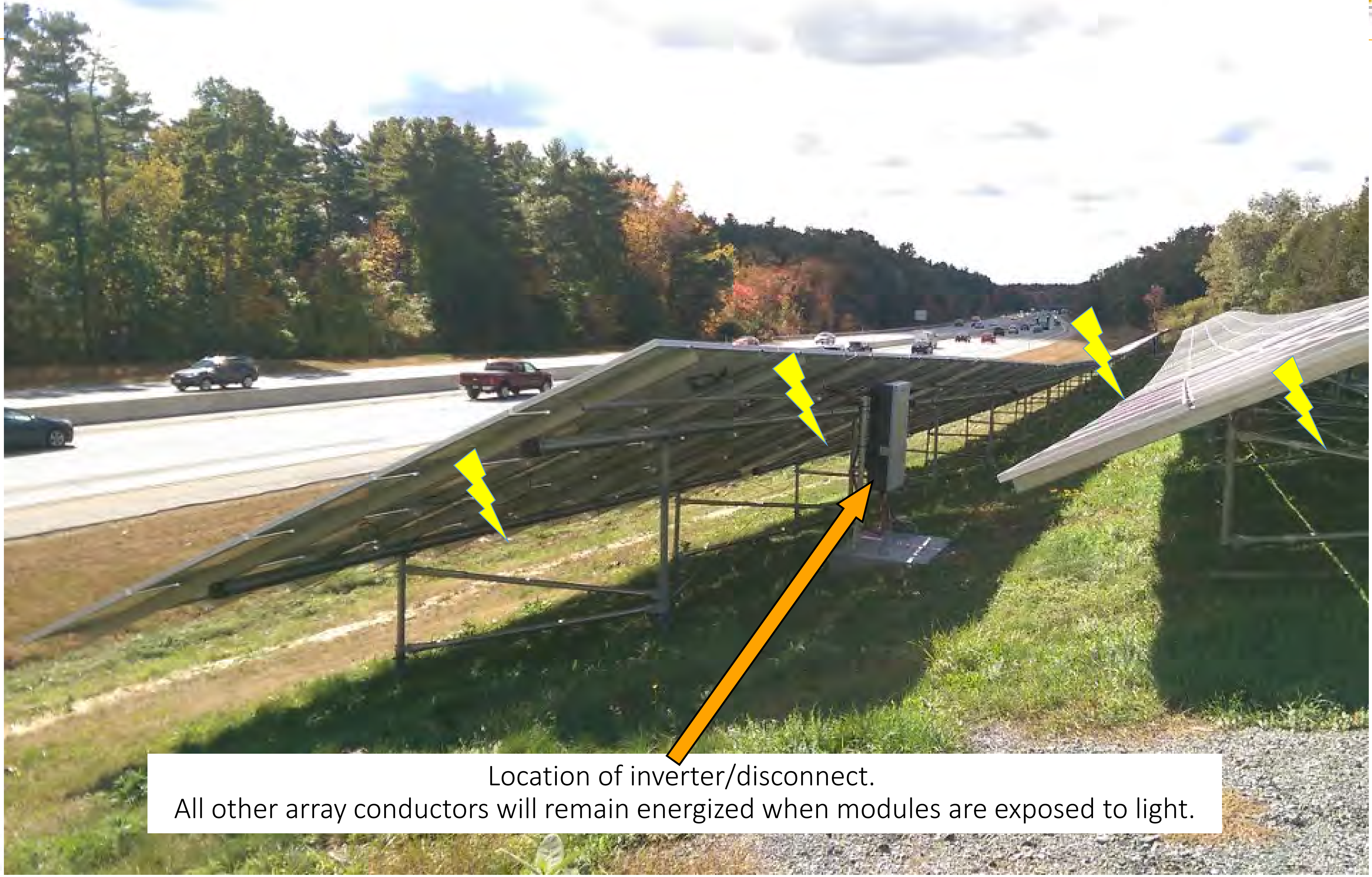

Location of inverter/disconnect.
All other array conductors will remain energized when modules are exposed to light.

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SMART

Rapid Shutdown of PV Systems on Buildings

Requirement in 2014 National Electrical Code (NEC): Article 690.12

Applies to all buildings permitted to the 2014 edition of the NEC

PV system circuits on or in buildings shall include a rapid shutdown function:

- 690.12(1) through (5)…

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About Article 690.12

2014 National Electrical Code

- Intended to protect first responders
- Original 2014 proposal:
  - Disconnect power directly under array
    - Module-level shutdown
- Compromise:
  - Combiner-level shutdown

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Rapid Shutdown of PV Systems on Buildings

2014 NEC Article 690.12

690.12(1)

- More than 10’ from an array
- More than 5’ inside a building

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Rapid Shutdown of PV Systems on Buildings

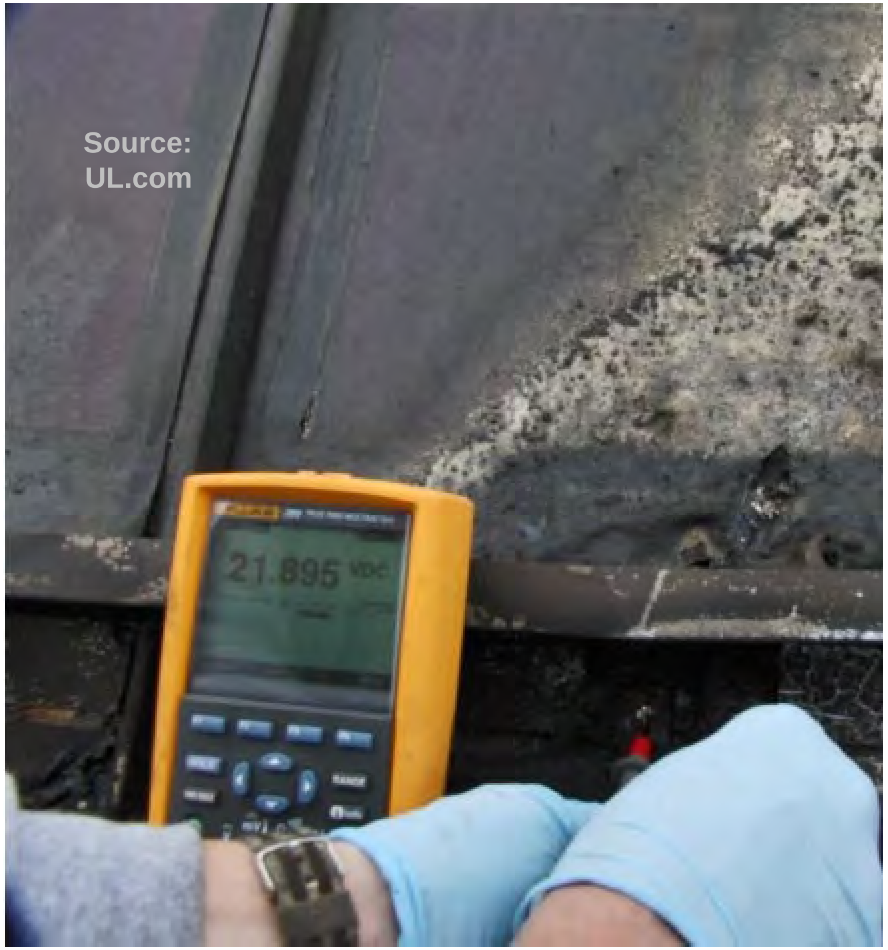
2014 NEC Article 690.12

690.12(2)

- Within 10 seconds
  - Under 30 Volts
  - 240 Volt-Amps (Watts)
- *A typical module:*
  - *~250 Watts*
  - *~30 Volts*

690.12(3)

- Measured between:
  - Any 2 conductors
  - Any conductor and ground



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Rapid Shutdown of PV Systems on Buildings

2014 NEC Article 690.12

690.12(4)

Labeled per 690.56(C)

**PHOTOVOLTAIC SYSTEM
EQUIPPED WITH RAPID SHUTDOWN**

- Minimum 3/8" CAPS
- White on **Red**
- Reflective

Rapid Shutdown of PV Systems on Buildings

2014 NEC Article 690.12

690.12(5)

"Equipment that performs the rapid shutdown shall be listed and identified."

About Article 690.12

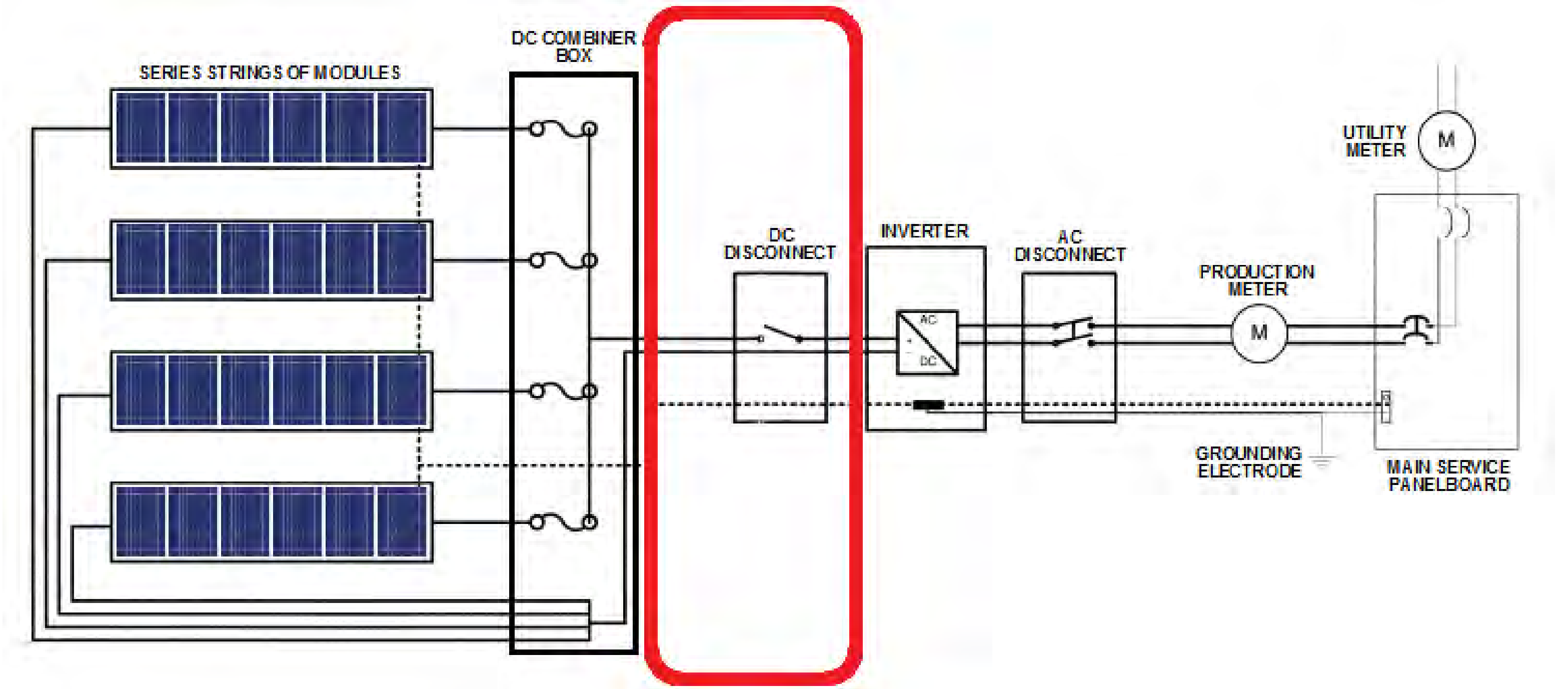
Open-ended **gray areas**:

- Location of “rapid shutdown initiation method”
- Maximum number of switches

About Article 690.12

Considerations:

- Disconnect power within 10 seconds
- Inverters can store a charge for up to 5 minutes (UL 1741)



About Article 690.12

SOLSMART

What complies:

- Microinverters
- AC modules
- DC-to-DC Optimizers/Converters
  - May or may not depending on the model

About Article 690.12

What complies:

Exterior string inverters if <u>either</u>:

- Located within 10 feet of array
- Inside building within 5 feet

"Contactor" or "Shunt Trip" Combiner Boxes/Disconnects

- Must be listed for "Rapid Shutdown" as a system

Many considerations & variations for full system compliance

- Plans should be discussed with AHJ prior to installation

Extinguishing a PV Fire and Hose Stream

Is water a good idea?

Firefighter Safety and Photovoltaic Installations Research Project

http://www.ul.com/global/documents/offerings/industries/buildingmaterials/fireservice/PV-FF_SafetyFinalReport.pdf

Firefighter Safety and Photovoltaic Systems

UL Findings – Hose Stream

Voltage of PV system

Nozzle diameter

Pattern of water spray

Distance between nozzle and live components

Conductivity of water

UL Findings – Hose Stream

SOLSMART

Firefighter Safety and Photovoltaic Systems

Smooth Bore
- Up to 1.25”

Adjustable
- Solid stream to wide fog

UL Recommendations:
- At least 20’ away for smooth bore
- At least 10° angle for adjustable
  - UL 401 Standard, 30° min cone angle
    - “Portable Spray Hose Nozzles for Fire-Protection Service”

Hose Stream

Test with pond water and <u>smooth bore</u> nozzle

Distance Feet	Smooth bore nozzle size	Pressure PSI	Voltage DC Volts	Leakage current Milliamps
10	1 inch	21	1000	5.7
10	1 inch	21	600	3.2
10	1 inch	21	300	1.6
10	1 inch	21	50	0.3
20	1 inch	23	1000	1.5

Firefighter Safety and Photovoltaic Systems

0 - 2 mA	2.1 - 40 mA	40.1 - 240 mA	> 240 MA
Safe	Perception	Lock On	Electrocution

Hose Stream

Test with pond water and narrow fog pattern at 5’

Zero leakage current at 1000 Volts

Firefighter Safety and Photovoltaic Systems

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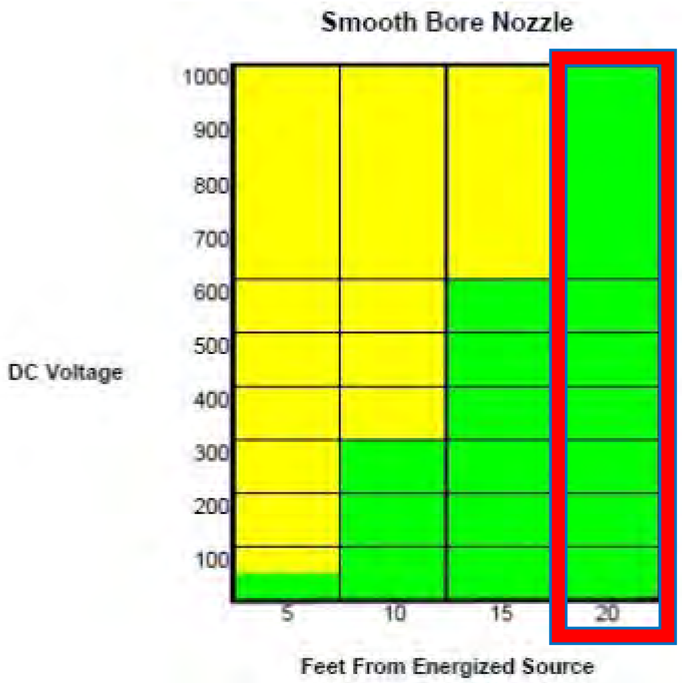
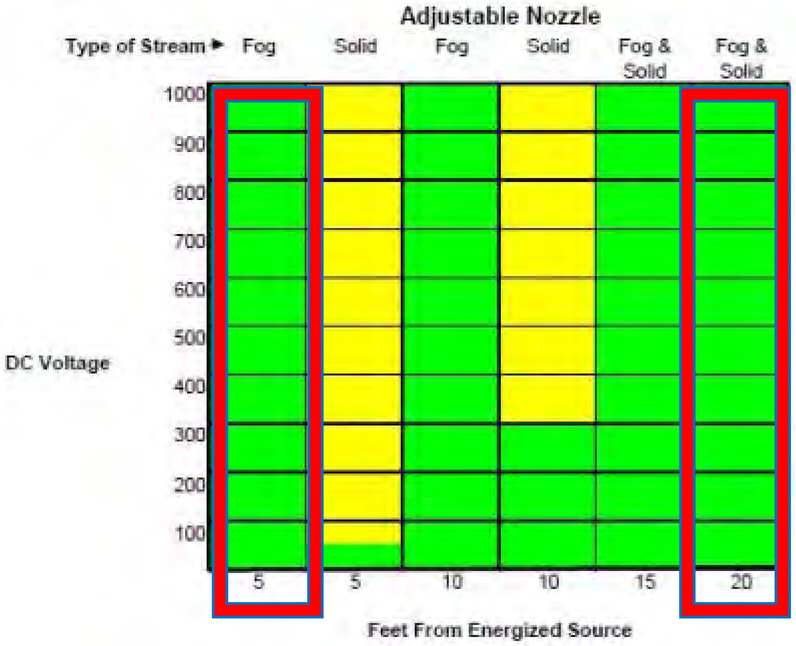
Hose Stream

In conclusion UL recommends:

- At least 20’ away for smooth bore
- At least 10° angle for adjustable
  - UL 401 Standard, 30° min cone angle
    - “Portable Spray Hose Nozzles for Fire-Protection Service”

Firefighter Safety and Photovoltaic Systems





Personal Protective Equipment (PPE)

Are we safe from all hazards?

Personal Protective Equipment (PPE)

UL tested firefighter gloves and boots to determine electrical insulating properties.

Various tests performed on items:

- New
- Soiled
- Wet
- Worn

Firefighter Safety and Photovoltaic Systems

Figure 29 Testing a glove in metal shot

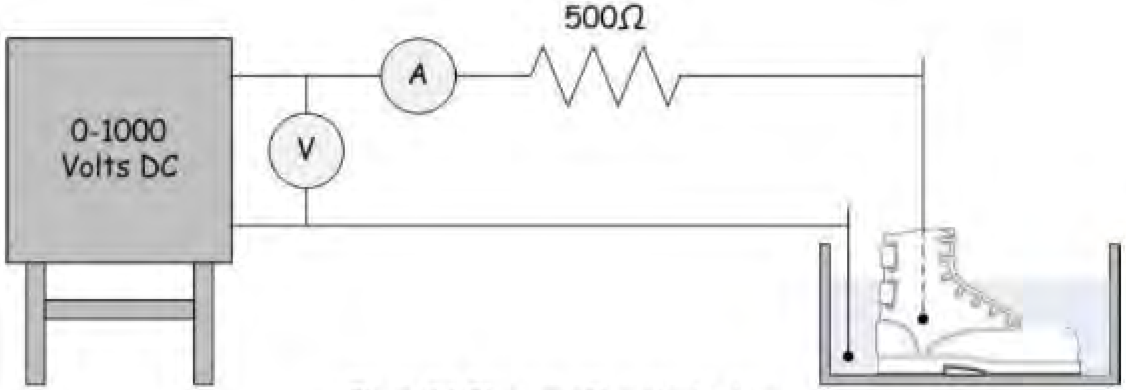


Figure 34 Diagram of boot test set-up

Personal Protective Equipment (PPE)

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Typical electrician rubber gloves evaluated to ASTM D 120, and must be worn with leather protectors

Firefighter boots and gloves typically tested to NFPA 1971

- Boots require similar test to electrician boots
- No electrical requirements for gloves

Personal Protective Equipment (PPE)

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1

2

3

Glove Sample	Soiled	Wetted Outside	Wetted Inside	Measured milliAmps, DC 50 Vdc	300 Vdc	600 Vdc	1000 Vdc
1	no	no	no				0
2	no	no	no				0
3	no	no	no				0
1	no	yes	no	91	>250		
2	no	yes	no	0.5	2	100	>250
2	no	yes	yes	38	89	>250	>250
3	no	yes	no	3	17	24	54
3	no	yes	yes	43	>250		
1	yes	no	no				0.5
2	yes	no	no				0
3	yes	no	no				0
1	yes	yes	no	91	>250		
1	yes	yes	yes	93	>250		
2	yes	yes	no	0	2	3	4
2	yes	yes	yes	64	>250		
3	yes	yes	no	0	0	0	0
3	yes	yes	yes	78	>250		

Safe | Perception | Lock On | Electrocution

Firefighter Safety and Photovoltaic Systems

Personal Protective Equipment (PPE)

1

2

3

Boot Sample	New	50% Toe Aged[1]	100% Toe Aged[2]	Hole in Bottom[3]	Measured milliAmps, DC[4] 50 Vdc	300 Vdc	600 Vdc	1000 Vdc
1	X							0
2	X							0
3	X				6	45	94	160
1		X			1	7	18	35
2		X			13	108	>250	
3		X			13	99	>250	
1			X		4	78	135	240
2			X		30	184	>250	
3			X		26	>250		
1				X	27	178	>250	
2				X	31	212	>250	
3				X	30	204	>250	

Safe	Perception	Lock On	Electrocution

Firefighter Safety and Photovoltaic Systems

Alternative Light Sources

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- Artificial light sources
  - In most cases, artificial light produced enough power to energize PV to a dangerous level
- Light from fire
  - UL concluded dangerous voltages were present at each distance
- Moonlight
  - UL concluded dangerous voltages were **not** present in moonlight conditions with no other ambient light present
  - From 20 minutes after sunset to 20 minutes before sunrise
  - Caution should still be used as equipment can vary

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Electrical Hazards

Cutting Live Conductors

UL tested effects of cutting conductors and conduit with live hazardous DC voltages:

- Uninsulated cable cutter
- Fiberglass handle axe
- Rotary saw
- Chain saw

Source: UL.com

Source: UL.com

Source: UL.com

Source: UL.com

Damaged Models/Equipment

UL tested two types of damage:

- Physical with axe or other tool
- Damage from fire

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Damaged Models/Equipment

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Physical damage test with glass frame modules:

- Axe or other tool was grounded, similar to wire cut test
- Arcing and flames occurred

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Source: UL.com

Damaged Models/Equipment

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UL tested many modules after exposure to fire:

UL

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Figure 101 Open flames on roof

Figure 102 Modules sagging

Figure 103 Roof and modules collapsing

Figure 104 Roof collapsed -fire extinguished

Damaged Models/Equipment

After fire:

- Array reconstructed

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Figure 113 Post fire, front surface

Figure 114 Post fire, back surface

Damaged Models/Equipment

Every module tested

Source: UL.com

Figure 117 - Module D1 – badly burnt on backside, but functional and producing full voltage

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Damaged Models/Equipment

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60% of modules still produced full power

Only 25% completely destroyed → no power

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Figure 112 Roof diagram after fire: X = no power, dashed-X = partial power

Shock Hazards

During and Post-Fire…

Shock Hazards

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UL identified many shock hazards present

- Bare conductors
- Energized racking
- Energized metal roof

Figure 184 Looking under module for dangers

Source: UL.com

Figure 185 cutting leads

Figure 183 Bare energized conductors contacting broken rails and metal frames

Night time fires involving PV systems

Use caution during overhaul as PV wiring can be hidden attics and walls

Modules can produce dangerous voltage from scene lighting

PV modules will become energized during daylight hours

Other Hazards

Beyond the wires…

Inhalation hazards (This is nasty smoke)

You MUST use SCBA when dealing with fire involving PV arrays

- Treat it like the Hazmat call it is

PV cells can produce three main chemicals when burning:

- Cadmium Telluride (usually on commercial or utility scale installations)
  - Carcinogenic
- Gallium Arsenide
  - Highly toxic and carcinogenic
- Phosphorous
  - The worst of the three
  - Lethal dose is 50 mg

In addition to electrical hazards

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Broken glass

Falling modules

Tripping and slipping hazards can be amplified on pitched roofs

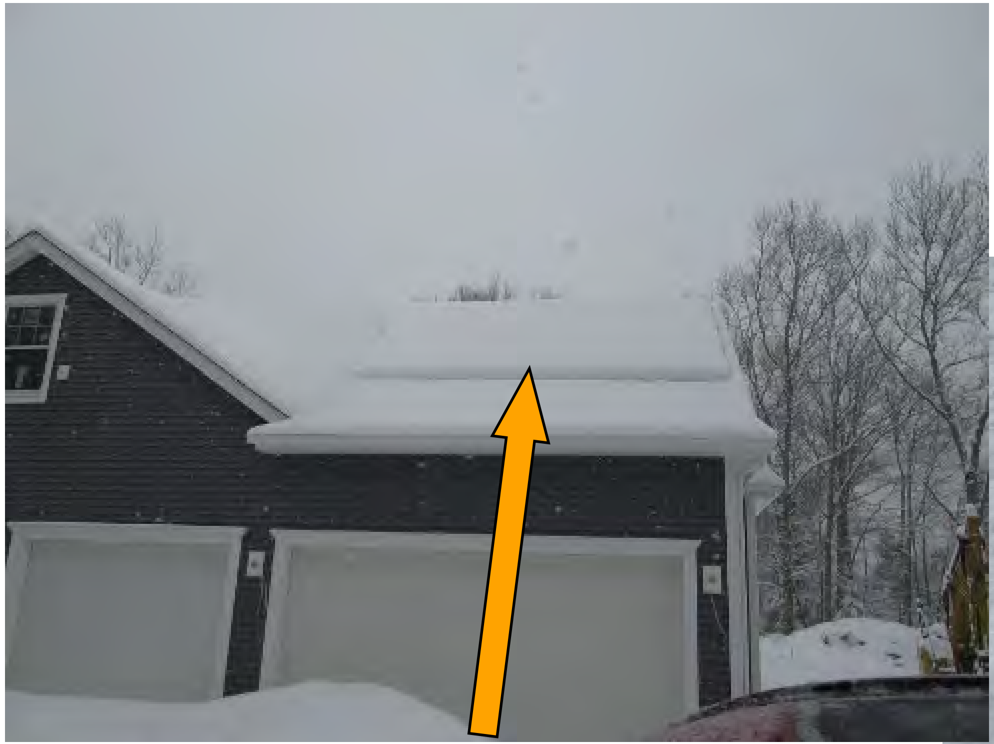
Insects and rodents

Trip/Slip Hazards

Be aware of conduit and conductors flat rooftops.

Poor wire management leads to additional hazards.

Trip/Slip Hazards



Array covered entirely in snow.

Rooftop conduits buried in snow.

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U.S. Department of Energy

In Conclusion

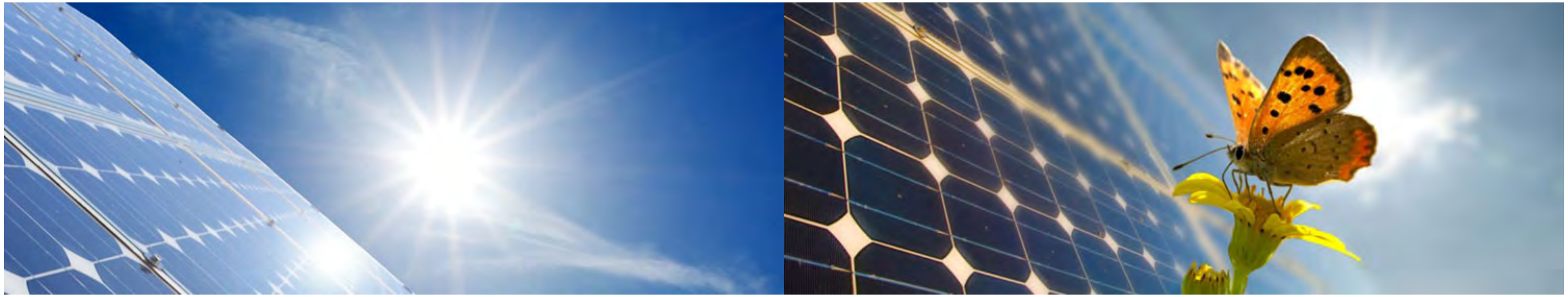
- Work with building department to determine locations of all PV systems on buildings in your district

- Familiarize yourself with the systems on large public buildings, installers/inspector will often welcome a tour to learn the hazards

- Always treat all conductors as live until proven otherwise by a qualified person

Currently there have been no United States fire service related deaths resulting from incidents involving Photovoltaic systems.

Through education, training, preplanning and a solid partnership with the PV industry our goal is to keep this number at ZERO.



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Resources

[UL Firefighter Safety and PV Course]
[IREC Online Training for Firefighters]
[Fire Fighter Safety and Emergency Response for Solar Power Systems]
[Rooftop Solar PV & Firefighter Safety]
[Free access to 2015 I-Codes]

Thank you!

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Case Study - Terracycle

Trenton, New Jersey

Date of fire: 3/27/12

Contractors finishing 100 panel PV system installation

Rooftop inverter arced, shocked several workers and started a fire in several junction boxes

Contractors disconnected sections to allow FF's to extinguish fires. Dry chemical extinguishers were used each time a box was taken offline. Almost 2 hours until all power was cut.

Old Bridge Volunteer Fire Department

East Brunswick, NJ

- Date of fire: February 11, 2016
- Macy's Department store, East Brunswick Square mall
- Fire reported at approximately 10:00 am
- Incident Commander reports fire in Solar panels on roof
- 2nd Alarm transmitted
- Access to roof made and disconnects utilized
- Aerial ladder used with fog pattern to extinguish fire
- Fire contained to Solar panels, overhaul withheld until contractor arrived on scene (1 hour from notification)
- Approximately 30 modules involved
- <u>Department had no formal training in Safety around solar panels</u>


901
macy's