Fire Safety for Solar PV

October12, 2017
NCTCOG, Dallas TX

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Reducing the cost of solar for 300 communities throughout the country

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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

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

- *Directs 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*
- *Lead the Massachusetts Commercial Solar + Storage program to provide education and technical assistance to commercial interested in solar + storage procurement*
- *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 and Disclaimer

Acknowledgements

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), Interstate Renewable Energy Council (IREC), the National Electrical Code (NEC), Solar ABCs, the Department of Energy (DOE), IAEI

Acknowledgements and Disclaimer

Disclaimer

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.

Acknowledgements and Disclaimer

Disclaimer

National Electrical Code

Texas recently adopted the the 2017 National Electrical Code. Not all jurisdictions presently enforce the 2017 version of the NEC. Effective March 13, 2015, the City of Dallas adheres to the 2014 NEC with Dallas Amendments. 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 concerns expressed by the fire fighting community with regard to solar electric systems.

Acknowledgements and Disclaimer

Disclaimer

Texas & Dallas Construction Codes

At the state level, the Uniform Code Code cycle is based on the 2006 International Codes. Texas Jurisdictions are authorized by state law to adopt later edition of the IBC, IRC, IPC, IMC, IFGC, and IECC. This presentation has been adapted to reflect the 2015 International Codes and recommended best practices.

The City of Dallas The Building Code Council adopted amendments that have been approved by the Rules Advisory Council are as follows (Jurisdictions may vary statewide):

- 2015 Fire, Building, Plumbing, Mechanical, Residential, International Energy Conservation, Fuel & Gas, and Green Construction Codes **with Dallas Amendments**
- 2003 Existing Building with Dallas Amendments

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

About Egan Waggoner

- Consultant, Solar PV and Renewable Energies
  - Meister Consultants Group, A Cadmus Company

  - M.S. Environmental Science, Energy & Water Resources
    - SUNY College of Environmental Science
  - B.A. Biology, University of Kansas

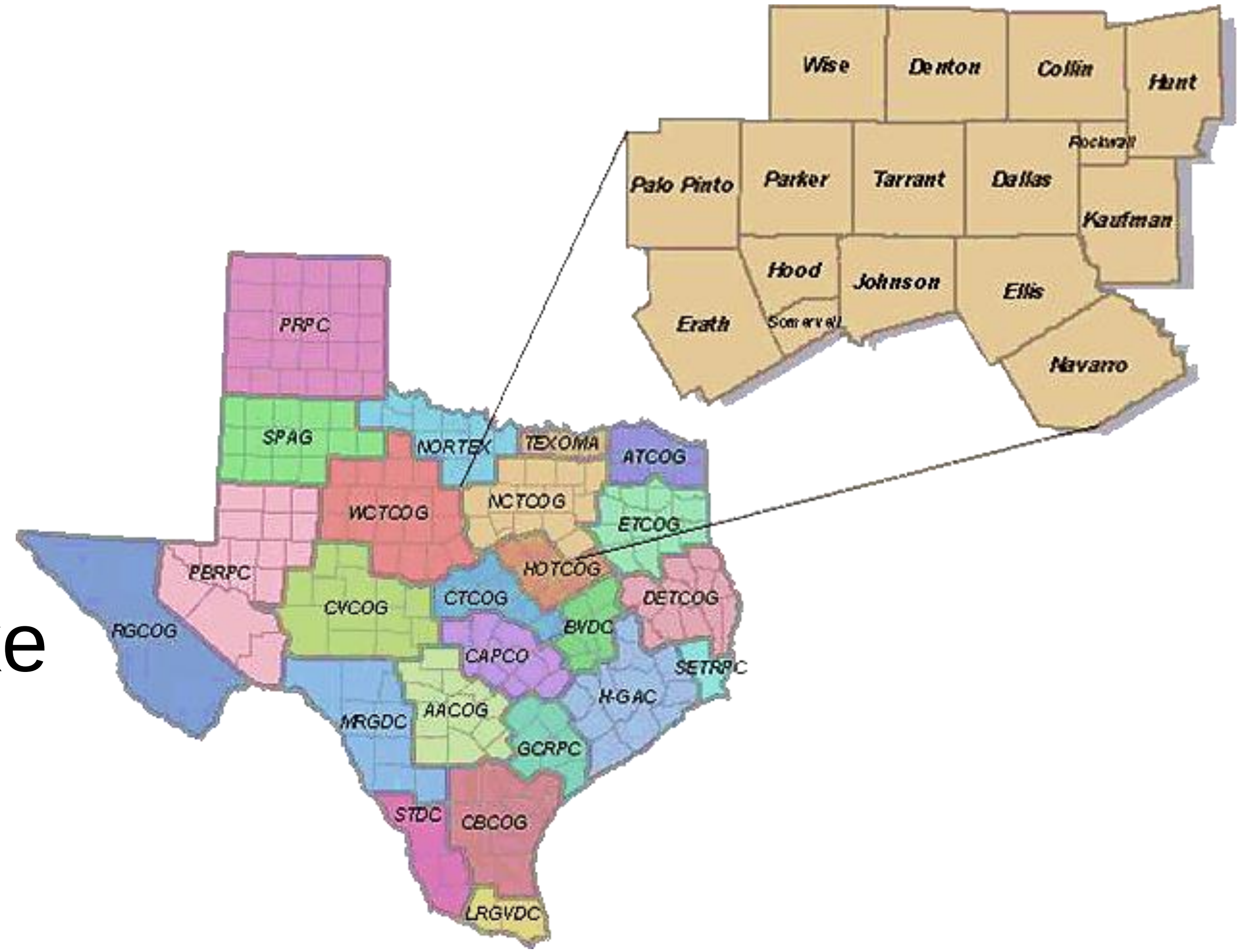
- Technical Team Coordinator - NY-Sun PV Trainers Network
- Solsmart Technical Assistance
- NYSERDA large scale renewables team
- NYSERDA storage technical assistance team

Audience Introduction

- Where are you from?

- What's your job or role in local government?

- What are you hoping to take away from today's presentation?



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Introduction to Solar Technology

Solar Photovoltaic (PV)

Solar Hot Water

Concentrated Solar Power

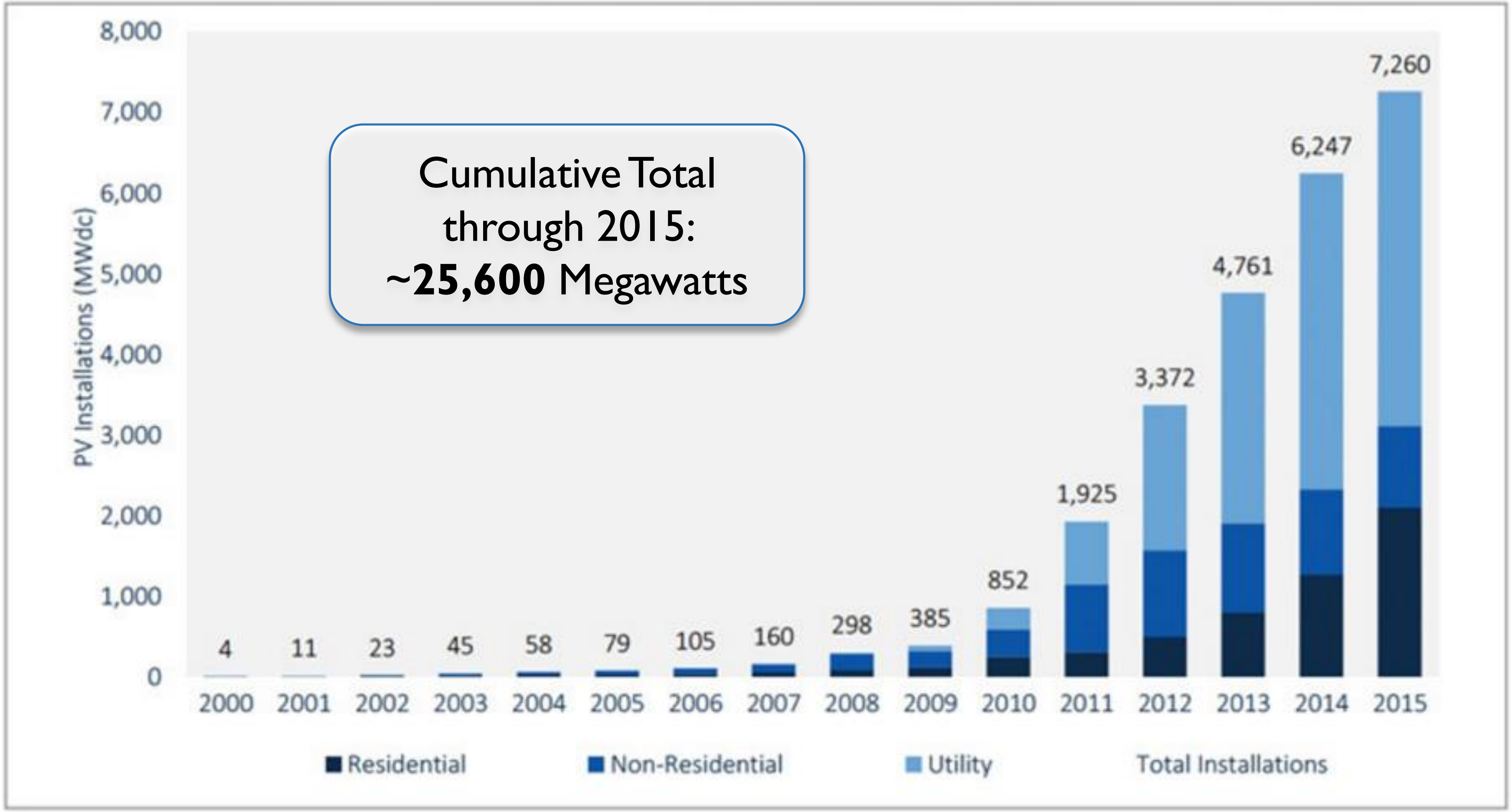
Introduction to Solar Technology

Solar Photovoltaic (PV)

Solar Hot Water

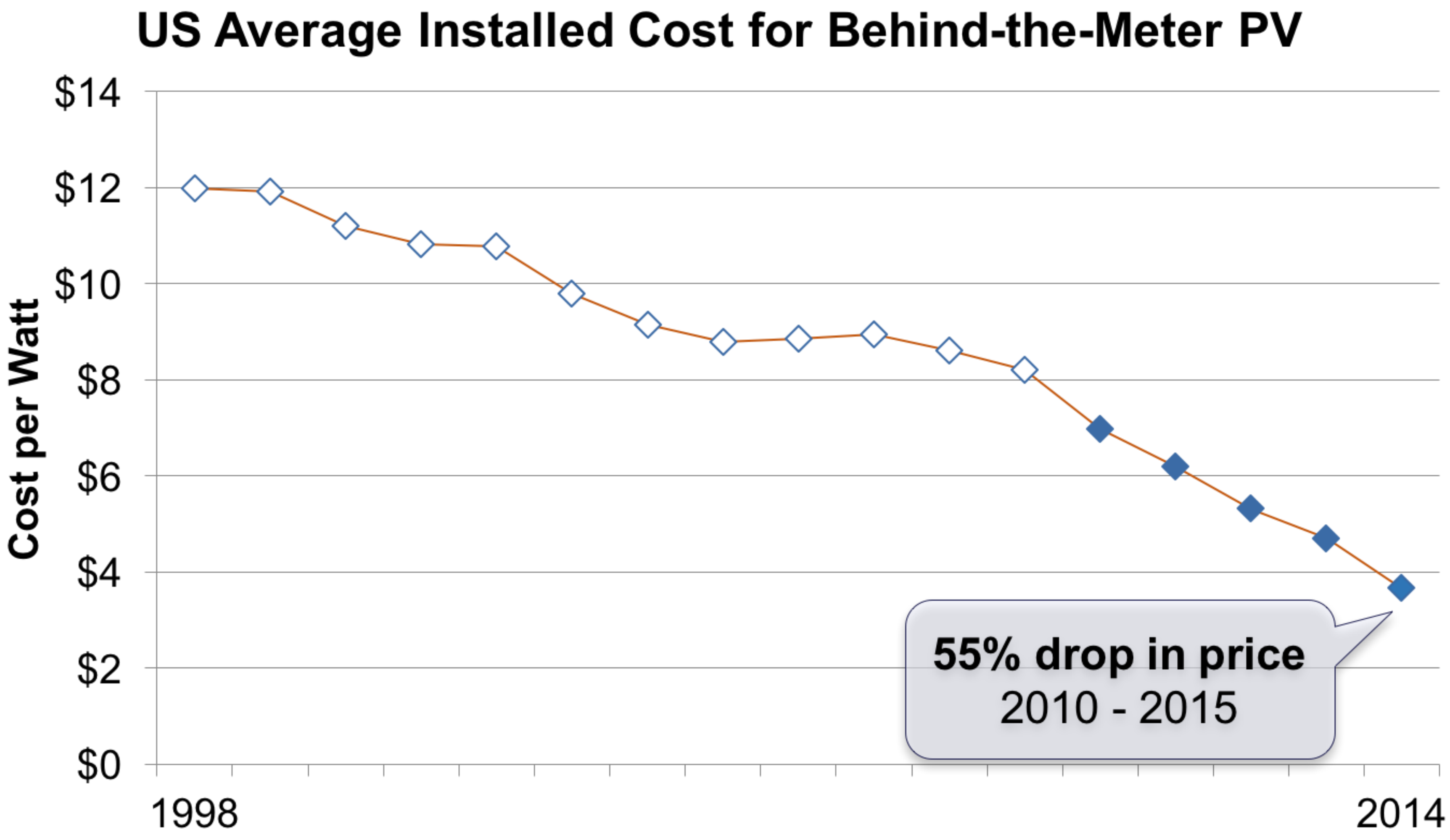
Concentrated Solar Power

US Solar Market – annual installations



Source: SEIA/GTM Research, U.S. Solar Market Insight: 2015 Year-in-Review

US Residential Solar PV Cost



Source: Tracking the Sun VI: The Installed Cost of Photovoltaics in the US from 1998-2013 (LBNL); Solar Energy industry Association, Solar Market Insight Report 2014 Q4

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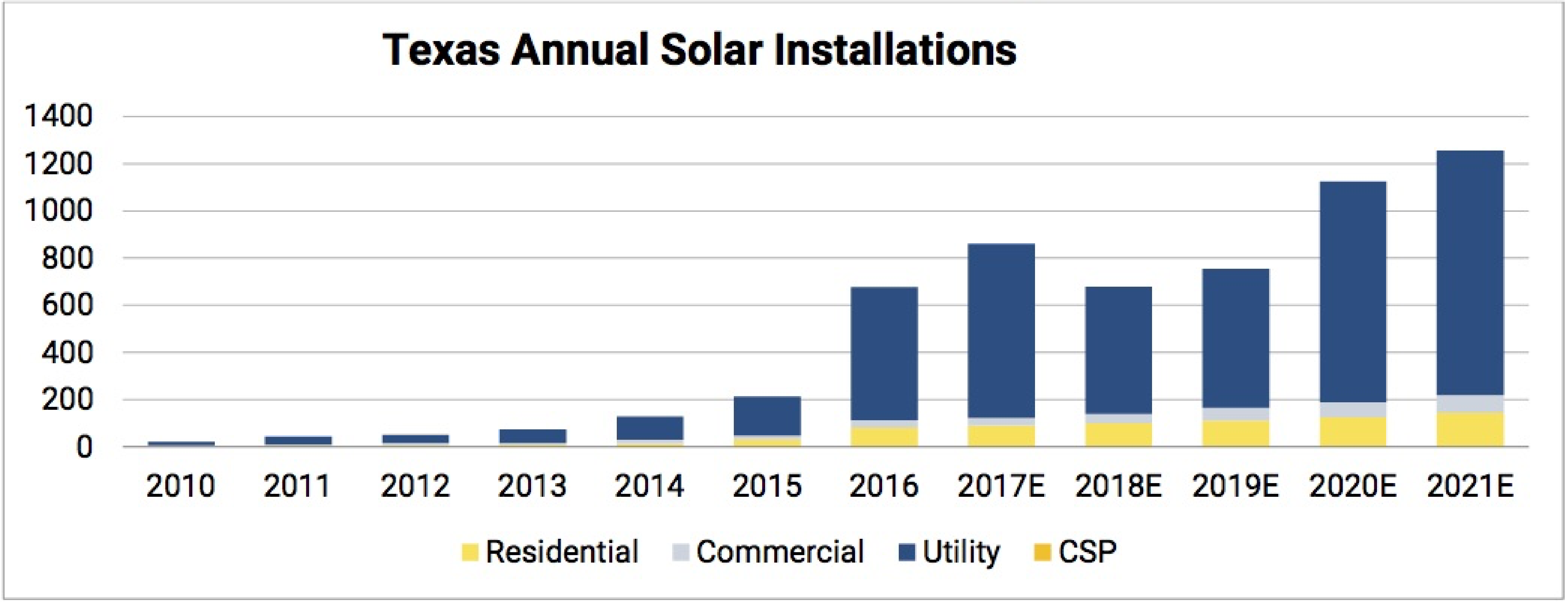
Texas Solar Market



Source: SEIA/GTM Research U.S. Solar Market Insight, 2016: http://www.seia.org/state-solar-policy/texas

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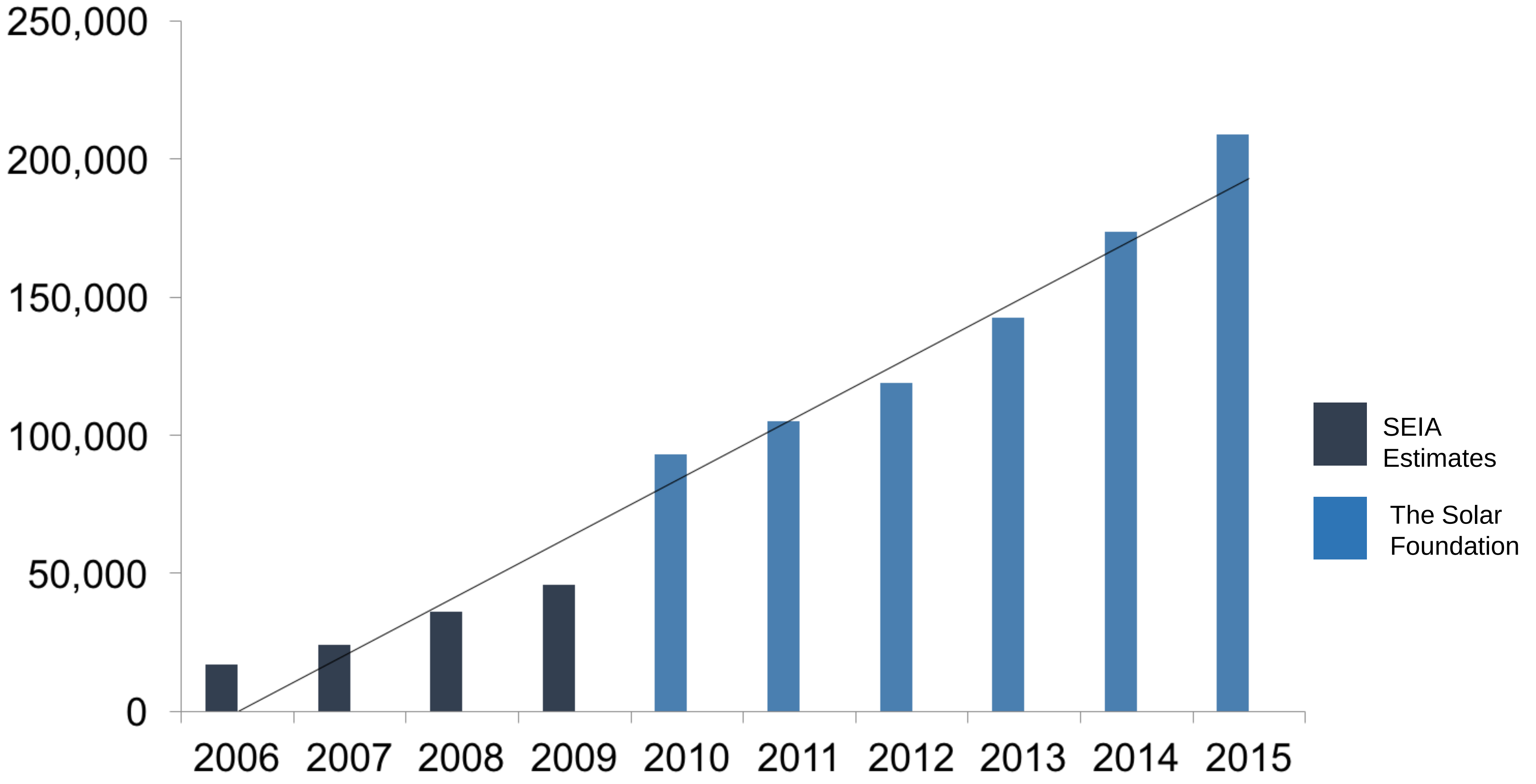
Solar Job Growth in the US



Source: SEIA Estimates (2006-2009),The Solar Foundation’s National Solar Jobs Census 2010 (2010),The Solar Foundation’s National Solar Jobs Census 2013 (2011-2015).

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Solar Jobs in TX

In 2016, Texas had

9,396 persons employed in solar jobs

across

565 different companies

The Solar Foundation – National Solar Jobs Census (2015)

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Quick Facts on Texas Solar Market

7th solar installations in 2016

3rd in solar jobs across US

#7 cumulative installed solar capacity

Source: SEIA; The Solar Foundation;

What is PV?

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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

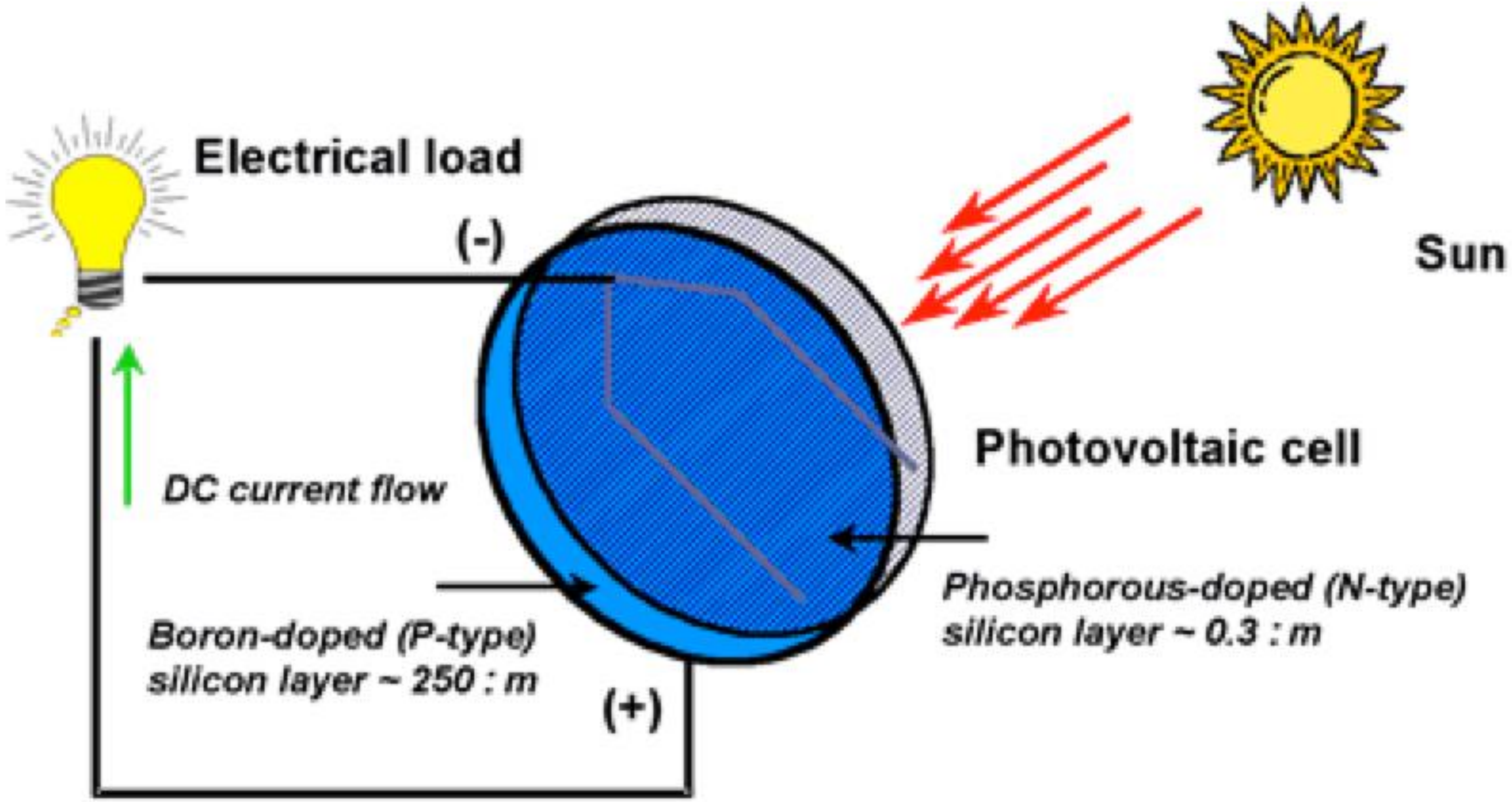
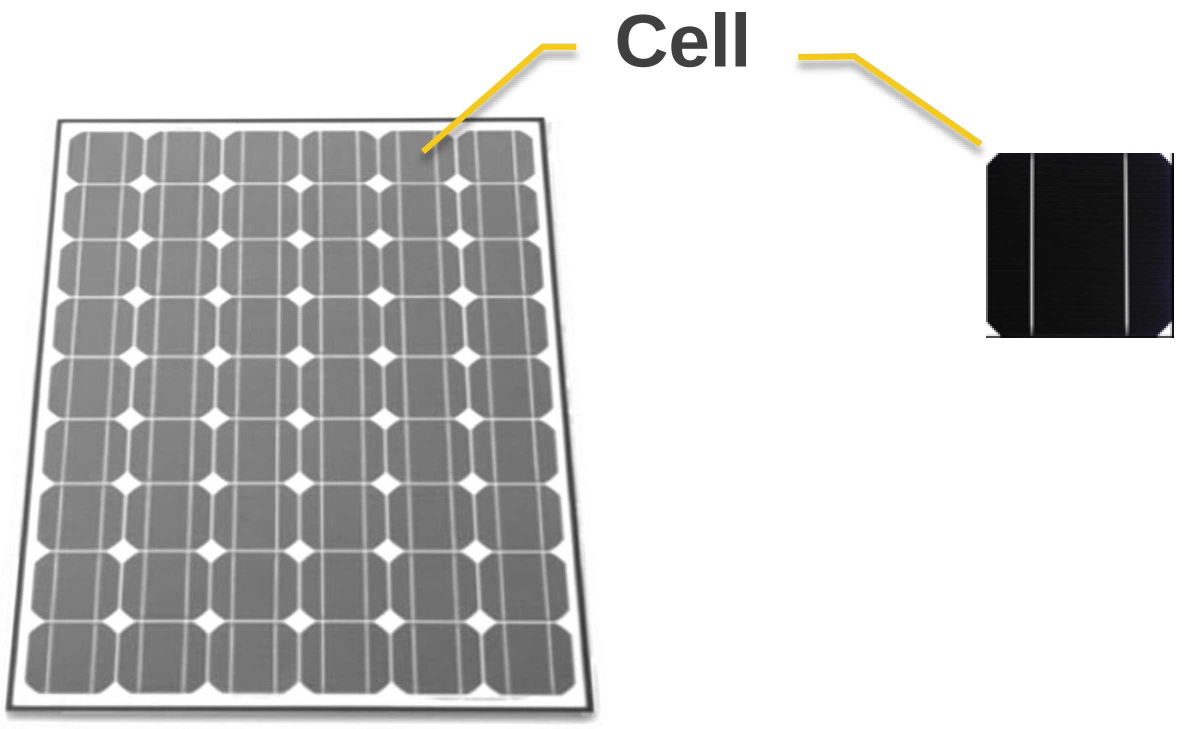


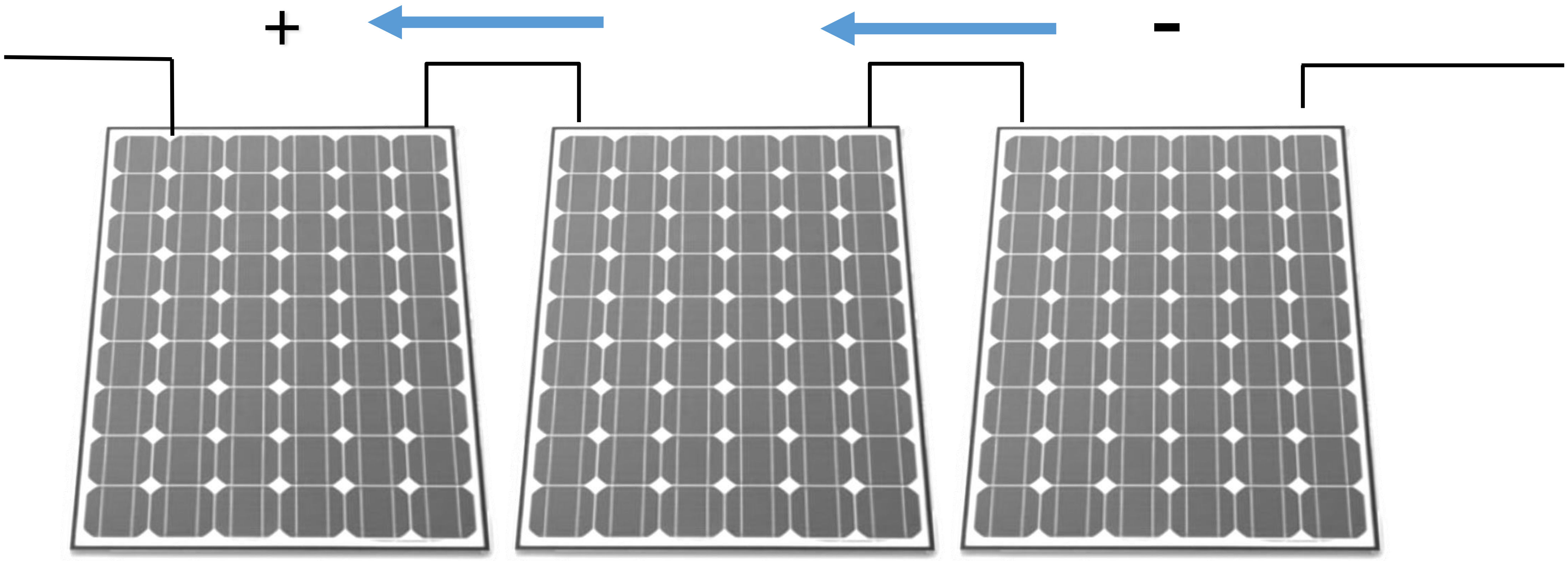
Image from MIT power supply presentation

Some Basic Terminology



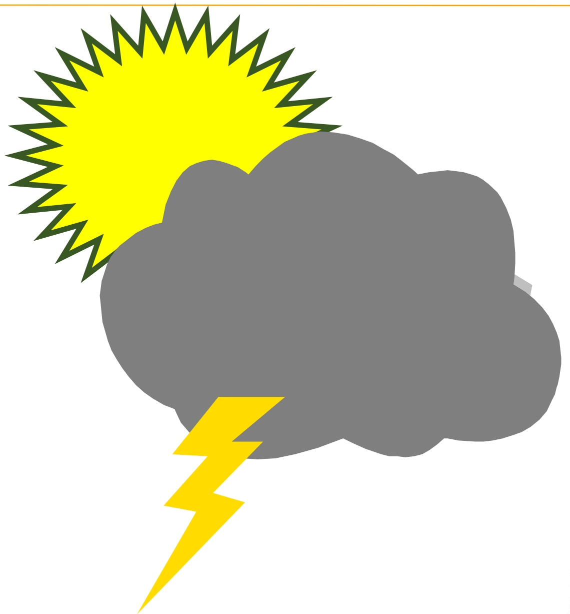
Panel / Module

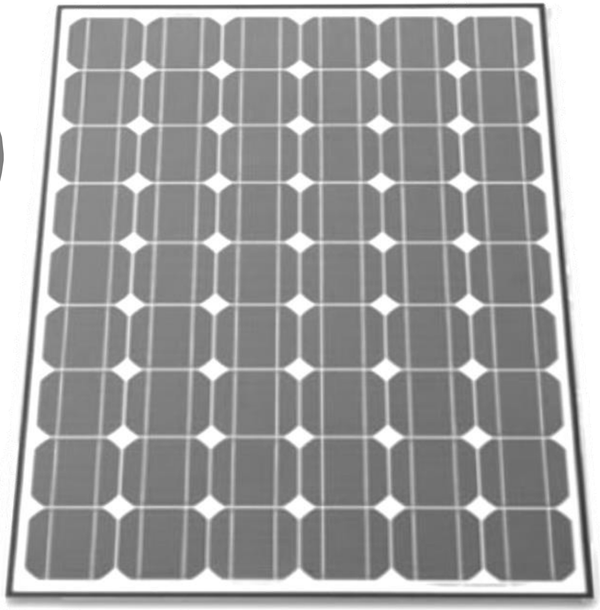
Some Basic Terminology



Array

Some Basic Terminology





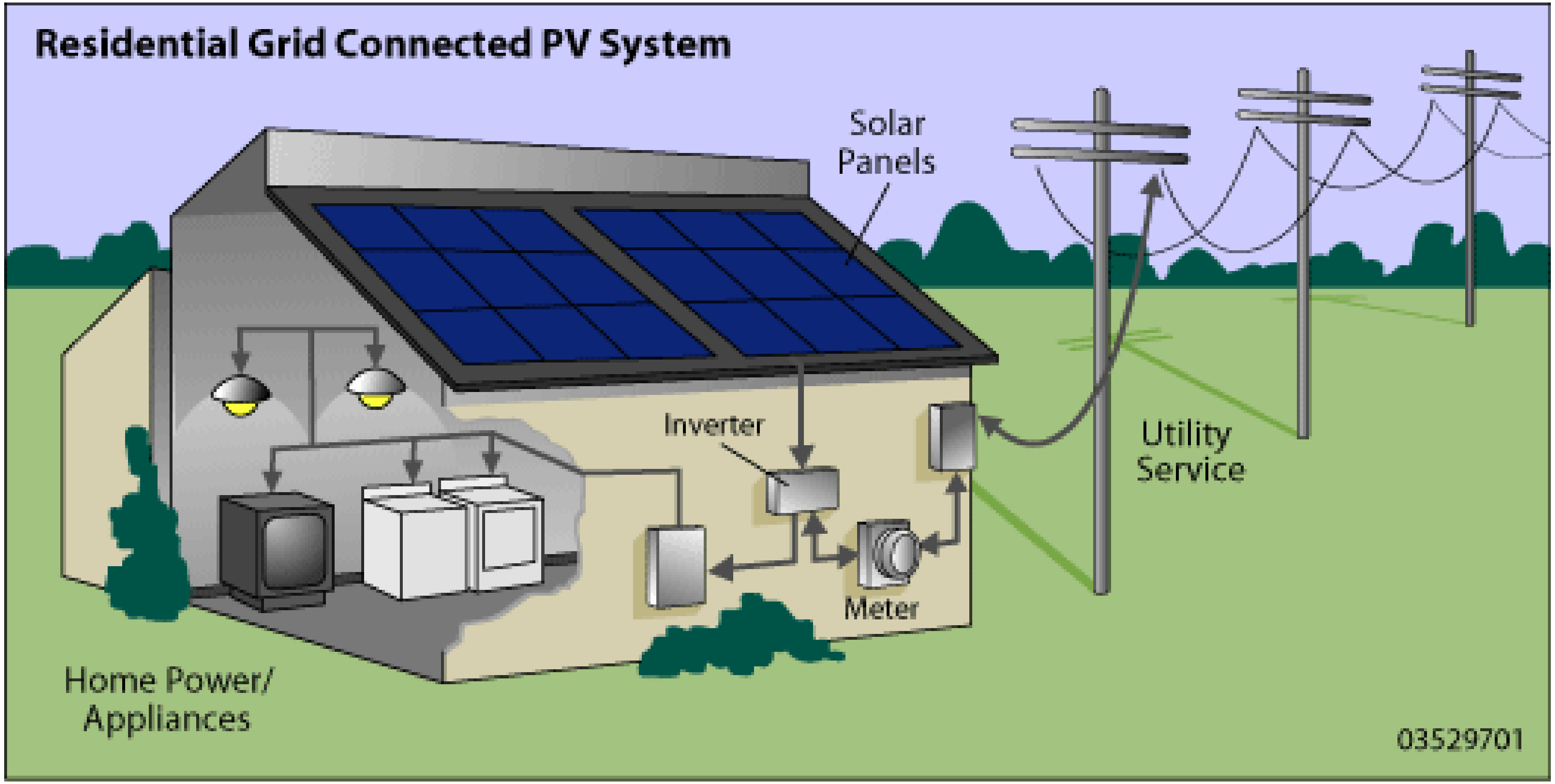
Production

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+

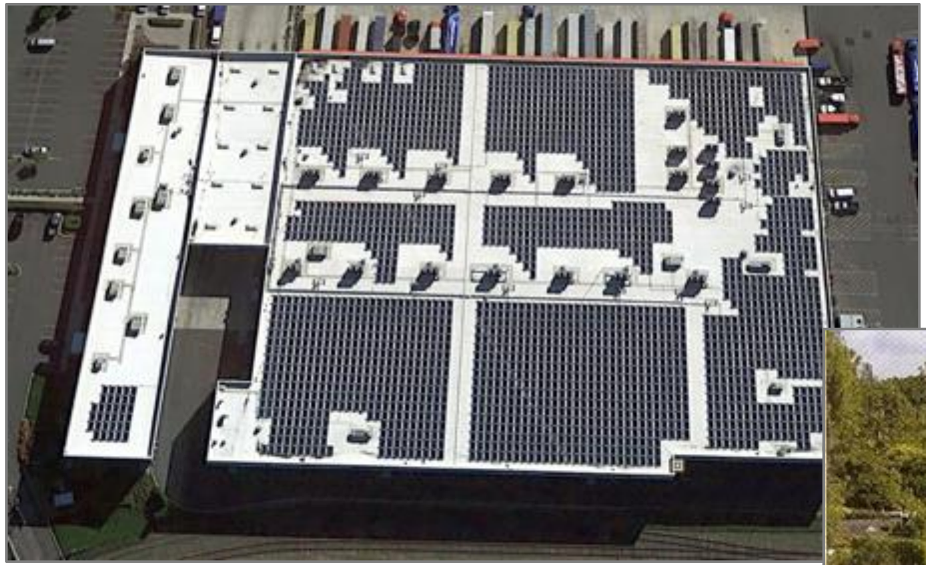
Solar PV System Types

Roof Mount	Ground Mount	Parking Canopy
		

Residential Rooftops

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

Commercial Rooftops



Commercial Rooftops

Shading Structures or Canopies

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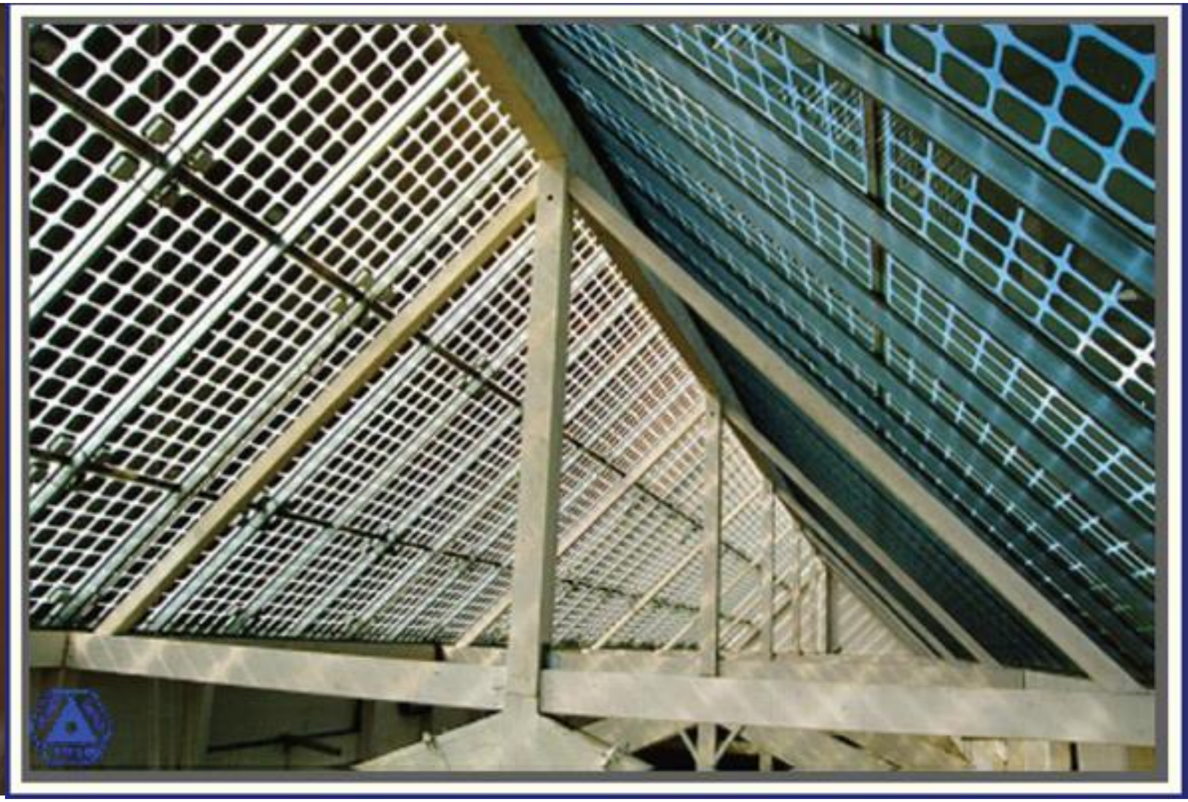
Ground Mount Systems

Rooftop Canopies



Pole Top Mounts

Solar Skylights



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Solar Shingles

Image from PV Magazine

Building Integrated

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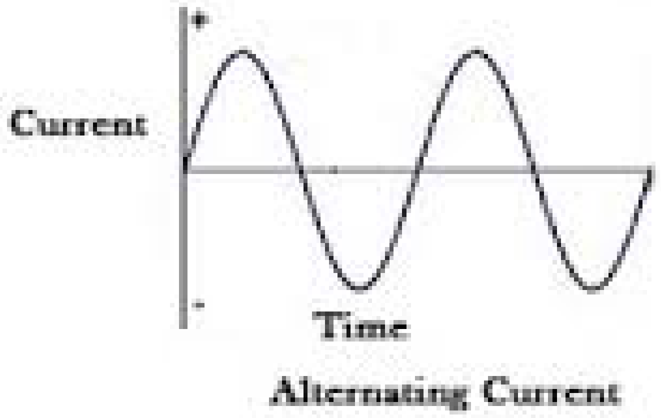
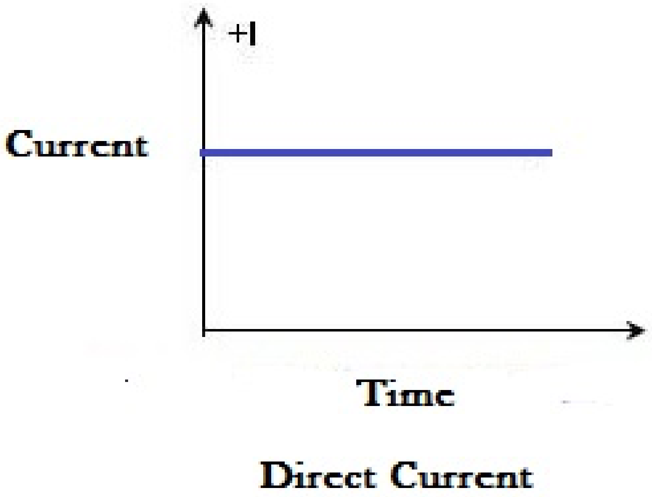
Types of Electrical Current

Alternating Current



- Utility Power
- Generators

Direct Current

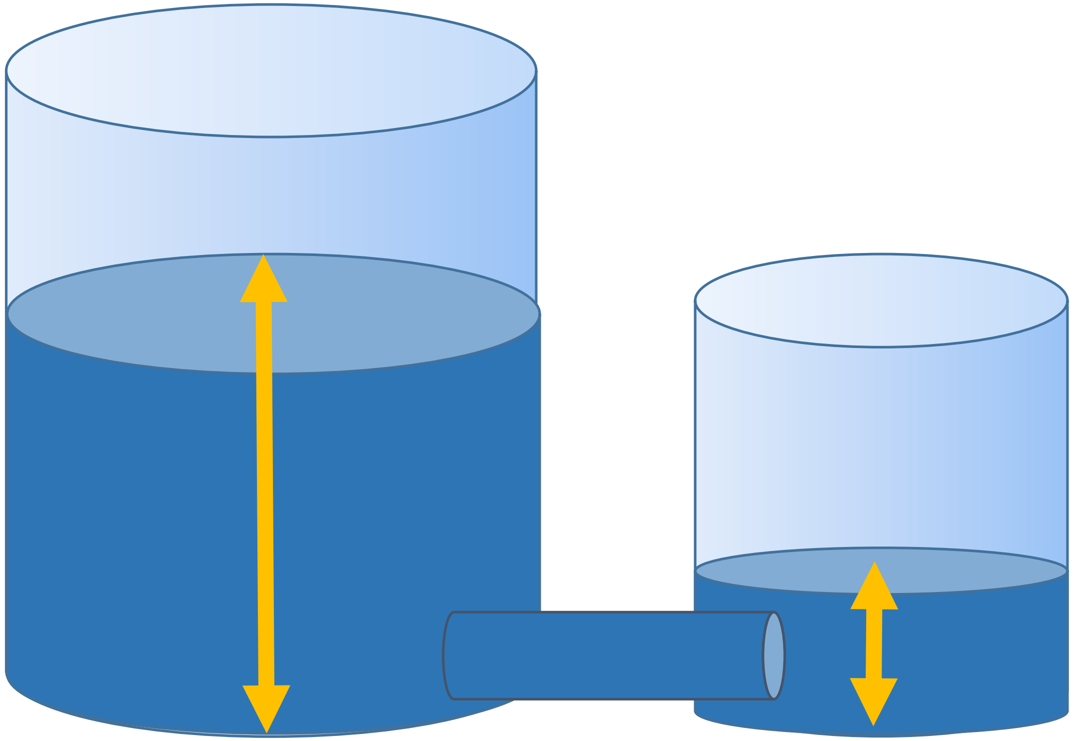


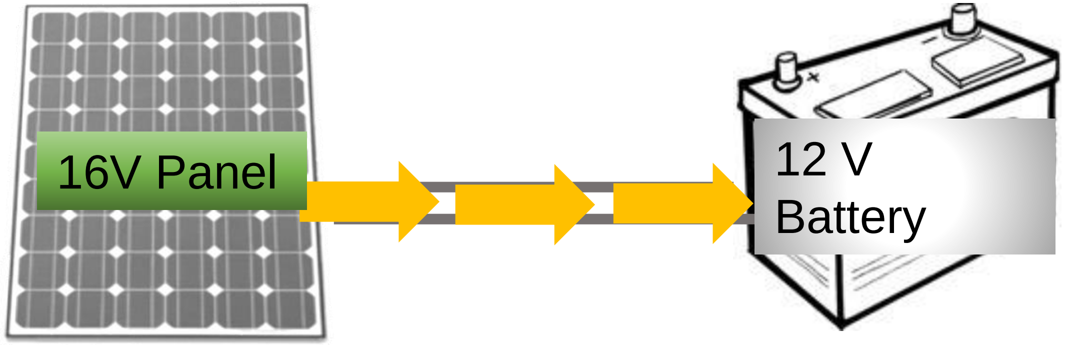
- PV Cells
- Batteries

Images courtesy of Durofy

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

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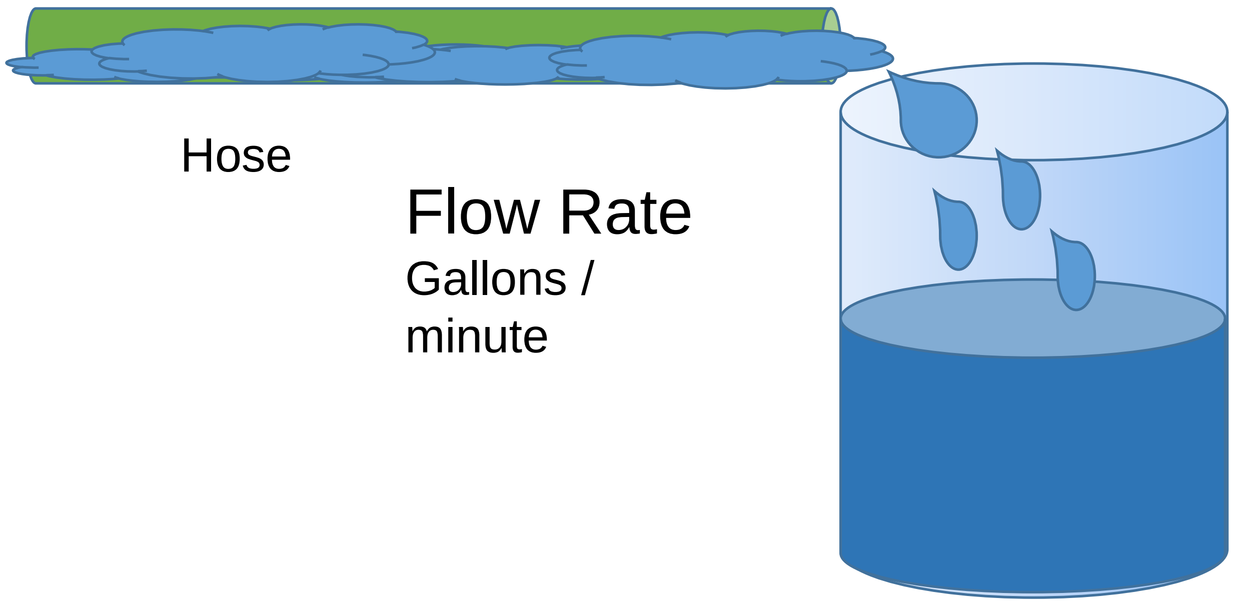
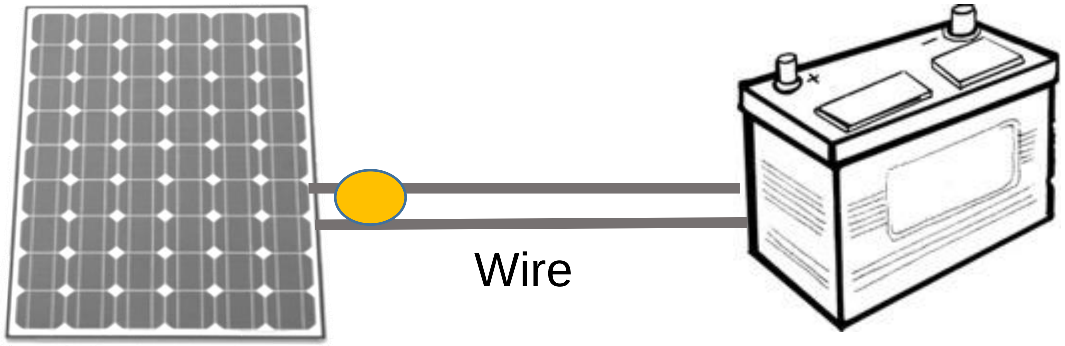
Water Analogy	Electrical Concept
Water flow rate → gallons per minute	Electron flow rate → Amps





Graphics: Egan Waggoner

Concept source: Solar Energy International

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Resistance

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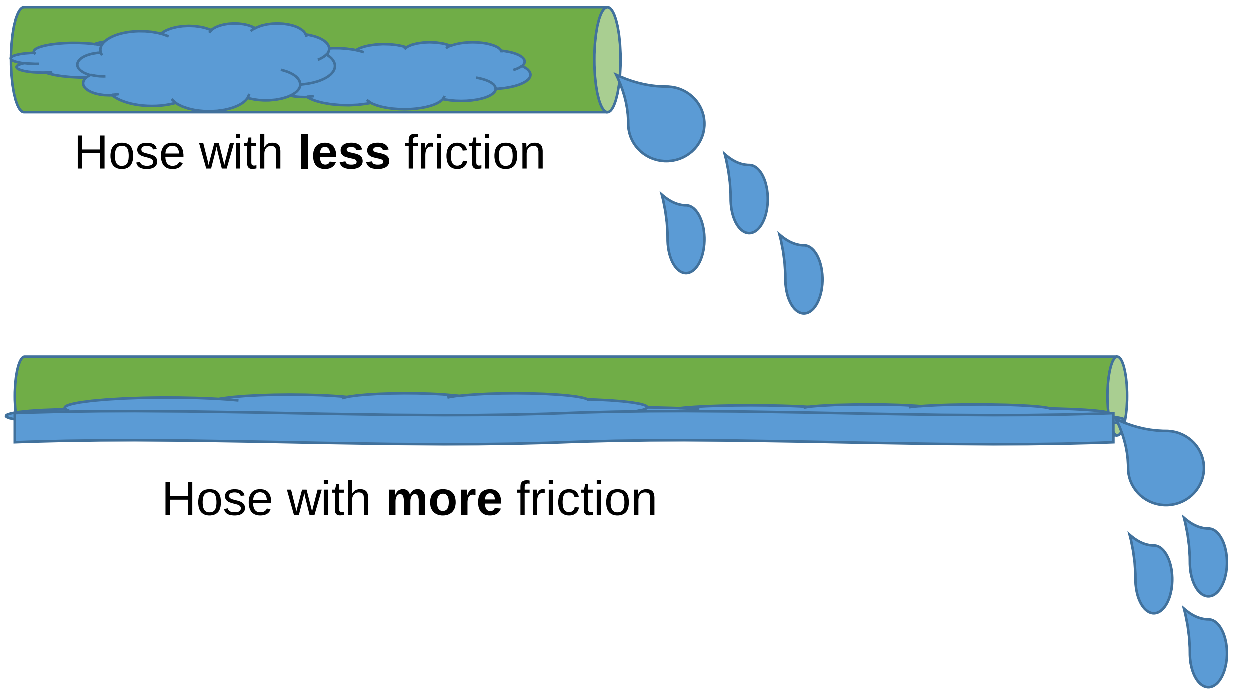
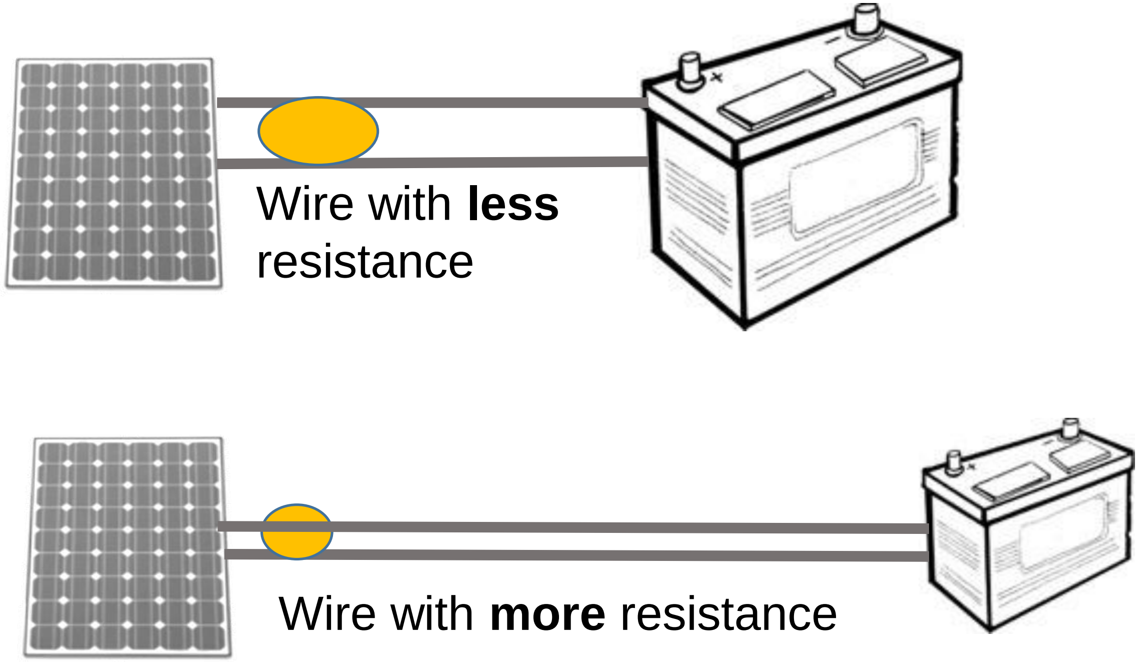
Water Analogy	Electrical Concept
Opposition to flow → friction in hoseline	Opposition to flow → Resistance





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Graphics: Egan Waggoner

Concept source: Solar Energy International

Resistance

Water Analogy	Energy Concept
PSI = GPM x FL	V = I x R
PSI = Pressure GPM = Gallons per minute FL = Friction loss in hoseline Potential difference → Pressure	V= Voltage I = Current (Amps) R =Resistance (Ohms) Potential difference → Pressure

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

System Components: Modules

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1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch/Overcurrent Protection

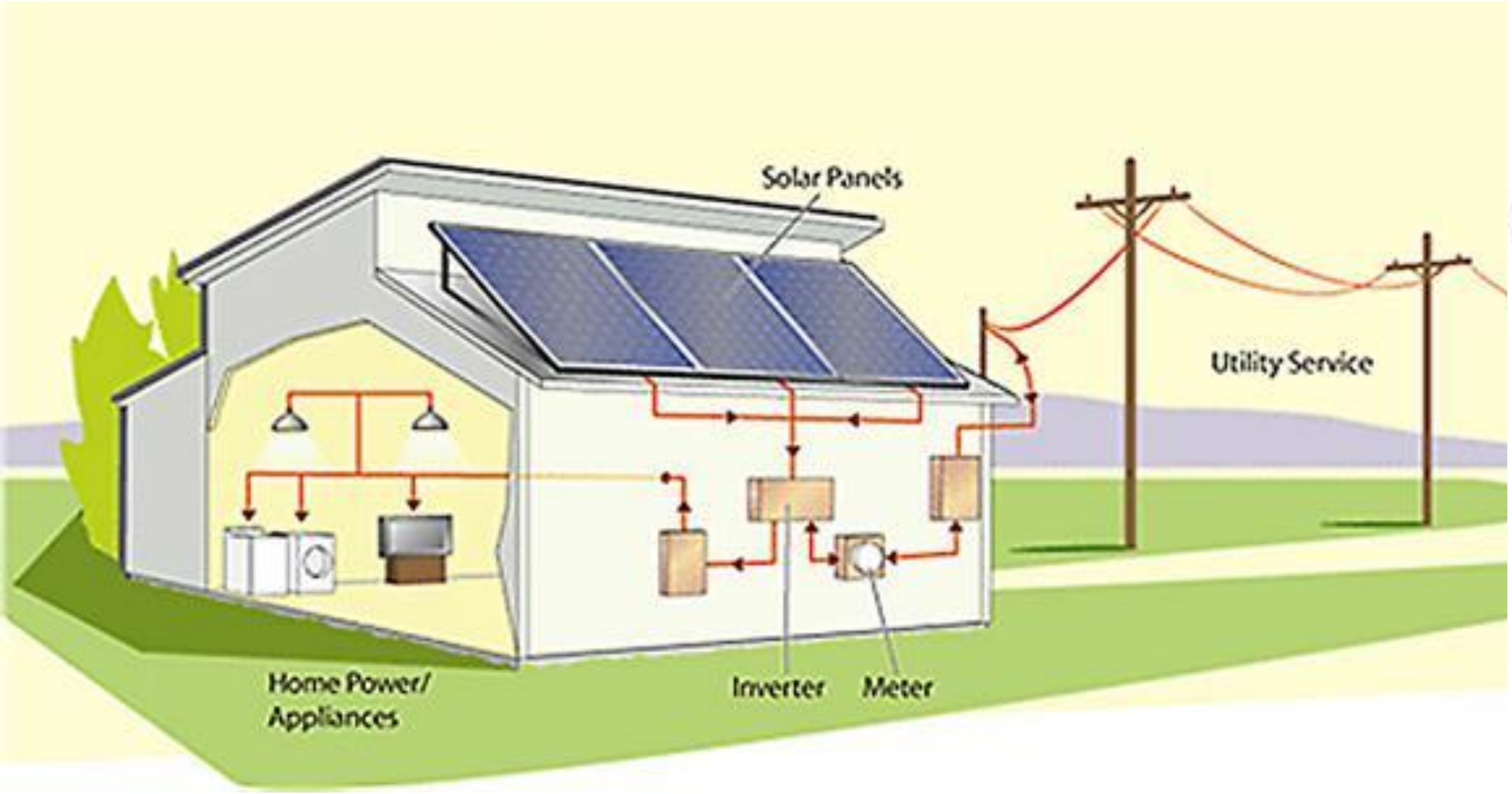
4 Inverter

5 AC Disconnect Switch/ Overcurrent Protection

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

Solar Electric System Components



System Components: Modules

1

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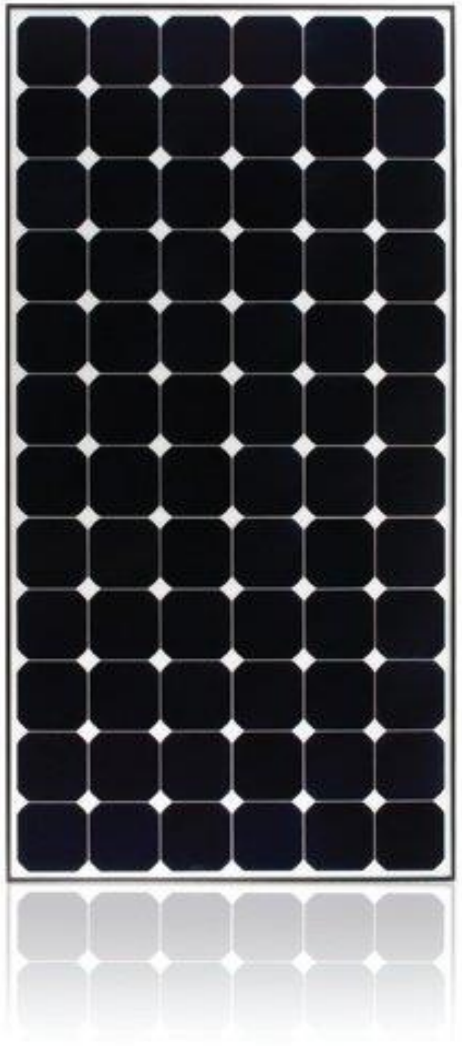
System Components: Modules

1 Poly

Mono



Thin film

System Components: Modules

1

Module Specifications Sheet:

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

System Components: Modules

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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

System Components: Combiner Boxes

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch/Overcurrent Protection

4 Inverter

5 AC Disconnect Switch/ Overcurrent Protection

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

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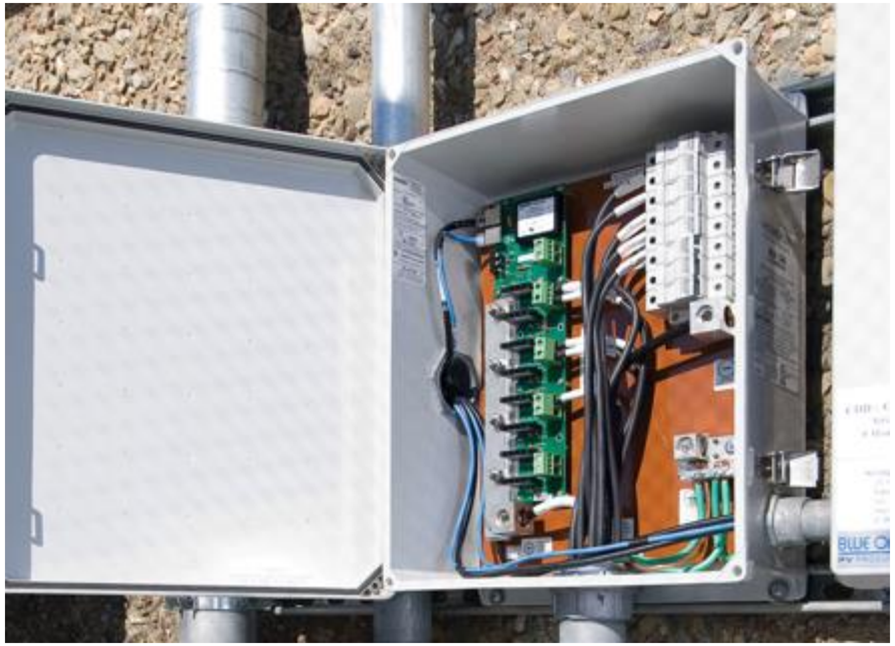
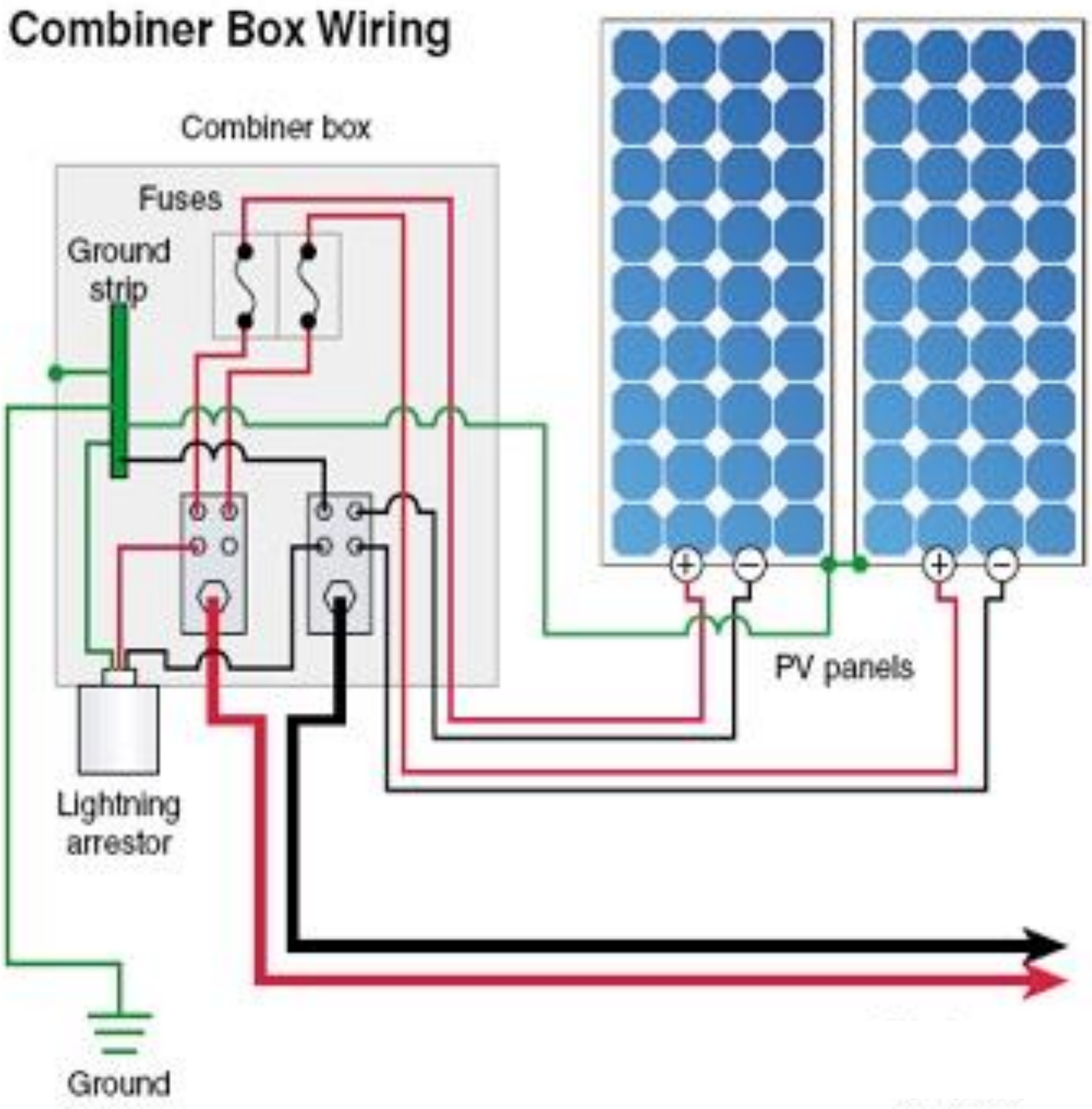
System Components: Combiner Boxes

2



System Components: Combiner Boxes

2



System Components: DC Disconnect Switches

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch/Overcurrent Protection

4 Inverter

5 AC Disconnect Switch/ Overcurrent Protection

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.

System Components: DC Disconnect Switches

3

Five pieces of information:

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

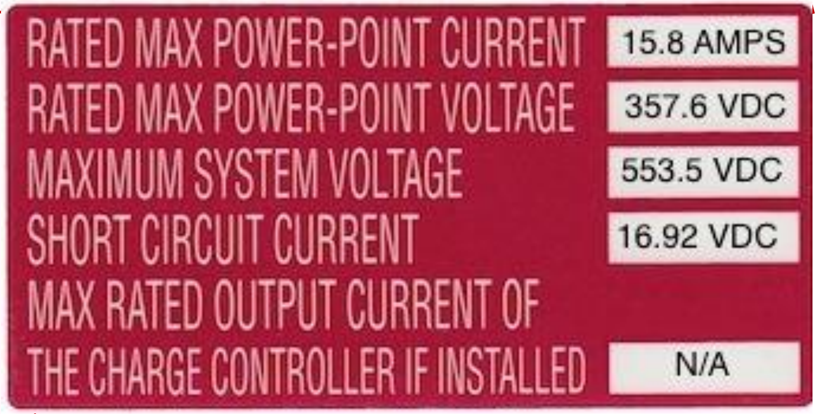
Current
- *Isc* (short circuit current)
- *Imp* (maximum power point current)

Current
- Presence of *charge controller*

Per NEC 690.52

DC Disconnect/Breaker

Per NEC 690.53



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.

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System Components: DC Disconnect Switches - Rapid Shutdown

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PHOTOVOLTAIC SYSTEM EQUIPMENT WITH RAPID SHUTDOWN

- Appears in the 2014 NEC to address the concerns of first responders when responding to a fire on a structure or system
- For roof mounted PV systems but may apply to ground mount systems in some circumstances
- Allows first responders to quickly and easily control PV system circuits when leaving an an array in a PV system

System Components: DC Disconnect Switches - Rapid Shutdown

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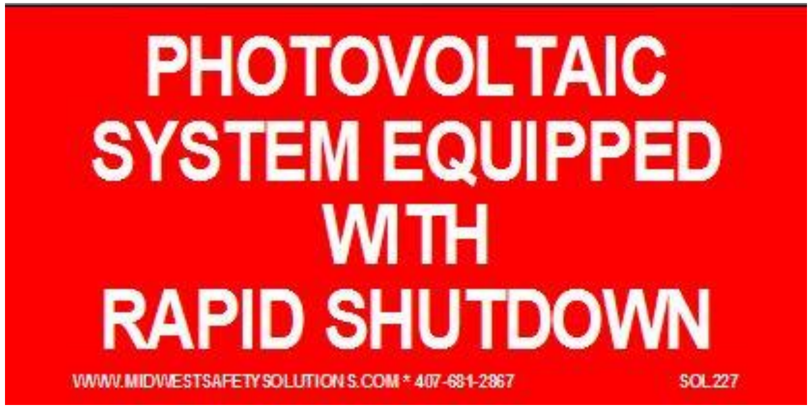

System Components: Inverter

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1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch/Overcurrent Protection

4 Inverter

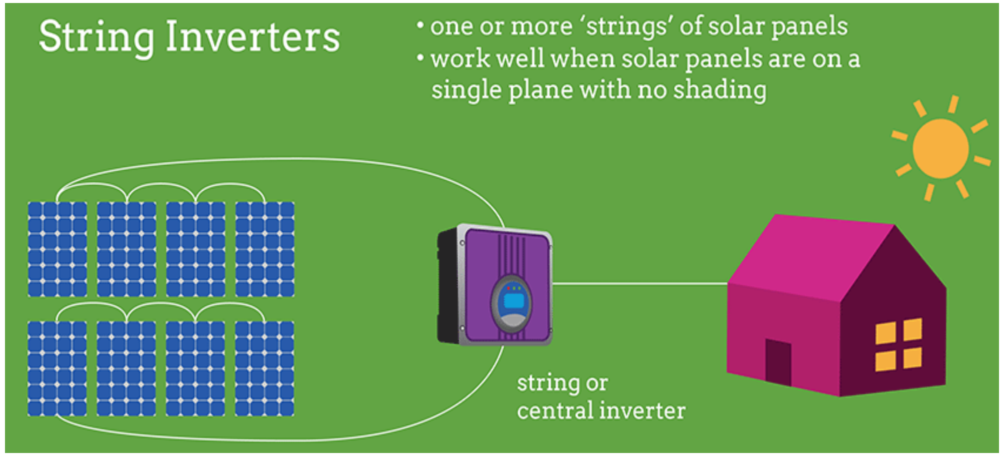
5 AC Disconnect Switch/ Overcurrent Protection

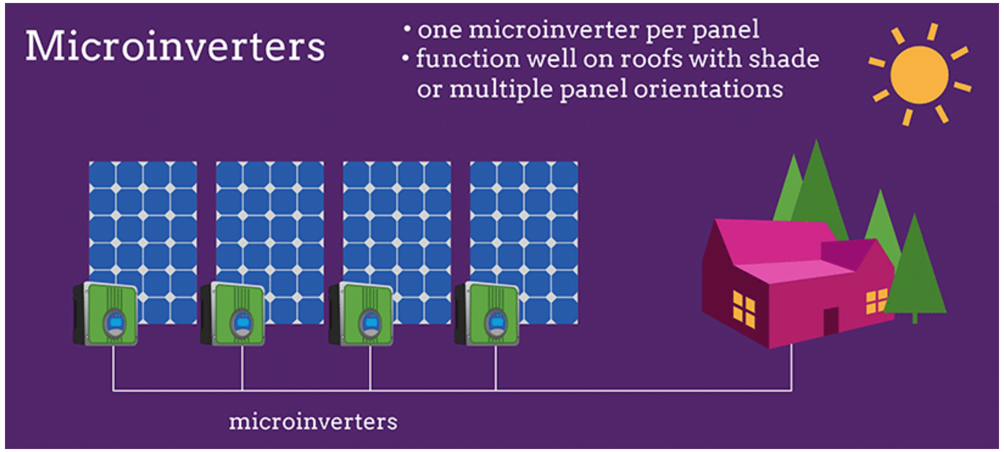
6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

System Components: Inverters

4





- Inverters (non-battery) convert dc power from the PV modules to AC power.
- Disconnecting the AC utility power sources turns off the inverter, but DOES NOT disable the DC solar module circuit.

System Components: Non Battery String or Central Inverters

4

Non 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.

System Components: Micro inverters

4

Non 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.

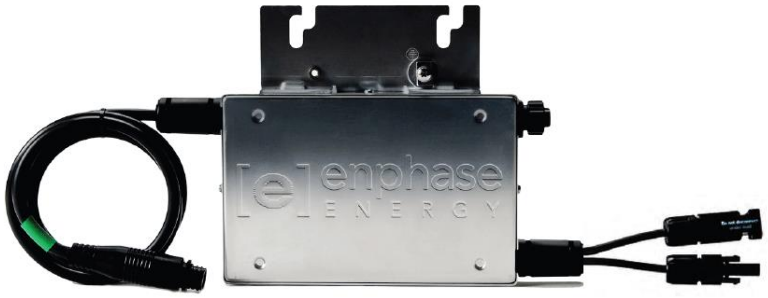


Image on right from CESA fire safety training

System Components: Large Central/Utility Scale Inverter

4

Images courtesy of the NY-Sun PV Trainers Network

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

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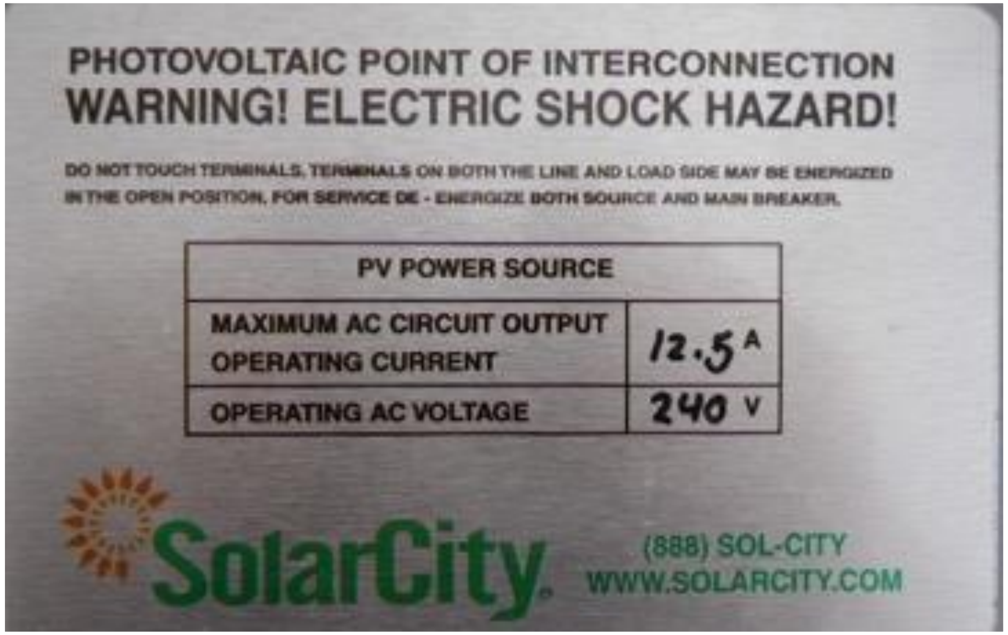
- **1** Modules
- **2** Combiner Boxes/Overcurrent Protection
- **3** DC Disconnect Switch/Overcurrent Protection
- **4** Inverter
- **5** AC Disconnect Switch/ Overcurrent Protection
- **6** Utility Interconnection/Overcurrent Protection
- **7** Utility Grid and/or Batteries

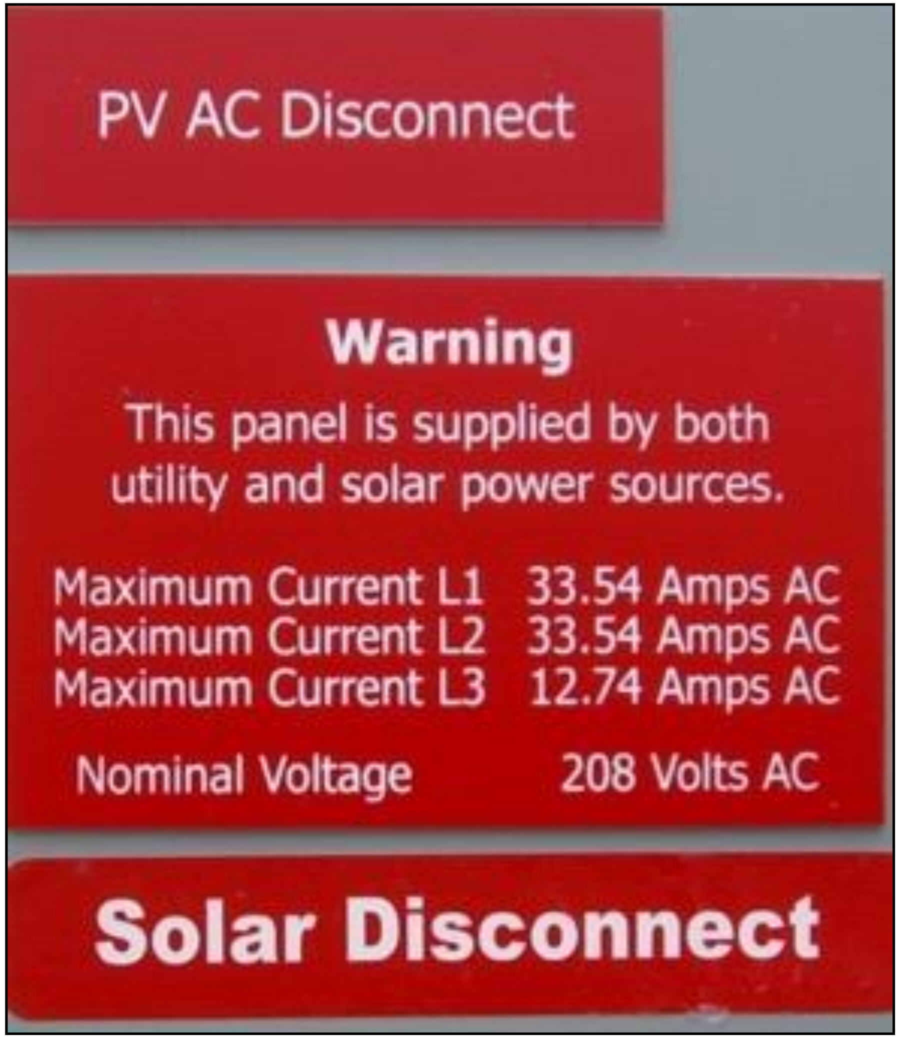
System Components: AC Disconnects

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)





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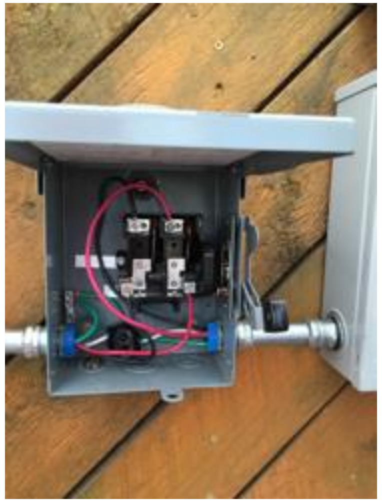
System Components: AC Disconnects

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

System Components: Utility Interconnection

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch/Overcurrent Protection

4 Inverter

5 AC Disconnect Switch/ Overcurrent Protection

6 Utility Interconnection/Overcurrent Protection

7 Utility Grid and/or Batteries

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 NFC690.14(2)

SOLAR EL… …UTION: …C 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 NEC705.22.4 and NI 90.64.

System Components: Utility Interconnection

6

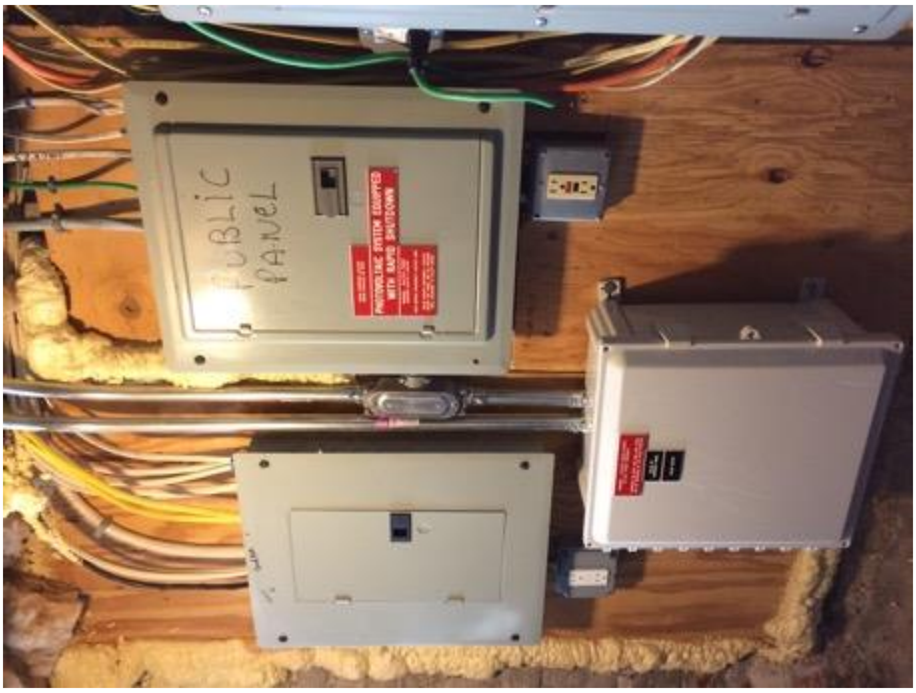


Photo courtesy of Chad Laurent

System Components: Understanding Schematic Drawings

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1 Modules

2 Combiner Boxes/Overcurrent Protection

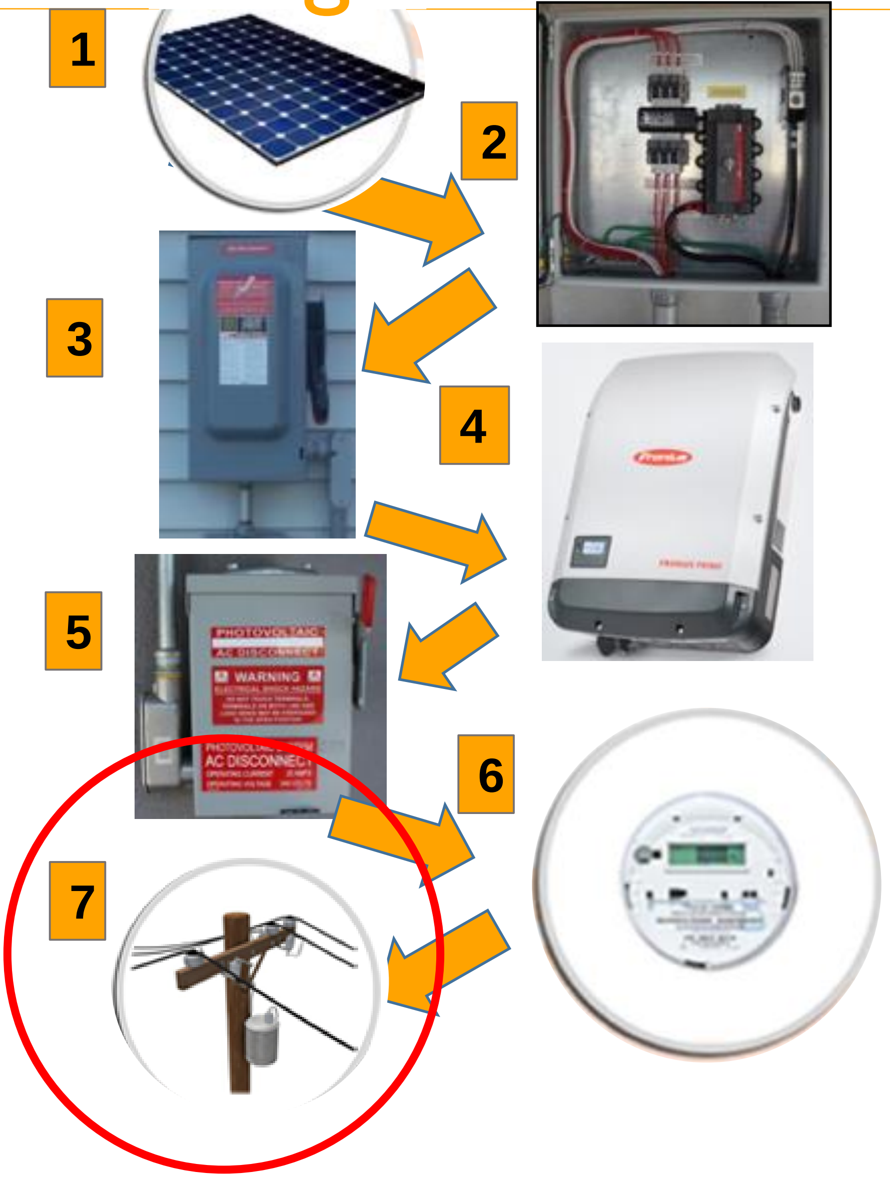
3 DC Disconnect Switch/Overcurrent Protection

4 Inverter

5 AC Disconnect Switch/ Overcurrent Protection

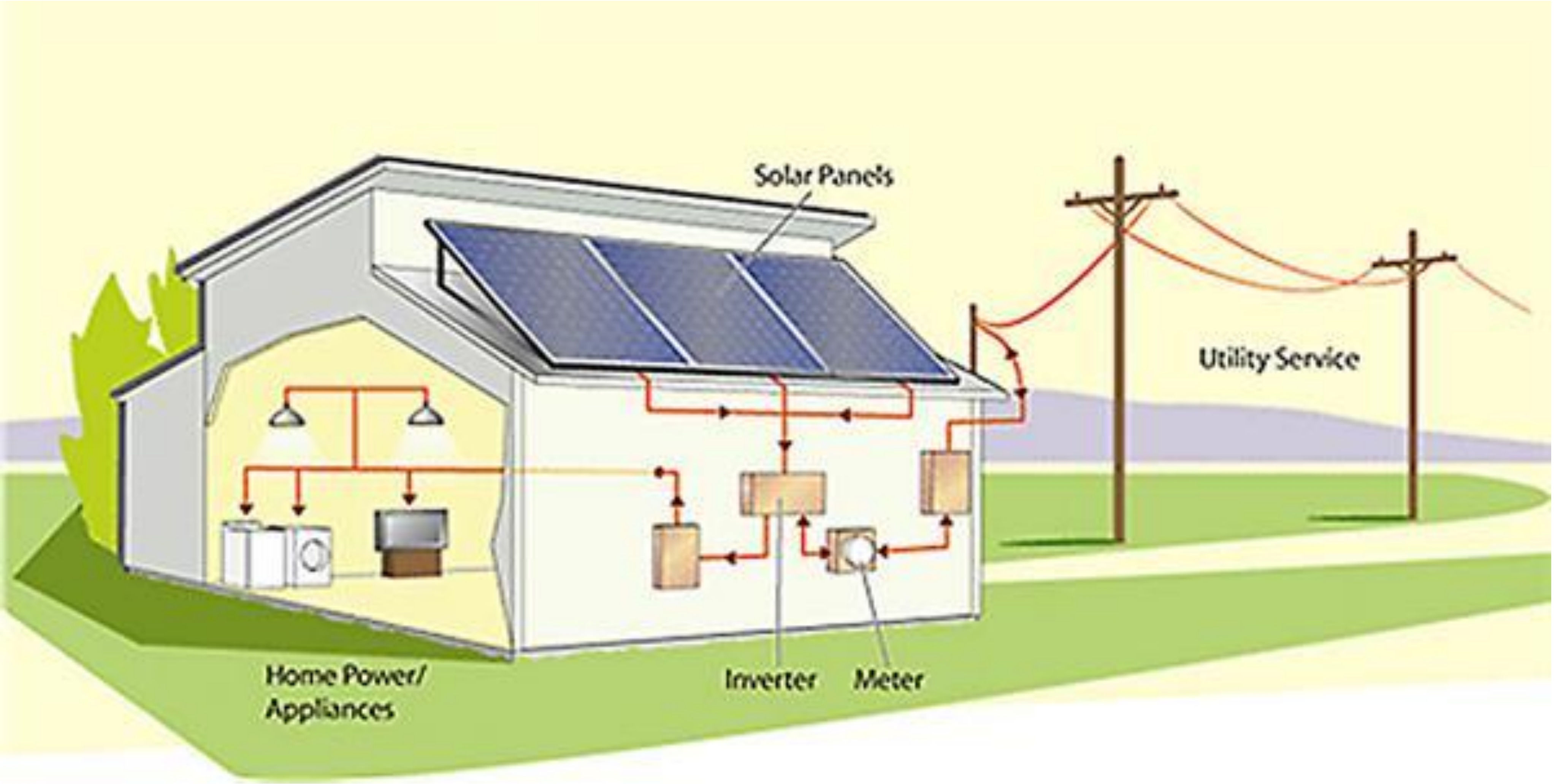
6 Utility Interconnection/Overcurrent Protection

7 Utility Grid



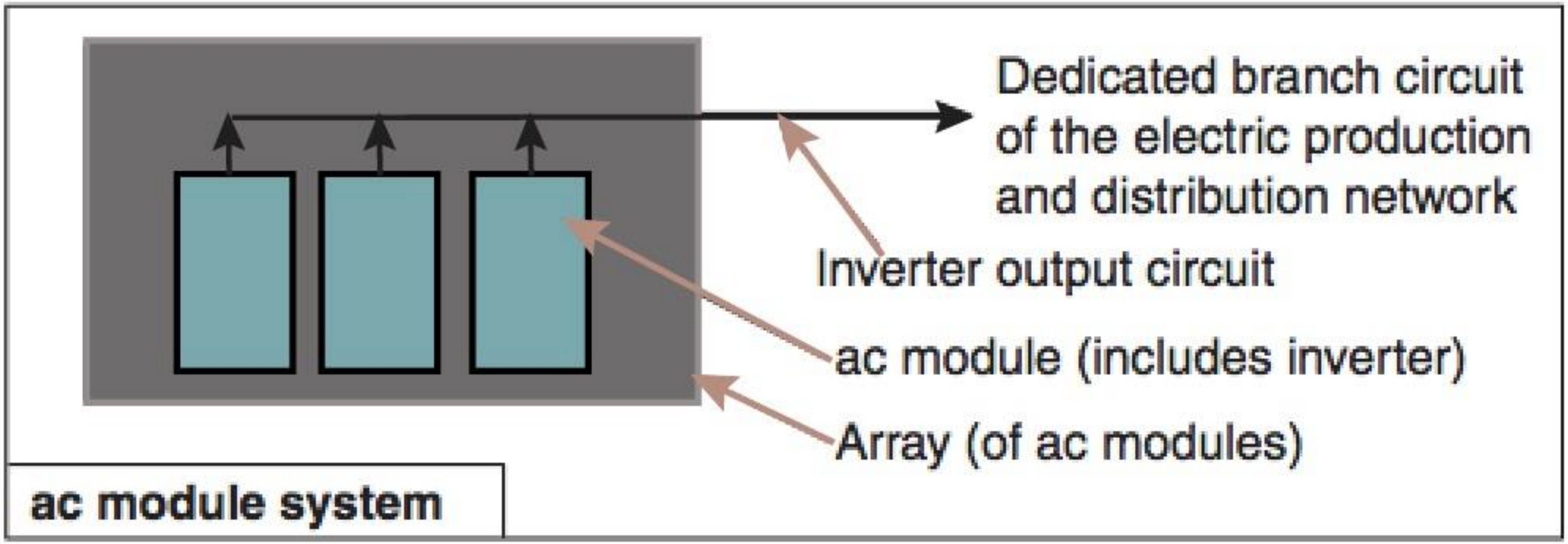
Solar Electric System Components

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

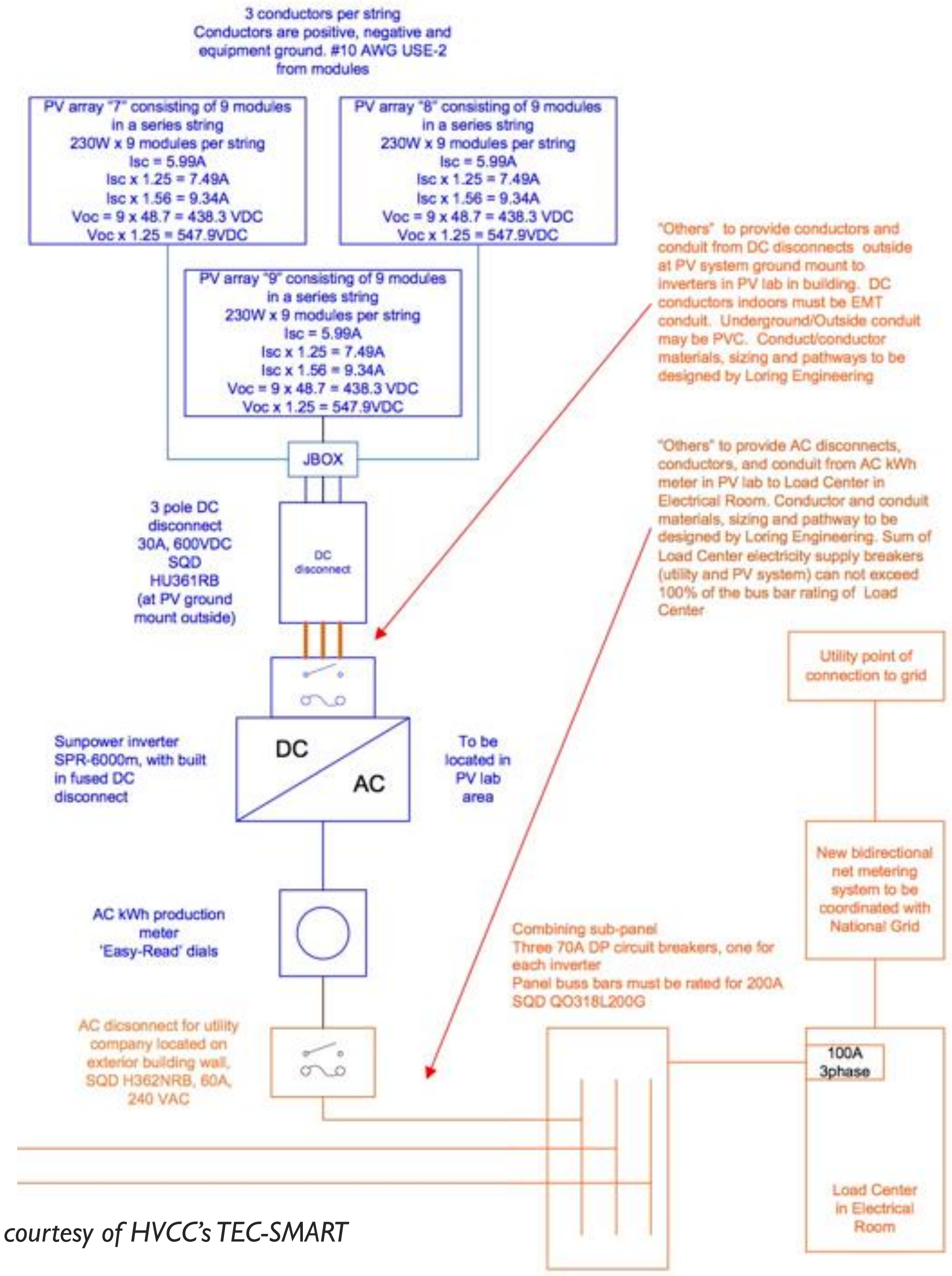


Image courtesy of HVCC's TEC-SMART

Understanding Schematic drawings: String tied inverter systems

7

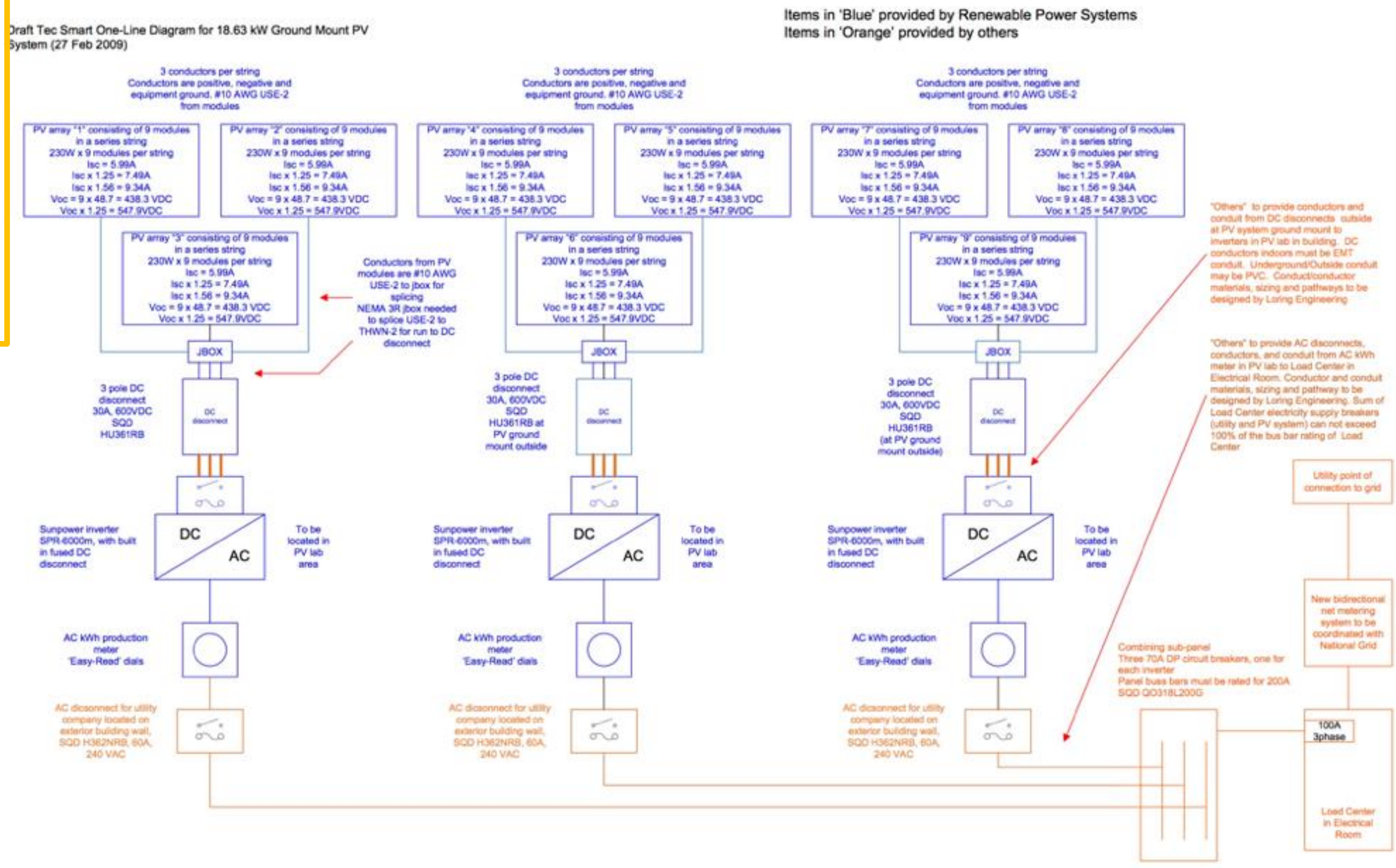


Image courtesy of HVCC's TEC-SMART

System Components: Battery Backed up

1 Modules

2 Combiner Boxes/Overcurrent Protection

3 DC Disconnect Switch/Overcurrent Protection

4 Inverter

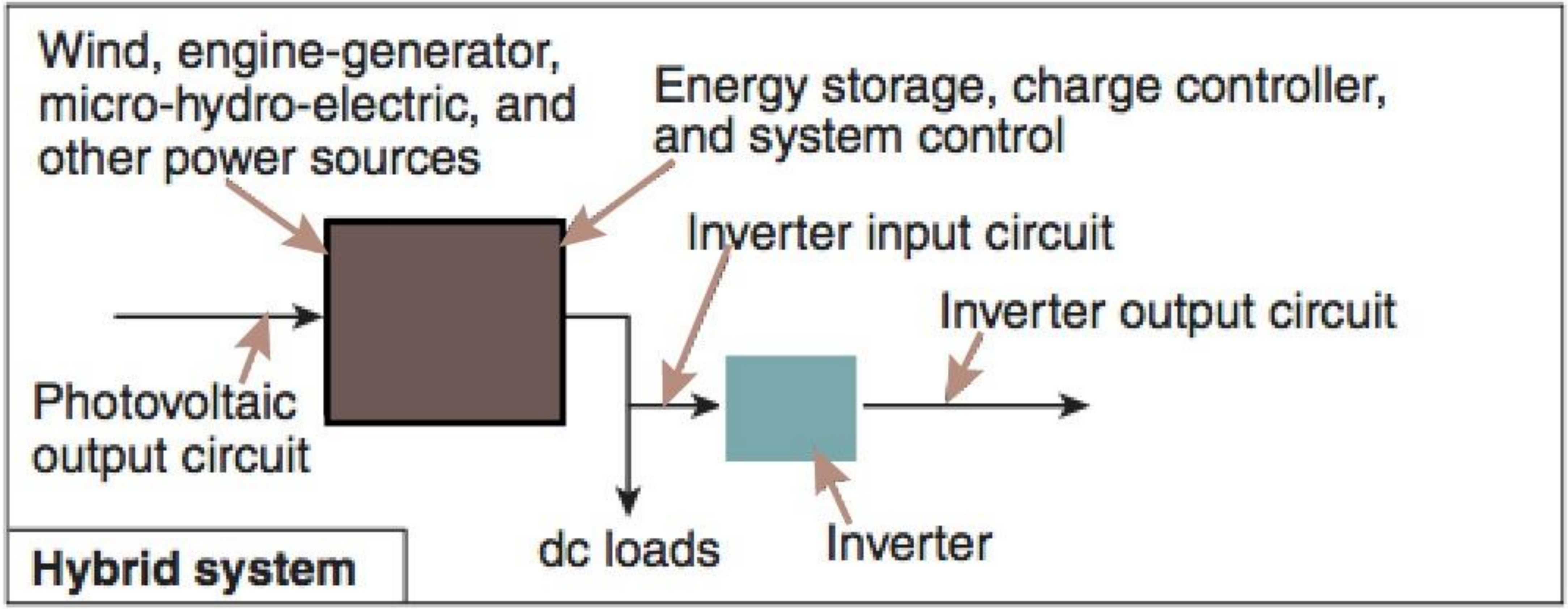
5 AC Disconnect Switch/ Overcurrent Protection

6 Utility Interconnection/Overcurrent Protection

7 Batteries and Utility Grid

Understanding Schematic Drawings: Hybrid System with Batteries

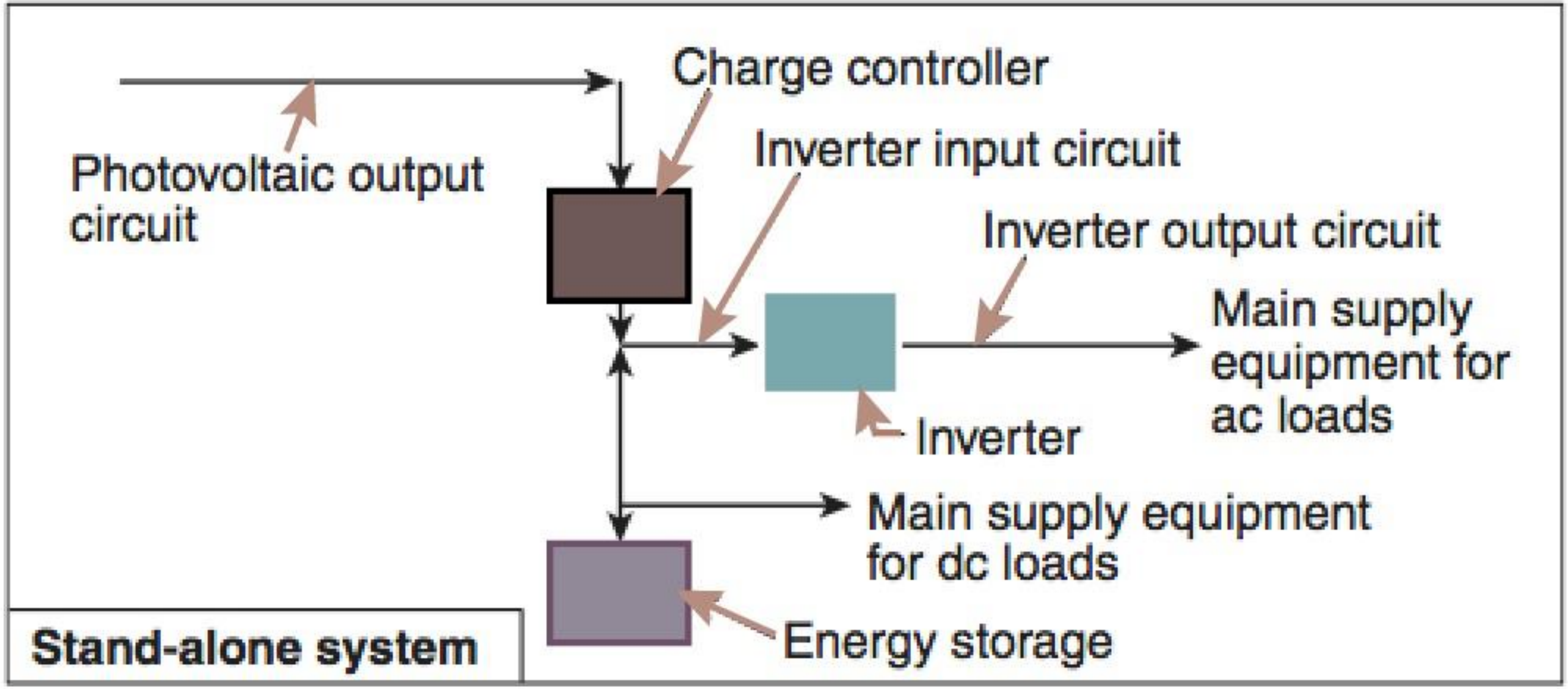
7



NEC 2014, Figure 690.1 (b)

Understanding Schematic Drawings: Standalone system with batteries

7



NEC 2014, Figure 690.1 (b)

Understanding Schematic Drawings: Schematic with battery Storage

7

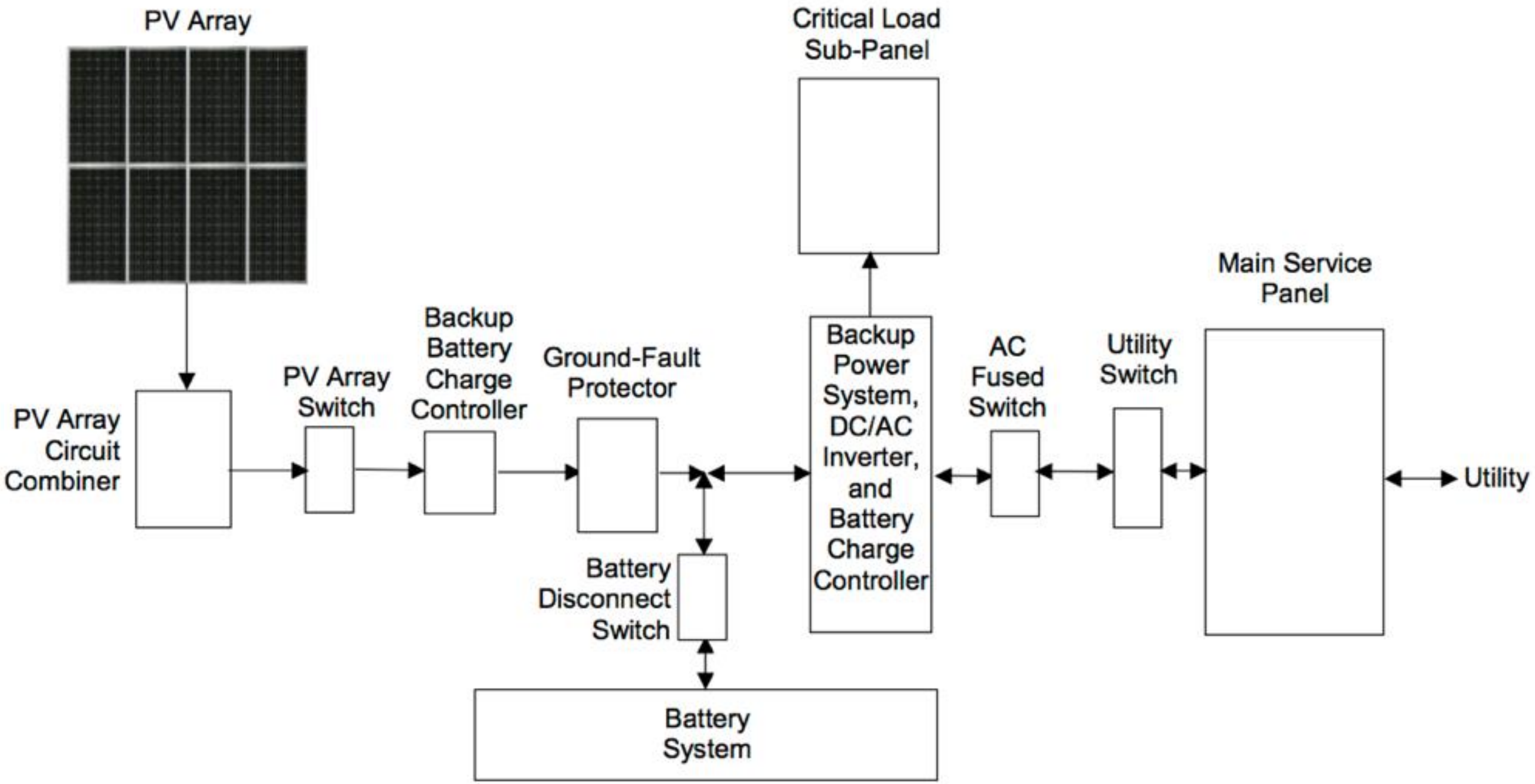


Image from CA Energy Commission's Guide to System Design and Installation

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Pop quiz

1. What's the role of the inverter?

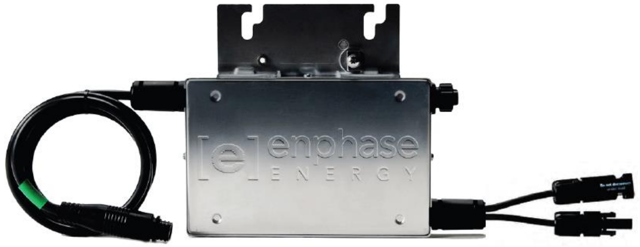
2. Name one difference between systems with storage (batteries) and those without.

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

Large Central/Utility
Scale Inverter

Battery String Inverter

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

Mothra

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]

Today's Agenda

- Introduction to solar technology [60 min]
- Identifying solar PV systems [45 min]
- Break [10-15 min]
- Solar PV hazards and safety [45 min]
- Identifying and disabling solar PV systems [45 min]

» **Solar PV Hazards & Safety**

› **Hazard overview**

› Site assessment

› Protecting yourself

› Texas Code and safety recommendations

Hazard Overview

1. Electrocution and electrical shock
2. Falls, trips & slips
3. Chemical burns
4. Roof loads: ventilation and roof collapse
5. Hazardous fumes
6. Stinging & biting insects

Hazard Overview: Electrocution

1. Electrocution

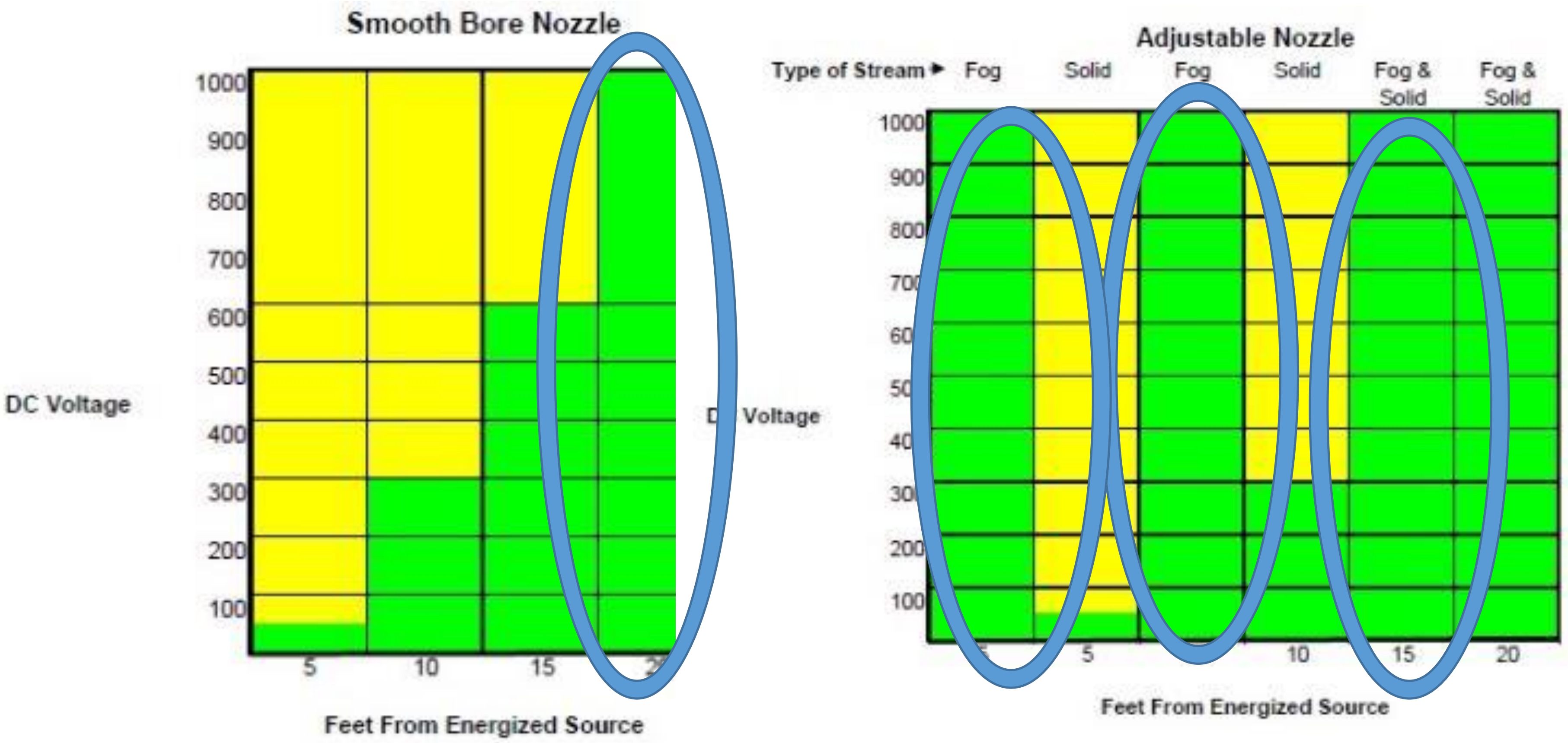
- PV modules should be considered energized at all times
- PV modules generate direct current electricity (DC). AC sensors (e.g. hot sticks) will not detect a flow of direct current.
- When damaged, modules present a shock hazard or when disconnected from the site's electrical system.

Hazard Overview: Electrocution

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

Physiological Effect	Ordinary DC Limit	DC Limits for Situations Restricted to Adults Only
Startle Reaction	2.0 mA	2.0 mA
Inability to Let Go	30 mA	40 mA
Ventricular Fibrillation	80 mA	240 mA
Electrical Burns	70 mA	70 mA

Hazard Overview: Electrocution



Hazard Overview: Slips, trips, & falls

2. Slips, trips, & Falls

- Never walk on modules
- Wet environments = slick modules
- Electrical perception may result in fall

Hazard Overview: Chemical burns

3. Chemical burns

- If there is on-site battery storage
- Hydrogen gas may also be present

Photo courtesy of John Calhoun

Hazard Overview:
Roof loads

4. Roof loads: ventilation and roof collapse

- Roof structure may be compromised or severely damaged by application of fire and water
- Impacts dead loads

Photo courtesy of Scott Sousa

Source: UL Firefighter Safety and Photovoltaic Installations Research Project

Hazard Overview: Hazardous Fumes

5. Hazardous Fumes

- Thin films modules ≈2% of systems release toxic chemicals under high heat environment
- Cadmium Telluride present in thin film modules ($1/100^{th}$ toxicity of Cd)

Hazard Overview: Stinging & biting insects

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6. Stinging & Biting insects

- Perfect environment for nesting bees and wasps
- Squirrels like them too

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]

» **Solar PV Hazards & Safety**

› Hazard overview

› **Site assessment**

› Protecting yourself

› Texas Code and safety recommendations

Site Survey & Assessment: Before Arrival

Information Dissemination:
Considerations for your municipality or Authority Having Jurisdiction (AHJ)

- Does your municipality share information about solar electric systems?
- How is the information shared about solar electric systems?
- Does someone verify the solar electric system information?
- How is information maintained (i.e. ROVER, I AM RESPONDING)
- Examples?

Site Survey & Assessment: At Arrival

- Site Assessment or initial size up (360 Survey)
- Is the system identifiable?
  - What type of system is on-site?
  - Are the components identifiable?

- Disconnect Main Electrical Panel
- Activate **AC** and **DC** disconnect Switches
- When in doubt, **Shut everything down!**

Today's Agenda

- Introduction to solar technology [60 min]
- Identifying solar PV systems [45 min]
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- Identifying and disabling solar PV systems [45 min]

» **Solar PV Hazards & Safety**

- › Hazard overview
- › Site assessment
- › **Protecting yourself**
- › Texas Code and safety recommendations

Protecting Yourself

1. Assume solar PV modules are always generating electricity, even at night
   - Yes, even at night
   - Don't break, damage, or cut the modules
   - Don't walk across PV modules
   - Foams are minimally effective
   - Not all tarps block sunlight
2. Wear Protective Clothing…
3. SCBA – Wear and keep on-person
4. Use insulated tools
5. Leave your jewelry & chains at home

Protecting Yourself

- Lock out Tag out (LOTO) Main Electrical Panel
- Lock out/tag out system disconnects (LOTO)
- Is there roof access
  - Ladder or aerial operations
  - Ventilation possible? Remember don't damage the modules

Protecting Yourself

Source: UL Firefighter Safety and Photovoltaic Installations Research Project

Today’s Agenda

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- Introduction to solar technology [60 min]
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» **Solar PV Hazards & Safety**
- › Hazard overview
- › Site assessment
- › Protecting yourself
- › **Texas Code and safety recommendations**

Best Practices

- **R324.7Access and pathways.**
  Roof access, pathways and spacing requirements for solar photovoltaic systems **shall be provided in accordance** with Sections R324.7.1 through R324.7.6

  Exceptions No. 1: Roof access, pathways and spacing requirements need not be provided where an alternative ventilation method has been provided, or where vertical ventilation techniques will not be employed.

  Exceptions No. 2:. Detached garages and accessory structures.

Best Practices

- **R324.7- Roof access points shall be located: .**

- In areas that establish access pathways which are independent of each other and as remote from each other as practicable so as to provide escape routes from all points along the roof;
- In areas that **do not require** the placement of ground ladders over openings such as windows or doors or areas that may cause congestion or create other hazards;
- strong points of building construction, such as corners, pilasters, hips, and valleys, and other areas capable of supporting the live load from emergency responders;

Best Practices

- **R324.7- Roof access points shall be located: .**
- Where the roof access point does not conflict with overhead obstructions such as tree limbs, wires or signs;
- Where the roof access point does not conflict with ground obstructions such as decks, fences, or landscaping; and

- In areas that minimize roof tripping hazards such as vents, skylights, satellite dishes, antennas, or conduit runs

Photo courtesy of DOE/NREL

Best Practices

- **605.11.1.2 Solar photovoltaic systems for Group R-3 buildings.**

  Solar photovoltaic systems for Group R-3 buildings **shall comply with** Sections 605.11.1.2.1 through 605.11.1.2.6.

  Exception: These requirements **shall not apply** to structures designed and constructed in accordance with the International Residential Code.

Best Practices

- **605.11.1.2.1 Size of solar photovoltaic array.**

  Each photovoltaic array shall not exceed 150 feet in any direction.

- **605.11.1.2.2 Ground access areas.**

Ground access areas shall be located directly beneath access roofs and roof access points. The minimum width of the ground access area shall be the full width of the access roof or roof access point, measured at the eave. The minimum depth shall allow for the safe placement of ground ladders for gaining entry to the access roof.

Best Practices

- **605.11.1.2.3 Single-ridge roofs.**

Panels, modules, or arrays installed on roofs with a single ridge shall be located in a manner that provides two, 36 inches wide access pathways extending from the roof access point to the ridge. Access pathways on opposing roof slopes shall not be located along the same plane as the truss, rafter, or other such framing system that supports the pathway.

Exception: This requirement **shall not apply** to roofs with slopes of two units vertical in 12 units horizontal (2:12) or less.

Best Practices

605.11.1.2.3 Single-ridge roofs.

Panels and modules shall be located in a manner that provides **two, 3-foot-wide access pathways** from the eave to the ridge.

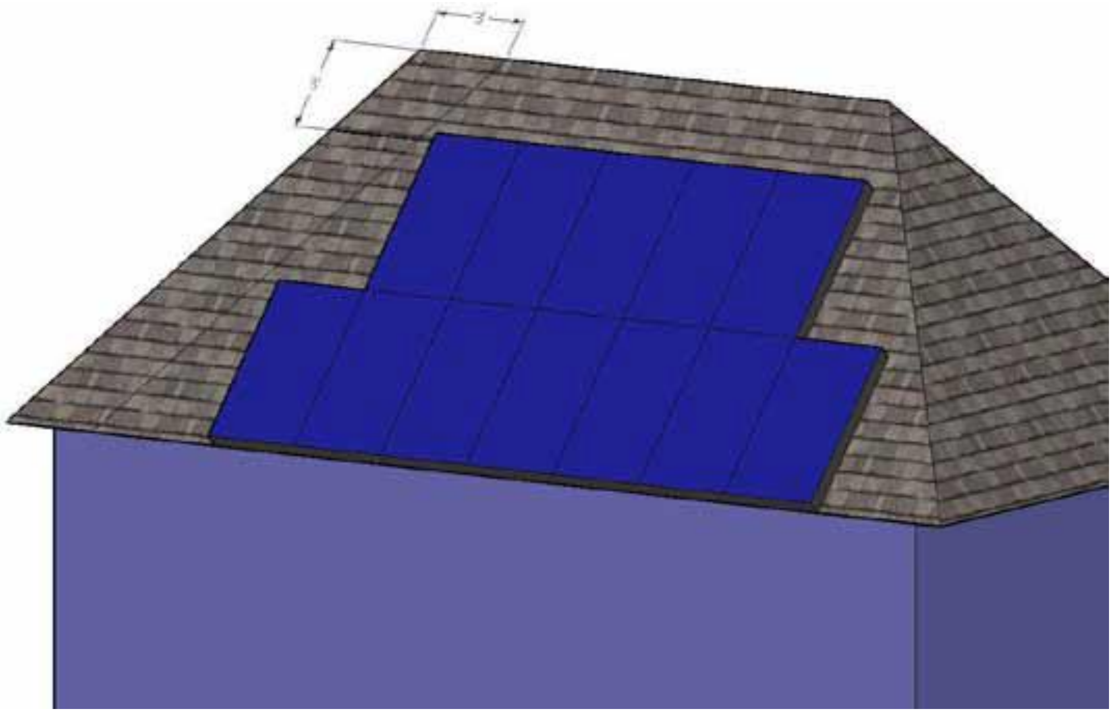
Photo courtesy of DOE/NREL

Best Practices

- **605.11.1.2.4 Hip roofs.**

  Panels, modules, and arrays installed on structures with hip roofs **shall be located in a manner** that provides a clear access pathway not less than 36 inches wide, extending from the roof access point to the ridge, on each roof slope where panels, modules, or arrays are located.

  Exception: These requirements **shall not apply to** roofs with slopes of two units vertical in 12 units horizontal (2:12) or less.



Source: Solar America Board for Codes and Standards Report

Best Practices

605.11.1.2.4 Hip roof layouts.

Hip roof layouts need one **3-foot-wide** clear access pathway from the eave to the ridge on each roof slope **where panels and modules are located**.

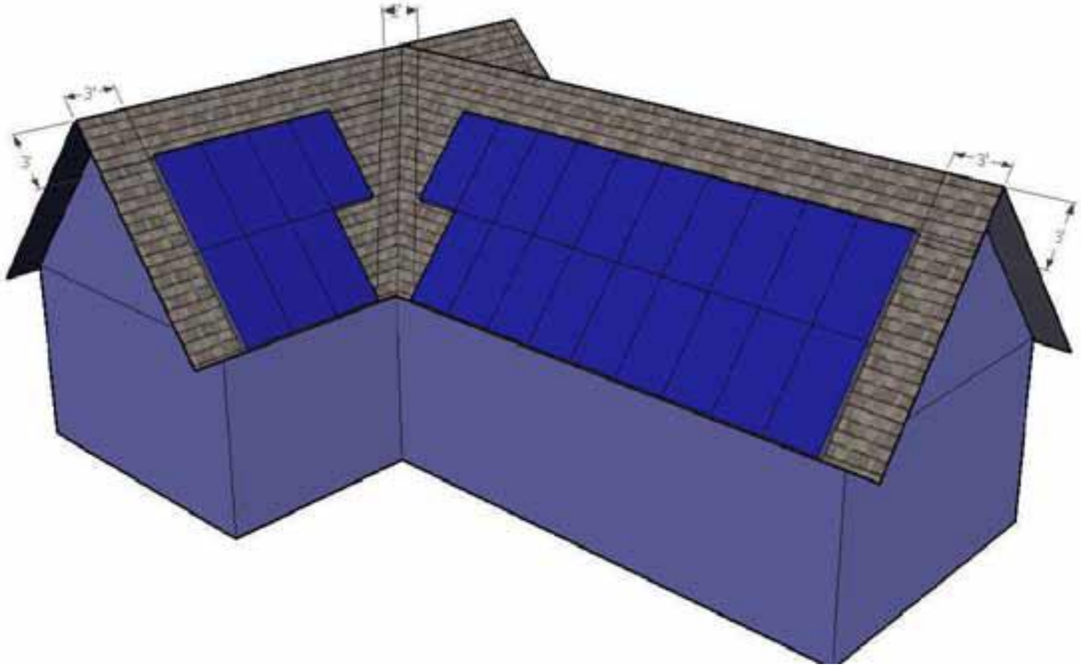
Photo courtesy of DOE/NREL

Best Practices

- **605.11.1.2.5 Roofs with hips and valleys.**

  Panels and modules installed on Group R-3 buildings with roof hips and valleys **shall not be located closer** than 18 inches to a hip or a valley where panels/modules are to be placed on both sides of a hip or valley. Where panels are to be located on only one side of a hip or valley that is of equal length, the panels **shall be permitted** to be placed directly adjacent to the hip or valley.

  Exception: These requirements **shall not apply** to roofs with slopes of two units vertical in 12 units horizontal (2:12) or less.



Source: Solar America Board for Codes and Standards Report

Best Practices

605.11.1.2.4 Roofs with hips and valleys.

Panels and modules **shall not be located closer than 18 inches to a hip or a valley** where panels/modules are to be placed on both sides of a hip or valley.

Photo courtesy of DOE/NREL

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Best Practices

605.11.1.2.5 Roofs with hips and valleys.

Where panels are to be located on only one side of a hip or valley that is of equal length, the panels **shall be permitted** to be placed directly adjacent to the hip or valley.

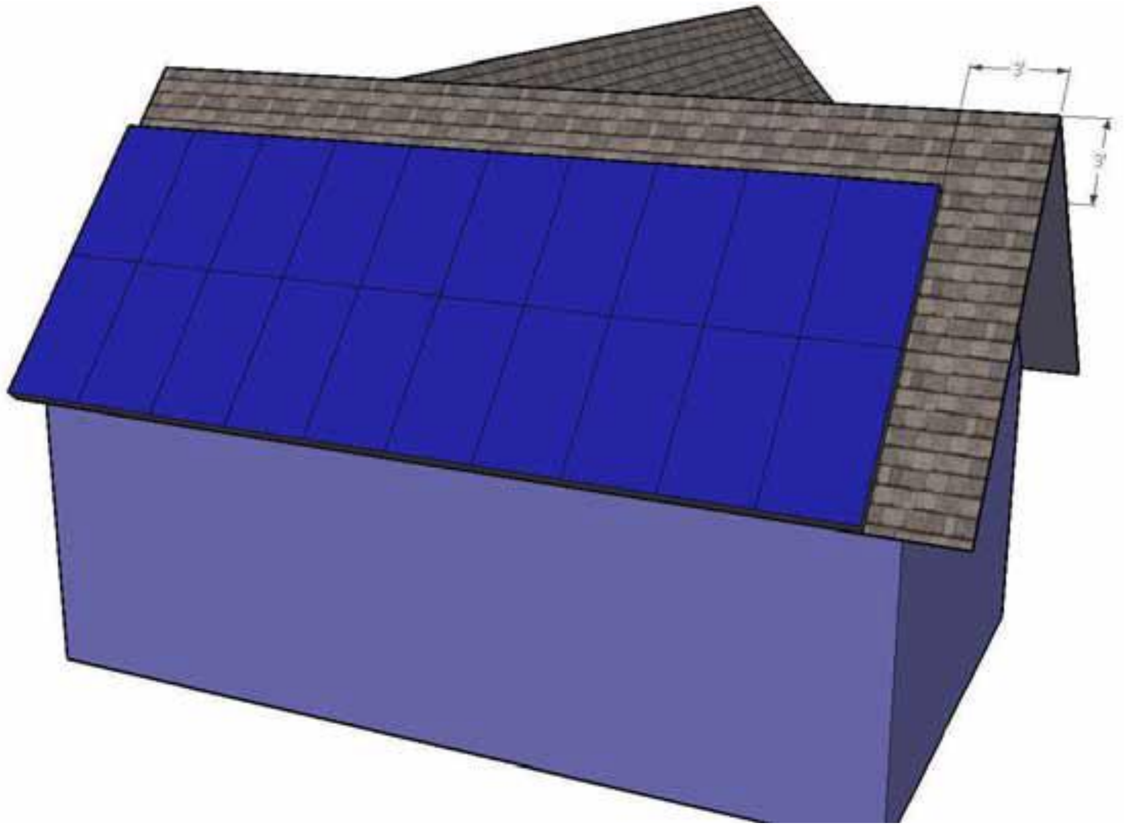
Photo courtesy of DOE/NREL

Best Practices

- **605.11.1.2.5 Allowance for smoke ventilation operations.**

  Panels and modules installed on Group R-3 buildings **shall be located not less** than 3 feet (914 mm) from the ridge in order to allow for fire department smoke ventilation operations.

  Exception: Panels and modules **shall be permitted to be located** up to the roof ridge where an alternative ventilation method approved by the fire chief has been provided or where the fire chief has determined vertical ventilation techniques shall not be employed.



Source: Solar America Board for Codes and Standards Report

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Best Practices

605.11.1.2.5 Allowance for smoke ventilation operations.

Panels and modules **shall be located not less than 3 feet (914 mm) from the ridge** in order to allow for fire department smoke ventilation operations.

Photo courtesy of DOE/NREL

Best Practices

- **605.11.1.3 Other than Group R-3 buildings.**

  Access to systems for buildings, other than those containing Group R-3 occupancies, **shall be provided in accordance** with Sections 605.11.1.3.1 through 605.11.1.3.3.

  Exception: Where it is determined by the fire code official that the roof configuration is similar to that of a Group R-3 occupancy, the residential access and ventilation requirements in Sections 605.11.1.2.1 through 605.11.1.2.5 **shall be permitted** to be used.

Best Practices

- **605.11.1.3.1 Access.**

  There **shall be a minimum** 6 foot-wide (1829 mm) clear perimeter around the edges of the roof.

  Exception: Where either axis of the building is 250 feet or less, the clear perimeter around the edges of the roof **shall be permitted to be reduced** to a minimum 4 foot wide.

Best Practices

605.11.1.3.1 Access.

There **shall be a minimum** 6 foot-wide (1829 mm) clear perimeter around the edges of the roof.

Photo courtesy of DOE/NREL

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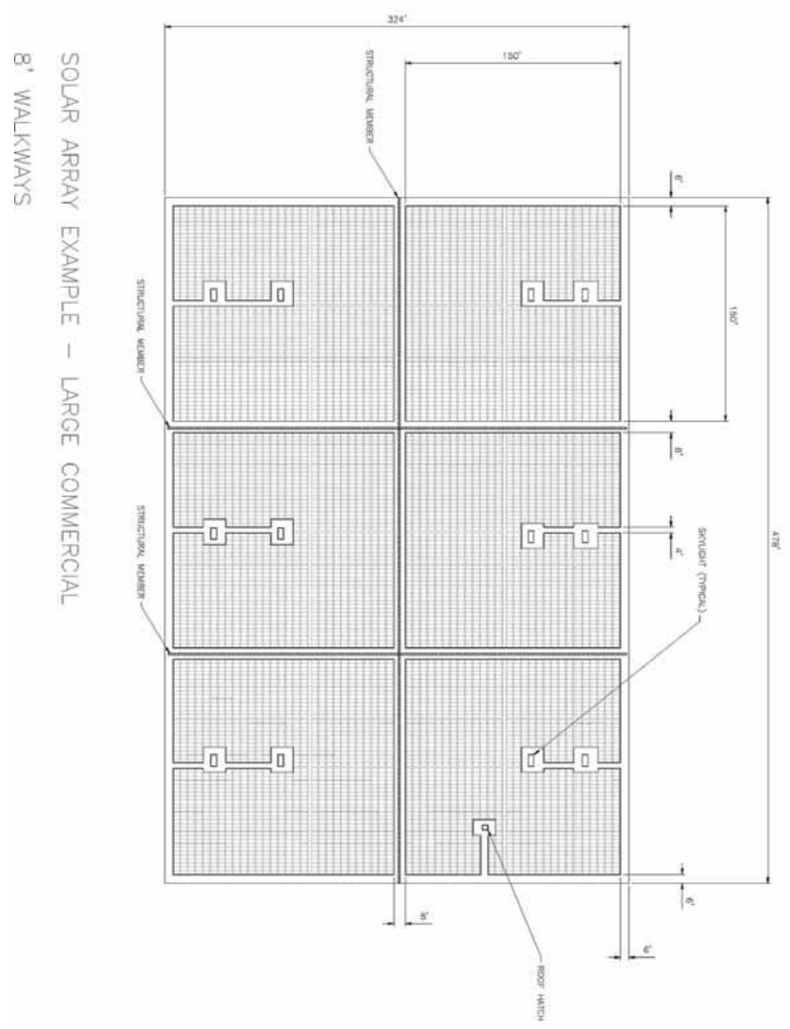
Best Practices

- **605.11.1.3.2 Pathways.**

The solar installation **shall be designed to provide** designated pathways. The pathways shall meet the following requirements:

1. The pathway **shall be over areas** capable of supporting fire fighters accessing the roof.
2. The centerline axis pathways **shall be provided in both axes** of the roof. Centerline axis pathways shall run where the roof structure is capable of supporting fire fighters accessing the roof.
3. Pathways **shall be a straight line** not less than 4 feet (1290 mm) clear to roof standpipes or ventilation hatches.
4. Pathways **shall provide not less** than 4 feet (1290 mm) clear around roof access hatch with not less than one singular pathway not less than 4 feet (1290 mm) clear to a parapet or roof edge.



Source: Solar America Board for Codes and Standards Report

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Best Practices

- **605.11.1.3.3 Smoke ventilation.**

The solar installation **shall be designed to meet** the following requirements:

1. Arrays **shall not be greater** than 150 feet by 150 feet in distance in either axis in order to create opportunities for fire department smoke ventilation operations.
2. Smoke ventilation options between array sections **shall be one of the following**:
    - 2.1. A pathway 8 feet (2438 mm) or greater in width.
    - 2.2. A 4-foot (1290 mm) or greater in width pathway and bordering roof skylights or gravity operated dropout smoke and heat vents on not less than one side.
    - 2.3. A 4-foot (1290 mm) or greater in width pathway and bordering all sides of non-gravity operated dropout smoke and heat vents.
    - 2.4. A 4-foot (1290 mm) or greater in width pathway and bordering 4-foot by 8-foot (1290 mm by 38 mm) "venting cutouts" every 20 feet (6096 mm) on alternating sides of the pathway.

Best Practices – 2015 IRC

R 324.6 Ground-mounted photovoltaic systems.

Ground-mounted photovoltaic Ground-mounted photovoltaic systems **shall** be designed and installed in accordance with Section R301 (Design Criteria).

- *R301 specifies the design loads for the mounting system and foundation based on the applicable wind loads, snow loads, live loads, dead loads, seismic loads, etc.*

Photos from Action Solar (North Carolina) website

Best Practices – 2015 IFC

605.11.2 Ground-mounted photovoltaic arrays

Ground-mounted photovoltaic **shall comply** with Section 605.11 and this section. Setback requirements shall not apply to ground-mounted, free-standing photovoltaic arrays. **A clear, brush-free area of 10 feet** (3048 mm) shall be required for ground-mounted photovoltaic arrays.

Photos from Action Solar (North Carolina) website

Large Commercial Industrial Ground Mount Systems

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U.S. Department of Energy

Pop quiz

1. What are the primary concerns of solar PV and fires?
2. What are the access pathway and ventilation requirements for residential buildings?
3. What are the access pathway and ventilation requirements for commercial buildings?
4. What are regulations governing ground mount PV systems?

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]

» **Identifying & disabling solar PV systems**

- › **Labeling & identifying PV systems**
- › Identifying and disconnecting PV systems

Identifying and disabling solar PV systems: Best practices

1. Locate the directory
2. Disconnect utility power to the building
3. Activate the AC disconnect
4. Activate the DC disconnect

Labeling and identification of PV systems

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2014 NEC 690.13 Photovoltaic System Disconnecting Means:

- Means shall be provided to disconnect the PV system from all wiring systems including power systems, energy storage systems, and utilization equipment and its associated premises wiring.

Labeling and Identification of PV Systems

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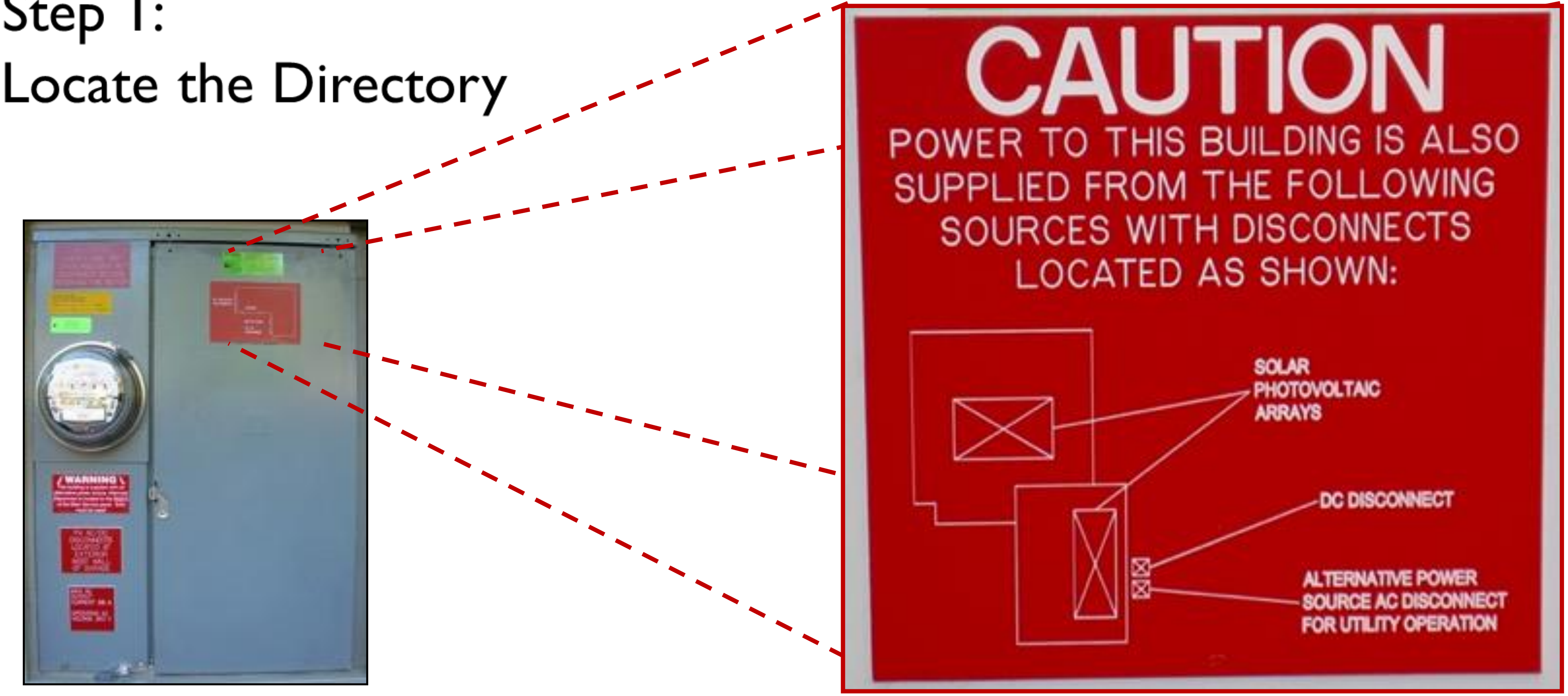
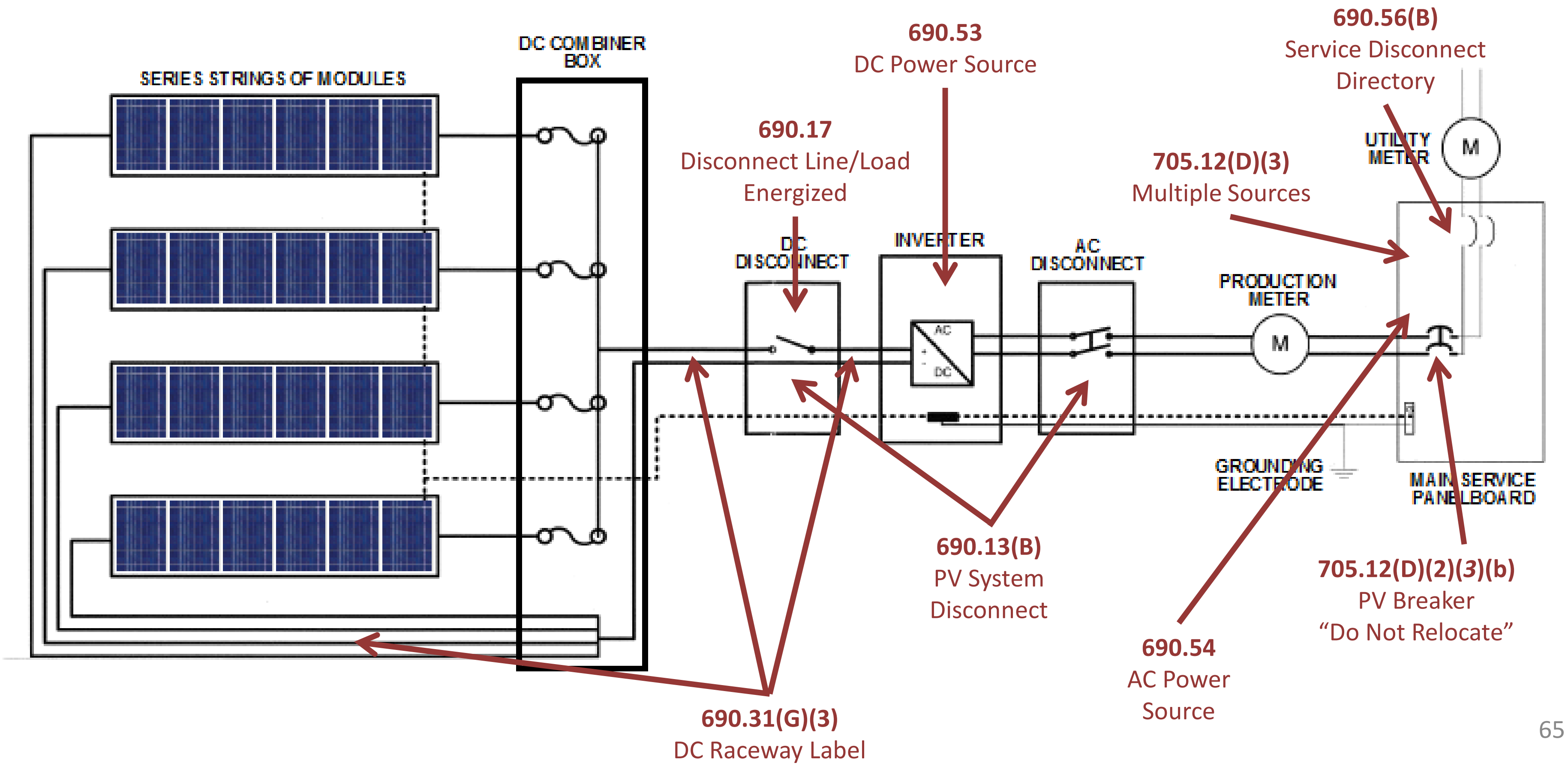
1. Step 1:
   - Locate the Directory



Photos courtesy of Rhonda Parkhurst

Labeling and Identification of PV Systems



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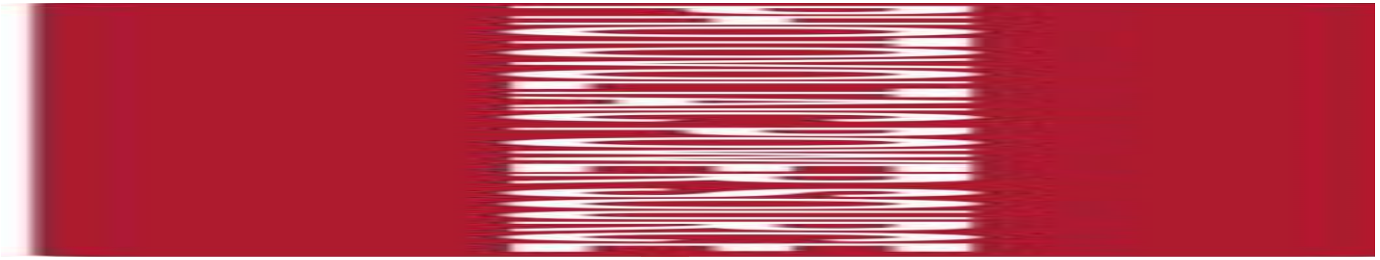
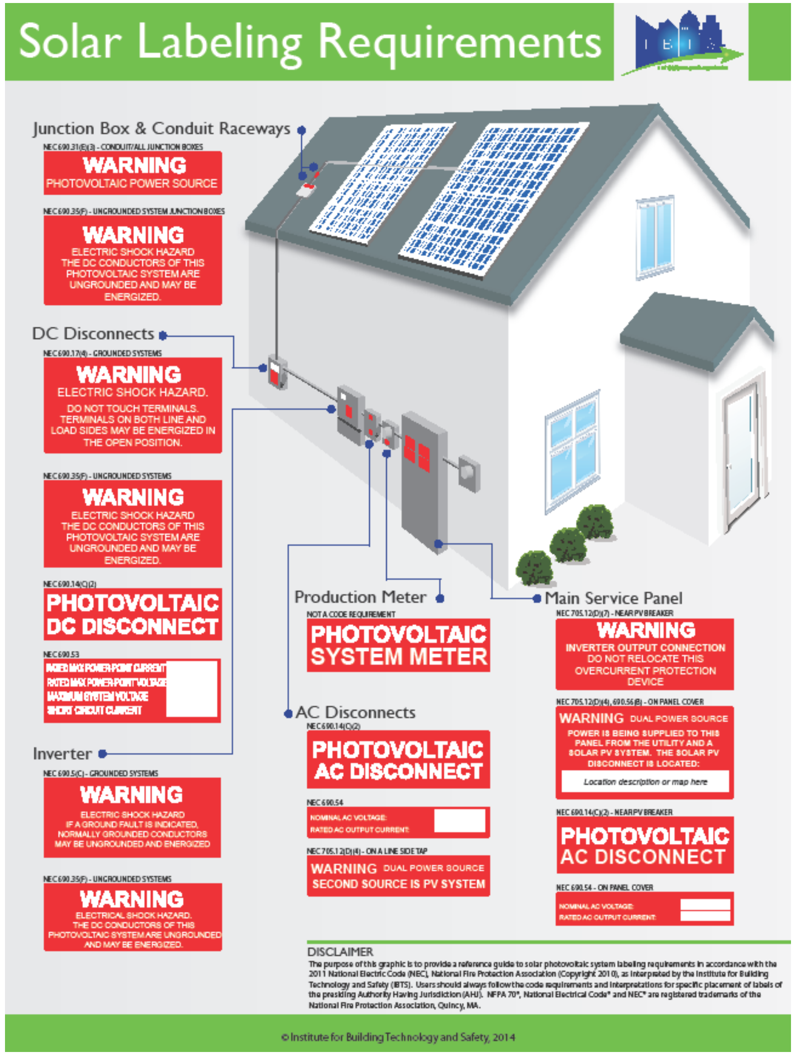
Labeling and Identification of PV Systems

- Labels must be red (IFC and UFC guidelines)
- White lettering, all capital letters
- Reflective, weather resistant (UL standard)
- Minimum of 3/8” all capital letters





Images courtesy of IBTS

Labeling and Identification of PV Systems

Conduit

IFC 605.11.1.4

> Marking shall be placed on all interior and exterior DC conduit, raceways, enclosures, and cable assemblies every 10 feet (3048mm) within 1 foot (305mm) of all turns or bends and within 1 foot (305mm) above and below all penetrations for roof/ceiling assemblies and all walls and/or barriers.

Location of circuits embedded in rooftop uncovered by PV modules must be marked

Labeling and Identification of PV Systems

Today's Agenda

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» **Identifying & disabling solar PV systems**

› Labeling & identifying PV systems

› **Identifying and disconnecting PV systems**

Identifying and Disconnecting Solar PV Systems

Approaching unknown systems:

1. **Grid-tied systems**
   1. Micro inverters
   2. String inverters
   3. Utility scale/large central inverters
   4. Systems with on-site storages
2. **Off-grid systems**

Identifying and Disconnecting Solar PV Systems

Information Dissemination: Considerations for your municipality or Authority Having Jurisdiction (AHJ)

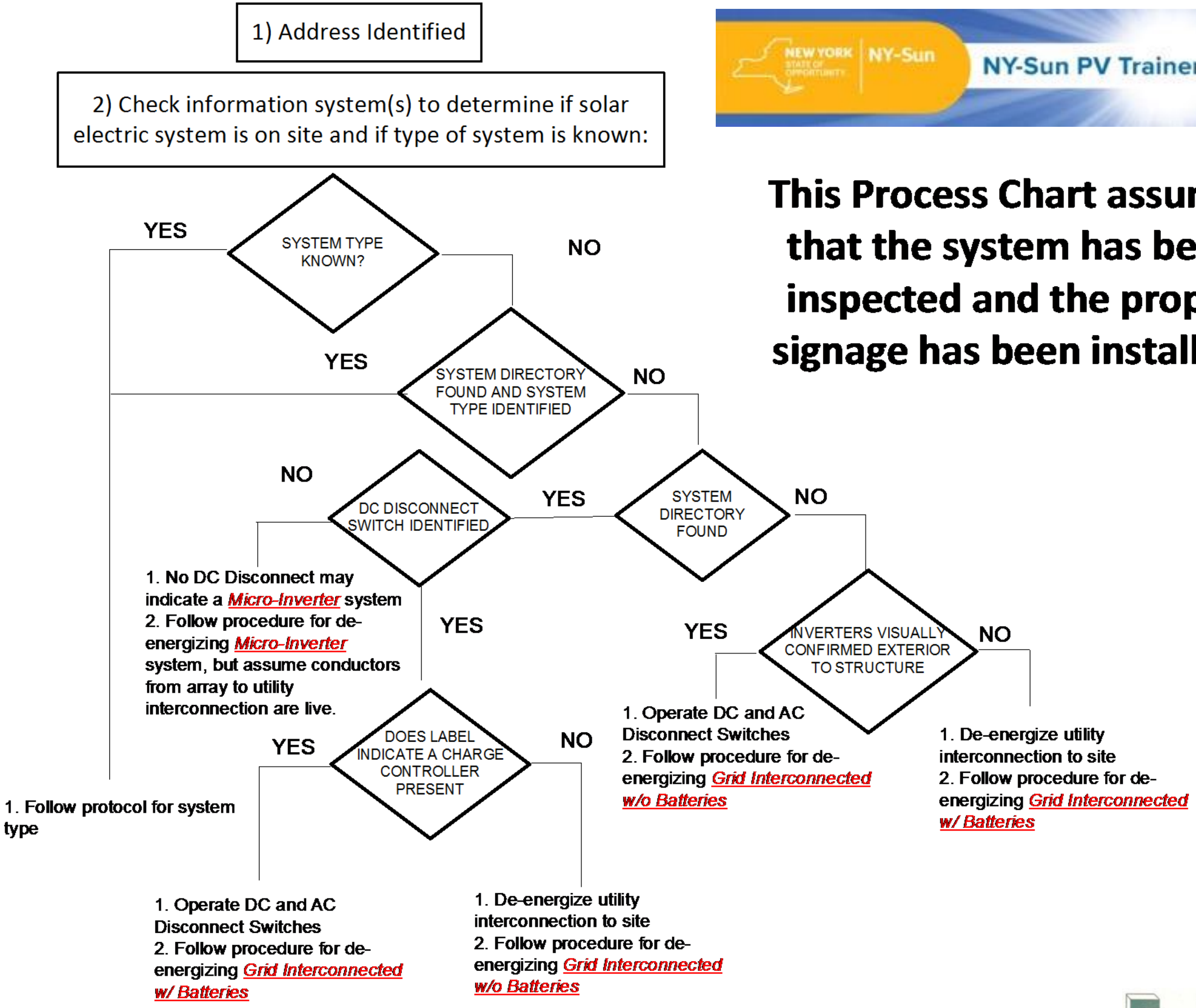
- Does your municipality share information about solar electric systems?
- How is the information shared about solar electric systems?
- Does someone verify the solar electric system information?
- How is information maintained (i.e. ROVER, I AM RESPONDING)
- Examples?

Identifying and Disconnecting Solar PV Systems

1. Identify the address - Check the information systems.
2. Is there a PV systems on-site?
3. What type?

If this fails, Plan B:

Entech Engineering, Inc. has developed a process chart for identifying and disabling unknown solar PV systems, assuming proper signage installed



NY-Sun PV Trainers Network

This Process Chart assumes that the system has been inspected and the proper signage has been installed.

Locating the AC disconnect

First step is to disconnect utility power to the building. At residential sites, the AC disconnect switch may be located at:

1. Utility meter
2. Labeled solar electric system disconnect switch
3. Labeled solar electric system breaker in a main or subpanel

At industrial sites with a utility central inverters, ac disconnect will be at:

1. Labeled solar PV system disconnect switch protected by fence, locked enclosure, or other barrier

Source materials courtesy of the PV Trainers Network and Entech Engineering

Grid-tied system with micro inverters

- Microinverters are situated ~1 feet from the panel
- Conduit between panel and inverters usually metallic
- Assume DC circuit is energized at all times

Enphase

Darfon


KACO

Source materials courtesy of the PV Trainers Network and Entech Engineering

Grid-tied system with micro inverters

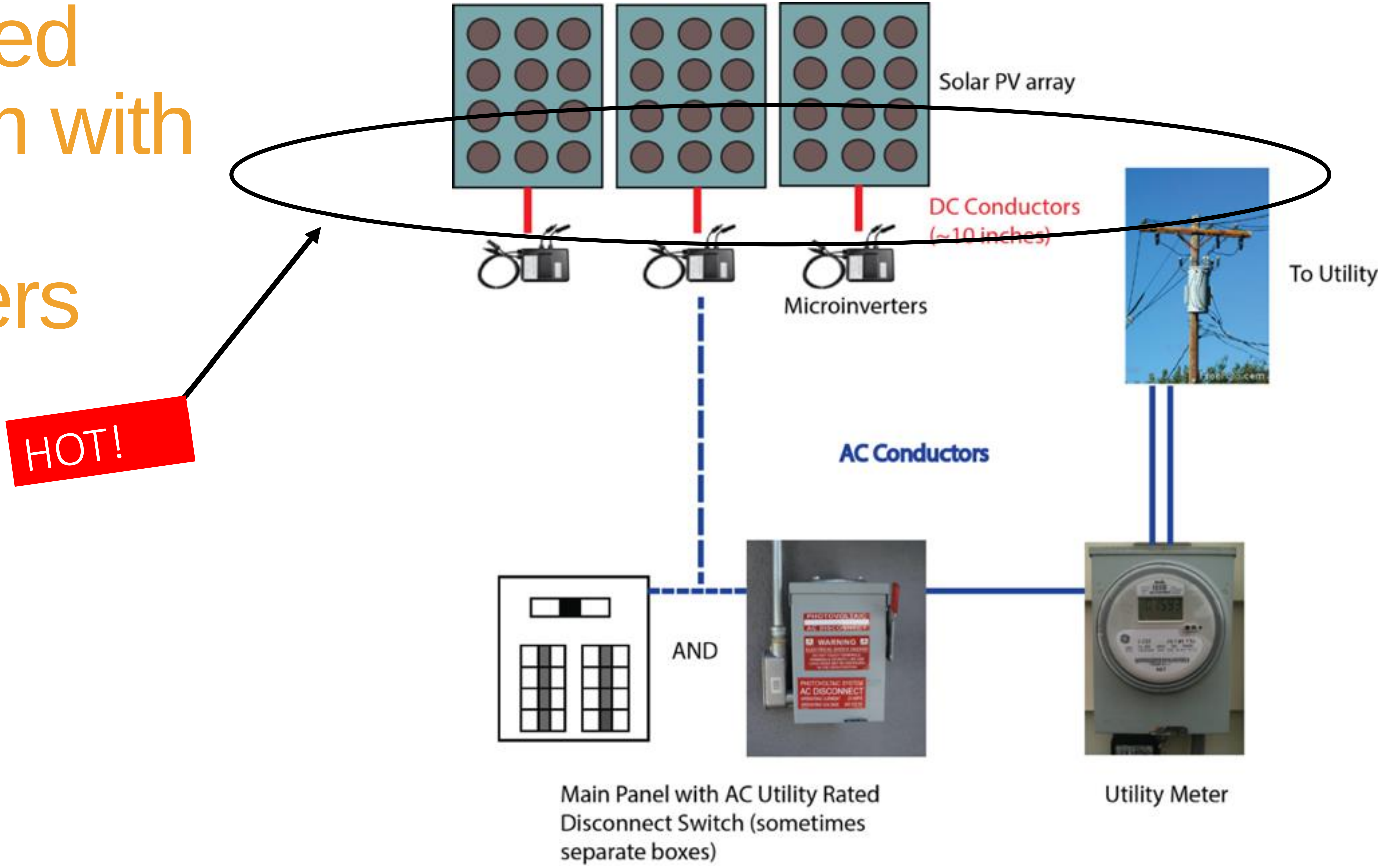
DC circuits: from panel to inverters, **cannot be de-energized**

AC circuits: de-energizing utility power will disconnect energy from disconnecting point to the inverters

1. Find System Directory, usually located at the building's main service disconnecting point
2. Disconnect utility power to building
3. AC conductors from utility to disconnecting point are energized
4. Avoid DC conductors immediately underneath the solar module

Source materials courtesy of the PV Trainers Network and Entech Engineering

Grid-tied system with micro inverters



Grid-tied system with string inverters

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- Inverters are located **where?**
- Usually metallic conduit between panel and inverters
- Assume circuit from panel to dc disconnect energized at all times

Sungrow

Ginlong

SMA Sunny Boy

Delta Products

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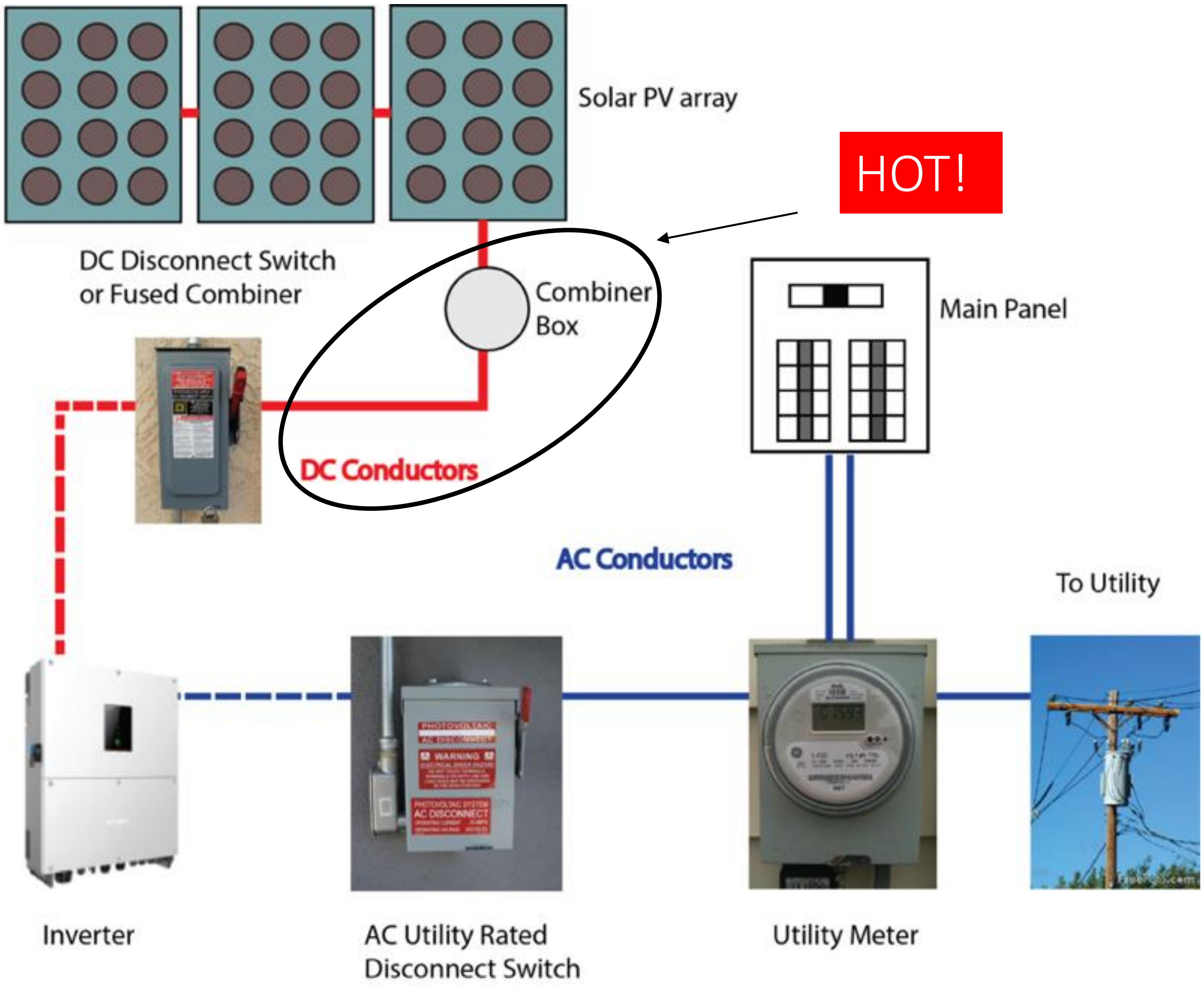
Grid-tied system with string inverters

DC circuits: operating dc disconnection will de-energize from switch to the inverter, not from switch to panel

AC circuits: de-energizing utility power will disconnect energy from **disconnecting point to the inverters**

1. Find System Directory, usually located at the building's main service disconnecting point
2. Disconnect utility power to building, operate dc disconnect switch
3. AC conductors from utility to disconnecting point are energized
4. Avoid DC conductors from solar module to the dc disconnect switch

Grid-tied system with string inverters



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U.S. Department of Energy

Utility scale/large central inverter

- Inverters often located in separate structure (e.g. side of building)
- Conduit between panel, combiner boxes, and inverters metallic or PVC
- Assume circuit from panel to dc disconnect energized at all times

Schneider Electric

Ingeteam

Eaton

Utility scale/large central inverter

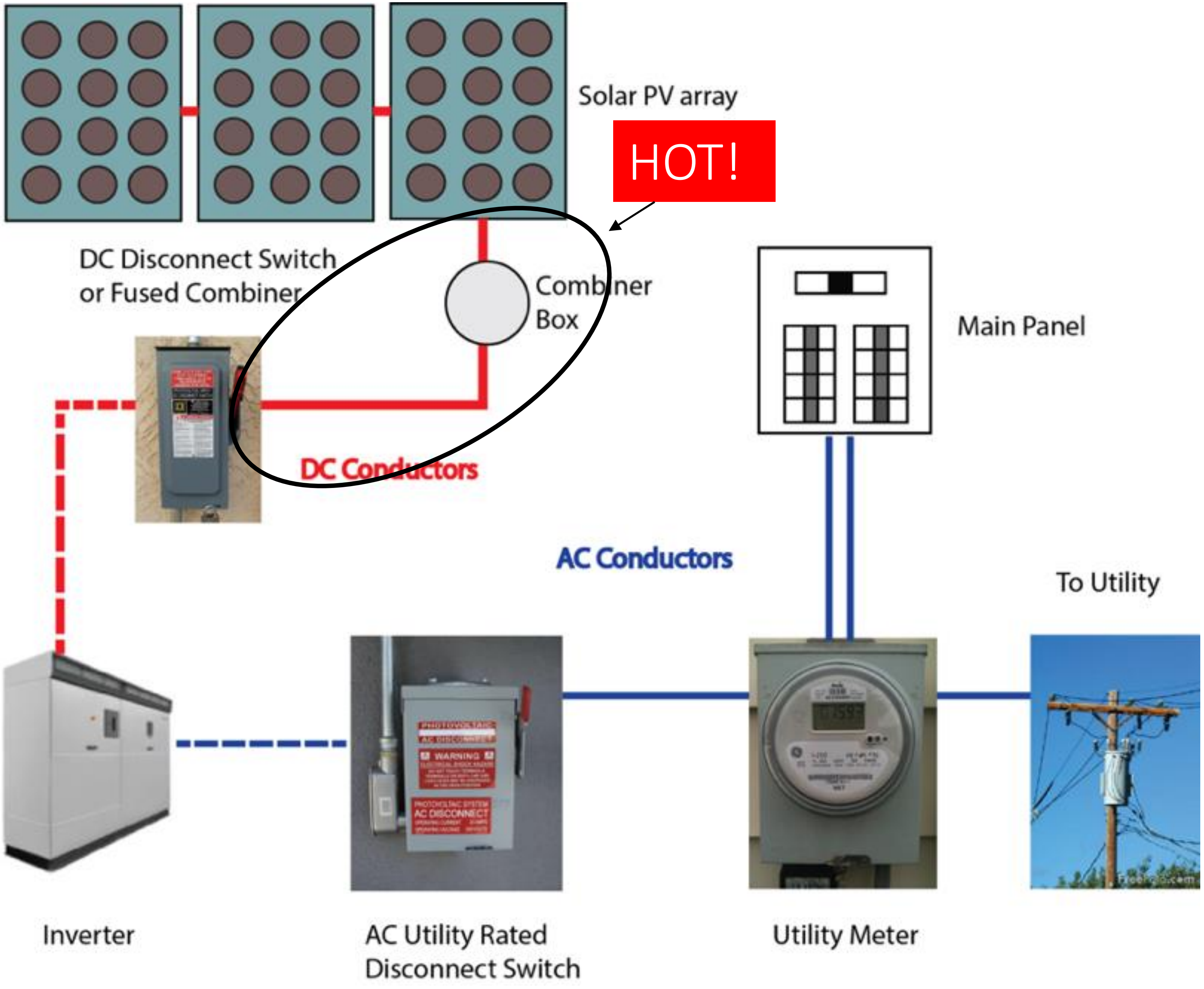
SOLSMART

DC circuits: operating dc disconnection will de-energize from switch to the inverter, not from switch to panel

AC circuits: de-energizing utility power will disconnect energy from disconnecting point to the inverters

1. Find System Directory, usually located at the building’s main service disconnecting point
2. Disconnect utility power to inverter, operate DC disconnect switch
3. AC conductors from utility to disconnecting point are energized unless meter is pulled
4. AC conductors from inverter to battery powered panel are energized unless inverter shut down breaker is off
5. Avoid DC conductors from solar module to the DC disconnect switch

Utility scale/large central inverter



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Grid-tied system with storage

Includes storage-specific components:

- Battery bank
- Inverter shut down breaker
- Emergency power circuit (usually ac) with independent panel

Sonnen

Pika Energy Island

US Battery

Tesla Powerwall

Grid-tied system with storage

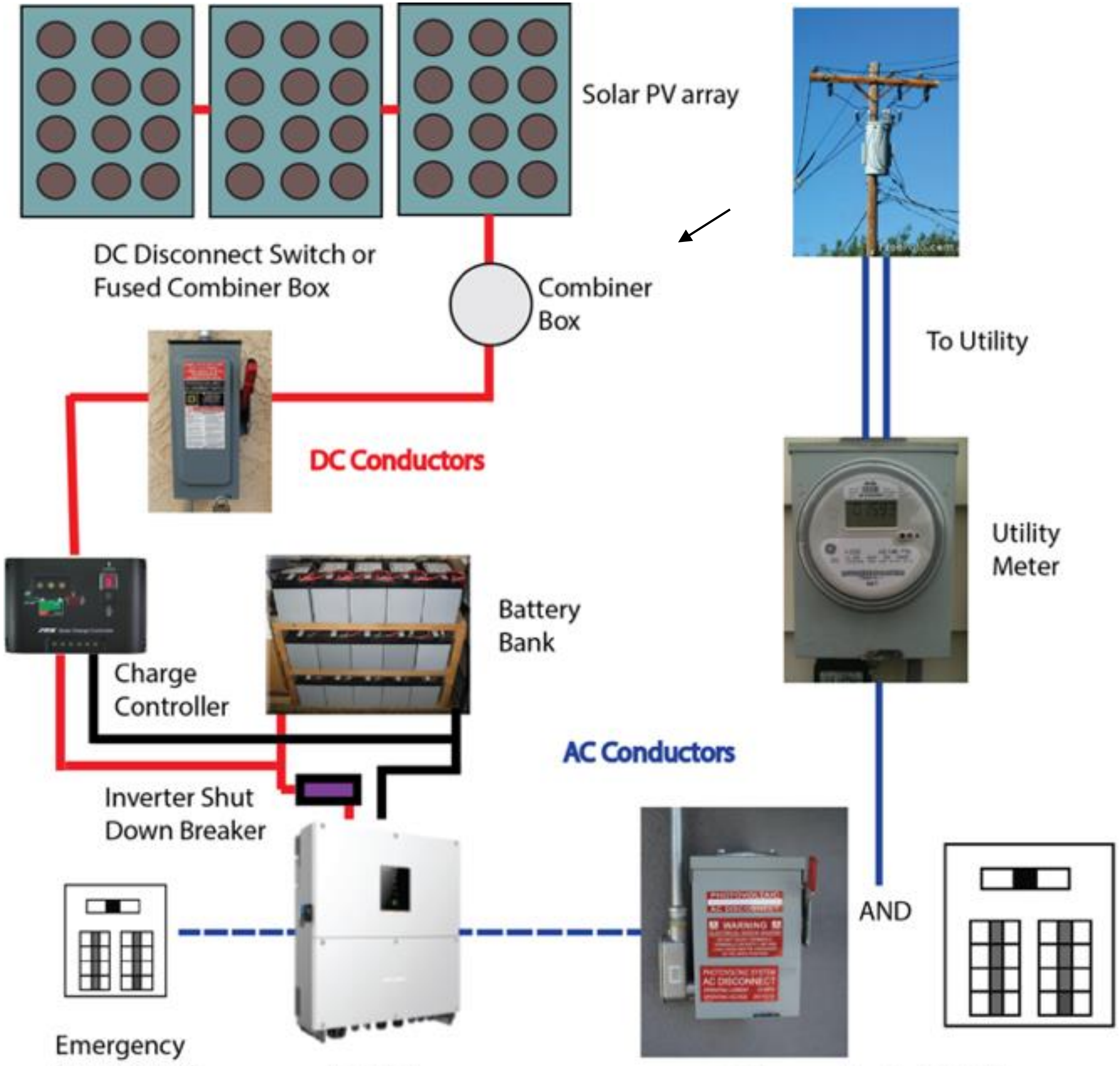
DC circuits: operating dc disconnection will not necessarily de-energize dc circuit

AC circuits: de-energizing utility power will disconnect energy from disconnecting point to the inverters

1. Find System Directory, usually located at the building's main service disconnecting point
2. Disconnect utility power to inverter, operate dc disconnect switch
3. AC conductors from utility to disconnecting point are energized unless meter is pulled
4. AC conductors from inverter to battery powered panel are energized unless inverter shut down breaker is off
5. Avoid DC conductors from solar module to the DC disconnect switch

Grid-tied system with storage

HOT?



Off-grid with battery storage

No grid interconnection

May be generator interconnection

DC circuits (rare) are powered directly by the battery

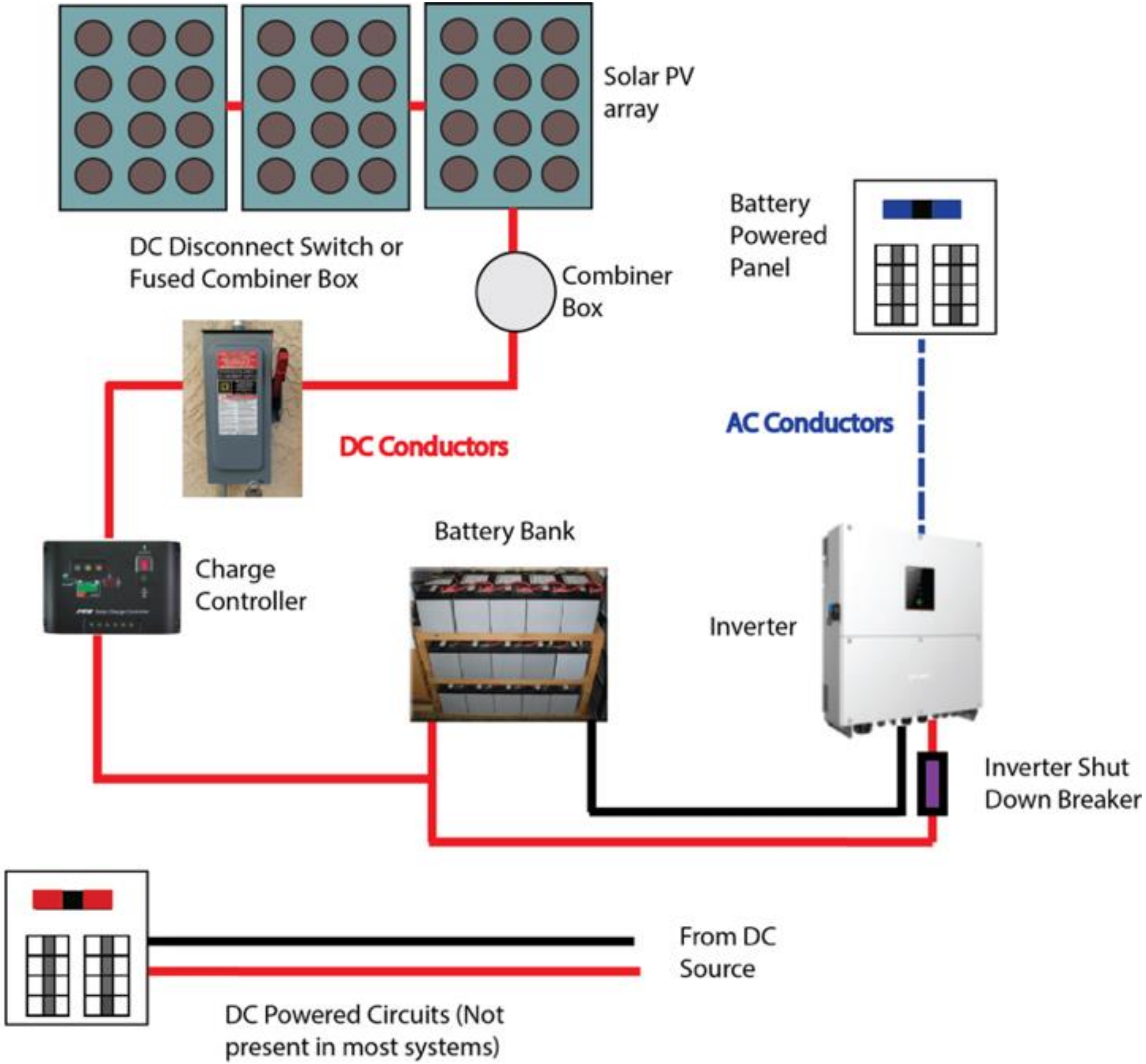
Off-grid with battery storage

DC circuits: operating dc disconnection will not necessarily de-energize dc circuit

AC circuits: de-energize by turning off the inverter shut down breaker

1. Find System Directory, usually located at the building's main service disconnecting point
2. **AC conductors** from inverter to battery powered panel are energized unless the inverter shut down breaker is off
3. Avoid **DC Conductors** immediately underneath solar modules to the **DC disconnect switch**
4. If dc subpanel is present, the dc conductors to this panel are energized directly from the battery. If there is no disconnect or breaker between the subpanel and the battery, turning off the subpanel is the only way to deenergize the dc subpanel. The conductors between the battery bank and the dc subpanel will still be energized.

Off-grid with battery storage



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](#)

http://gosolarnorthtexas.org/faq?field_audience_value=Fire+and+Code

http://gosolarnorthtexas.org/2016/solar-pv-fire-and-code-officials-workshop

Thank you!

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Consultant

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