1

Doug Smith, MCP/CBO

- Inspector/Plan Reviewer for over 20 years
- 19 ICC certifications
- Certified ICC Master Code Professional and CBO
- Taught electrical, solar PV, and ESS classes for over 14 years
- Performed well over ten-thousand electrical, solar PV, and ESS plan reviews
- Serve on *NEC* CMP 10 representing IAEI
- Currently serve as a Technical Committee (TC) Member for the following UL standards:
  - UL 61730 (previously 1703) – Flat-Plate PV Modules and Panels
  - UL 1741 - Inverters, Converters, Controllers, and Int. equip…
  - UL 2703 – PV Mounting Systems/Clamps/Gnd. Lugs
  - UL 6703 – Connectors for Use in PV Systems
  - UL 9540 - Energy Storage Systems and Equipment

2

Course Objective/Intent

- The objective of this presentation is to explain the core *NEC/IRC* requirements that govern residential energy storage systems (ESS). This presentation is based on the **2020/2023 *NEC* and 2021 *IRC/IFC***.
- The intent of this information is to be used as a guide only. This presentation is not intended to indicate any change in any code or local requirements by inference or omission. All diagrams are for illustration purposes only and actual wiring and installation may vary. This presentation is not intended to indicate if one piece or particular brand of equipment is better than another. Also, efficiency and ideal design considerations are not addressed herein. All applicable codes, standards, and manufacturer requirements must always be followed when designing, installing, and inspecting any electrical system, including solar PV and/or battery/energy storage systems.

3

Outline

1. **Requirements for Residential ESS:**
   1. **UL 9540 and UL 9540A – brief explanation**
   2. ***IRC/IFC* Requirements for Energy Storage Systems**
   3. ***NEC* Requirements for ESS**
   4. **Example ESS Plans and System Layouts**

4

Requirements for Energy Storage Systems (ESS)

Image from simpliphipower.com

5

Key Provisions of UL 9540: Energy Storage Systems and Equipment

6

UL 9540 – Edition 3

UL 9540 – Edition 3:

- ❑ Published June 28, 2023.
- ❑ Effective Date is September 2024.

7

UL 9540 Scope (continued)

Section 1.2:

- ❑ The systems covered under the UL 9540 standard include standalone systems, electric grid-tied systems, and systems used as ancillary equipment for other power generation systems.

Stand-alone and/or grid-tied ESS must comply with UL 9540.

Section 1.4:

- ❑ Both indoor and outdoor systems are included.

8

UL 9540 Scope (continued)

Section 1.5:

- Outside the scope of the UL 9540 standard are systems utilizing lead acid or Ni-cad batteries and the system falls within the scope of UL 1778 for uninterruptable power systems (UPS).

Image from csemag.com

9

UL 9540 Scope (continued)

UL 9540 – Figure 6.1 (updated)

- AC ESS – includes energy storage capability, protective features, and power conversion.

- DC ESS – only includes energy storage capability and protective features.

10

UL 9540, Compatibility

Section 15.2:

- Cannot assume that equipment is compatible with other equipment even though the equipment may be individually listed (and deemed safe individually).

Example of older battery backup PV system (does NOT have the UL 9540 listing)

11

UL 9540, listing of individual equipment

Section 24.1.1:

- Inverters, chargers, and charge control equipment must be evaluated per **UL 1741**, UL 62109-1, UL 1012, or UL 1564 as applicable per its intended application in the system.
- Electrochemical batteries must be listed per **UL 1973** (except lead acid or Ni-cad batteries can follow Appendix D in UL 9540).

12

UL 9540, ESS in Residential Living Space

Section 26.2.2:

- ESS installed in the living or habitable space of a residential dwelling unit (where permitted) must meet the **cell-level** performance requirements of UL 9540A, and such ESS must be marked per section 45.3(e)(1).
  - 45.3(e)(1) requires that such systems meeting the above noted criteria must be marked as "Suitable For Use in Residential Habitable Spaces." (note: the 2021 *IRC* R328.1 exception instead says "For Use In Residential Dwelling Units")

Residential ESS must at least meet the *Unit*-Level criteria of UL 9540A

Thus far, NO ESS is permitted to be located in the living or habitable space of a dwelling.

13

Overview of UL 9540A: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

14

UL 9540A, Large-Scale Fire Testing

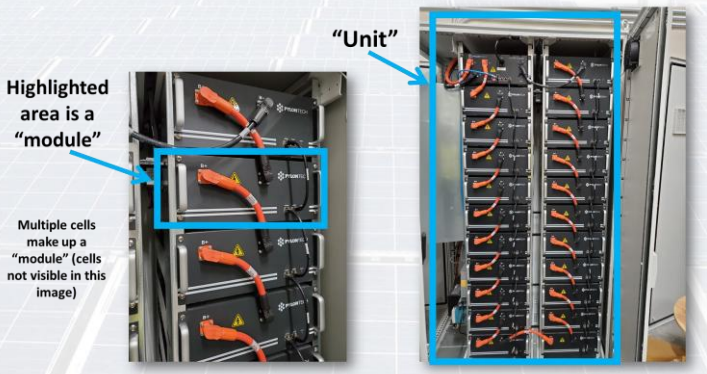
ESS MUST achieve (pass) cell-level test to be allowed in the habitable space of a dwelling!

- **Cell Level Testing** → If thermal runaway cannot be induced in the cell and any vented gas does not present a flammability hazard. → **No further testing required**
- **Module Level Testing** → Any effects of thermal runaway are contained by the module design, and any vented gasses are nonflammable. → **No further testing required**
- **Unit Level Testing** → Temp of modules is less than cell surface temperature at gas venting, and meets heat flux limits for means of egress. Temp increase of target walls less than 175°F. No explosion hazards. No flames extending beyond outer dimensions of BESS unit. → **No further testing required**

Installation level testing (includes fire protection equipment and does NOT apply to residential BESS)

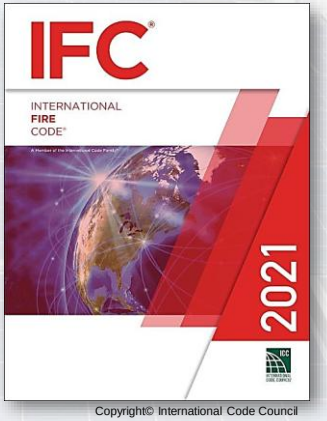
15

UL 9540A



16

IFC Requirements for Energy Storage Systems (for Group R-3 and R-4 Occupancies)



17

IFC Requirements for ESS

IFC R1207.11:

- Energy storage systems (ESS) in Group R-3 and R-4 occupancies must comply with the provisions of 1207.11.1 through 1207.11.9.
- Note, the only way an ESS can be installed in the living or habitable space of a dwelling unit is if the system has achieved the cell-level test of UL 9540**A** AND the equipment has the following marking "Suitable For Use in Residential Habitable Spaces". See UL 9540 Section 45.3(e)(1).

ESS can't be located in the living space of the home, but other spaces such as garages, outdoors, storage rooms, etc are often permitted (if provisions of *IFC* are met)

18

Storage room example

19

IFC Requirements for ESS

IFC 1207.11.1 – Equipment Listings:

- ESS shall be listed and labeled in accordance with **UL 9540**. ESS listed only for commercial or utility use cannot be installed at residential occupancy.
- Exceptions:
  - Where approved, repurposed unlisted battery systems from electric vehicles are allowed to be installed outdoors or in detached sheds located not less than 5 feet (1524 mm) from exterior walls, property lines and public ways.
  - ESS less than 1 kWh (3.6 megajoules)

20

Many violations!

21

Example of older battery backup PV system (does NOT have the UL 9540 listing)

22

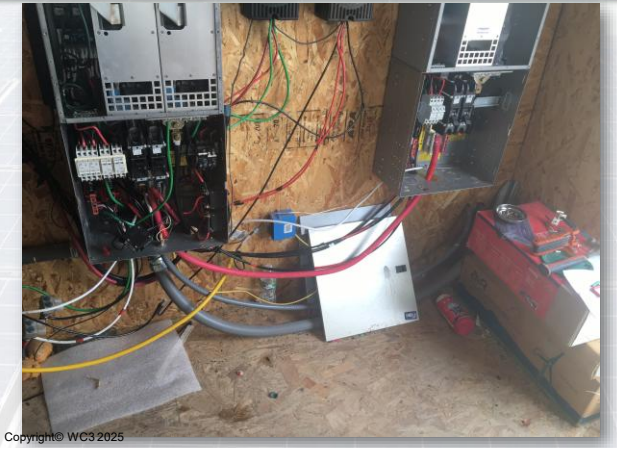
IFC Requirements for ESS

IFC 1207.11.2 – Installation:

- ESS shall be installed in accordance with the manufacturer's instructions and their listing.

23

Lots of Violations!!!



24

IFC Requirements for ESS

IFC 1207.11.2.1 – Spacing:

- Individual units (see also 1207.11.4) shall be separated from each other by not less than **three feet** except where smaller separation distances are documented to be adequate based on large scale fire testing complying with Section 1207.1.5 of the International Fire Code.

"Large-scale fire" testing is referring to testing in accordance with UL 9540A

25

Violations?

26

Violations?

27

Example of a Good Install

The Enphase® ESS has been tested per UL 9540A and is permitted to have units spaced less than 36" (but still must follow installation instructions).

28

Example of a Good Install

The SolarEdge® ESS has been tested per UL 9540A and is permitted to have units spaced less than 36" (but still must follow installation instructions).

29

IFC Requirements for ESS

IFC 1207.11.3 – Location:

- ESS shall be installed only in the following locations:
  1. Detached garages and detached accessory structures.
  2. Attached garages separated from the dwelling unit living space in accordance with Section 406.3.2 of the *IBC*.
  3. Outdoors or on the exterior side of exterior walls located not less than 3 feet from doors and windows directly entering the dwelling unit.
  4. Utility closets and storage or utility spaces within dwelling units and sleeping units.

NOTE: R328.4 of the *IRC* also requires any utility rooms or storage spaces to have finished or noncombustible walls and ceilings. But walls and ceilings of unfinished wood-framed construction shall be provided with not less than 5/8-inch Type X gypsum wallboard. Also, the *IRC* specifies that ESS shall not be installed in sleeping rooms, or closets or spaces opening directly into sleeping rooms.

30

Violations!!!

31

Violations?

32

IFC Requirements for ESS

IFC 1207.11.4 – Energy Ratings:

- Individual ESS units shall have a maximum rating of **20 kWh**. The aggregate rating of the ESS shall not exceed:
  1. 40 kWh within utility closets, basements, and storage or utility spaces.
  2. 80 kWh in attached or detached garages and detached accessory structures.
  3. 80 kWh on exterior walls.
  4. 80 kWh outdoors on the ground.

Note, at R328.5 in the IRC it says that ESS installations exceeding the permitted individual or aggregate ratings shall be installed in accordance with Section 1207 the International Fire Code.

33

IFC Requirements for ESS

IFC 1207.11.5 – Electrical Installation:

- ESS shall be installed in accordance with NFPA 70 (*National Electrical Code*). Inverters shall be listed and labeled in accordance with UL 1741 or provided as part of the UL 9540 listing. Systems connected to the utility grid shall use inverters listed for utility interaction.

34

IFC Requirements for ESS

IFC 1207.11.6 – Fire Detection:

- Rooms and areas within dwelling units, sleeping units, and attached garages in which ESS are installed shall be protected by smoke alarms in accordance with Section 907.2.10. (in the *IRC* the references section is R314)
- A heat detector (heat ALARM), listed and interconnected to the smoke alarms, shall be installed in locations within dwelling units, sleeping units, and attached garages where smoke alarms cannot be installed based on their listing.

35

36

IRC Section R314

R314.4 Interconnection. Where more than one smoke alarm is required to be installed within an individual dwelling unit in accordance with Section R314.3, the alarm devices shall be interconnected in such a manner that the actuation of one alarm will activate all of the alarms in the individual dwelling unit.

Physical interconnection of smoke alarms shall not be required where listed wireless alarms are installed and all alarms sound upon activation of one alarm.

37

IRC Section R314 (continued)

R314.6 Power Source. Smoke alarms shall receive their primary power from the building wiring where such wiring is served from a commercial source and, where primary power is interrupted, shall receive power from a battery. Wiring shall be permanent and without a disconnecting switch other than those required for overcurrent protection.

Exceptions:

1. Smoke alarms shall be permitted to be battery operated where installed in buildings without commercial power.
2. Smoke alarms installed in accordance with Section R314.2.2 shall be permitted to be battery powered.

R314.7 also allows the use of a full fire alarm system.

38

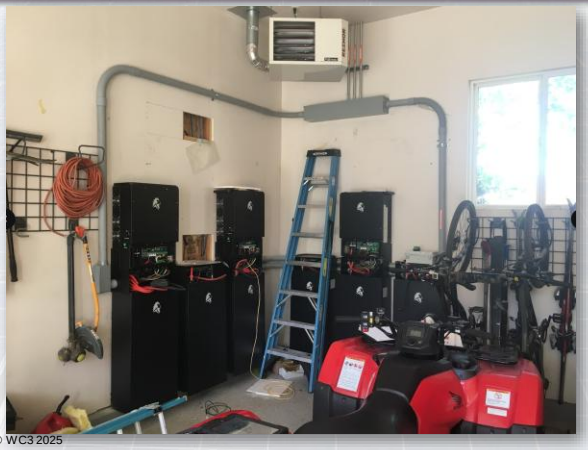
IFC Requirements for ESS

IFC 1207.11.7 – Protection from Impact:

- ESS installed in a location subject to vehicle damage shall be protected by approved barriers.

39

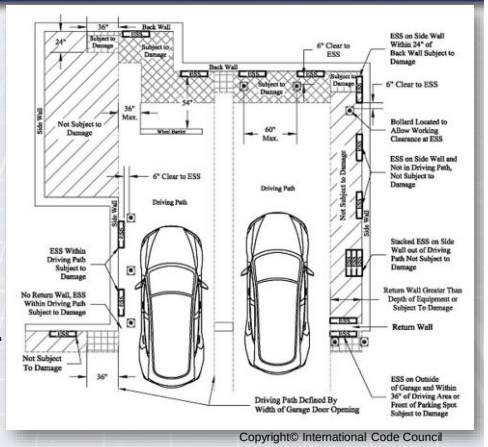
Violations!!!



40

Protection from Vehicle Damage

Figure 1207.11.7.1 of the 2024 *IFC* (or R328.8.1 from the 2024 *IRC*) helps provide guidance on what locations in a garage could be considered as subject to damage.



41

Protection from Vehicle Damage

Figure 1207.11.7.1 of the 2024 *IFC* (or R328.8.1 from the 2024 *IRC*) also helps provide guidance on *how* to protect equipment from physical damage.

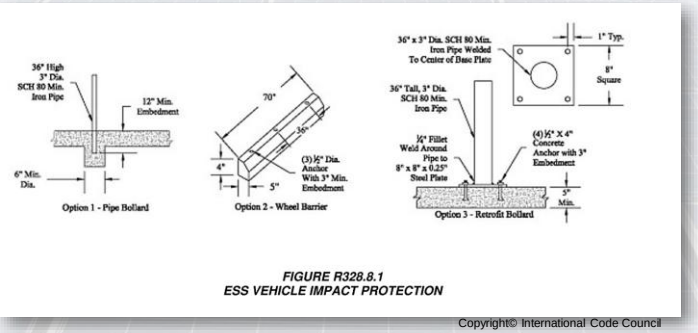


FIGURE R328.8.1
ESS VEHICLE IMPACT PROTECTION

42

IFC Requirements for ESS

IFC 1207.11.8 – Equipment Listings:

- ❑ Indoor installation of ESS that include batteries that produce hydrogen or other flammable gases during charging shall be provided with mechanical ventilation in accordance with Section 1207.6.1.

Note: most sealed batteries do not require ventilation per manufacturer's requirements.

IFC 1207.11.9 – Toxic & highly toxic gas:

- ❑ ESS that under normal charging and normal use that can produce toxic gases cannot be installed in a Group R-3 or R-4 occupancy.

43

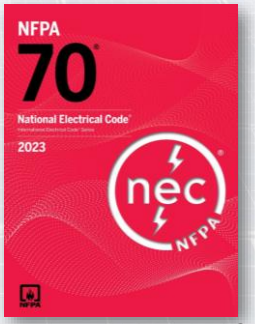
IFC Requirements for ESS

IFC 1207.11.19 – Electric Vehicle Use:

- ❑ The temporary use of an owner or occupant's electric powered vehicle to power a dwelling unit or sleeping unit while parked in an attached or detached garage or outdoors shall comply with the vehicle manufacturer's instructions and NFPA 70 (*NEC*).

44

Key Energy Storage System (ESS) Requirements per the 2023 *NEC*



NFPA 70 *National Electrical Code*©

45

NEC 706.5 – Listing

Energy storage systems (ESS) are required to be listed.

- Per informational note #3 of 706.1 and per Annex A in the *NEC*, the following standards apply:
  - UL 1973 for non-lead acid batteries
  - UL 1741 for inverters, converters and controllers
    - Inverters that are also utility interactive must be listed as such [see *NEC* 706.16(B) and (C)].
  - UL 9540 for ESS

46

NEC 706.15 – Disconnecting Means

706.15(A):

- There must be a disconnect for all ungrounded (hot) conductors derived from an ESS.
- The disconnect is permitted to be integral to listed ESS equipment.

47

NEC 706.15(A) – Continued

The required disconnect must be readily accessible and must comply with one or more of the following:

- Be within the ESS (part of the ESS).
- Within sight and within 10 feet of the ESS.
- When the disconnect is not within sight of the ESS, the disconnect, or the enclosure of the disconnect, must be capable of being locked per *NEC* 110.25.

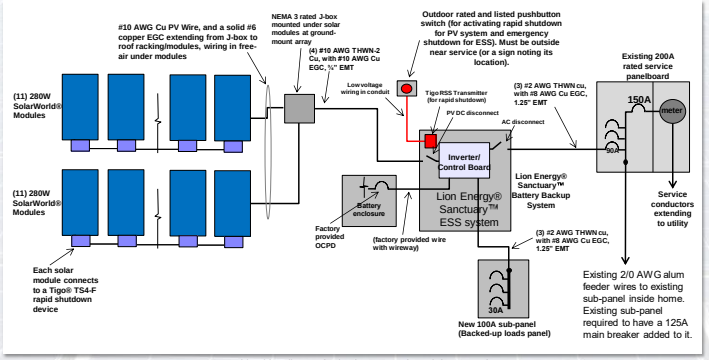
48

NEC 706.15(A) – Emergency Shutdown

- For all one-family and two-family dwellings, there must be provided on the outside of the home and at readily accessible location, an emergency shutdown initiation device to activate an **emergency shutdown function** of the ESS and cause the ESS to stop exporting power to the premises wiring system.

49

Example Shutoff Switch



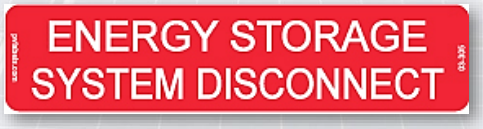
Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

50

NEC 706.15(C) – Disconnect Marking

706.15(C):

- Each ESS disconnect must clearly indicate on (closed) or off (open) positions.
- Such disconnect(s) must be marked "**Energy Storage System Disconnect**."

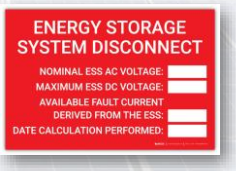


51

NEC 706.15(C) – Disconnect Marking

706.15(C) continued:

- The disconnect(s) must be marked with the following:
  - Nominal ESS AC voltage and maximum ESS DC voltage.
  - Available fault current derived from the ESS
  - Arc-flash label per acceptable industry practice (for example, see 130.5(H) of NFPA 70E)
  - Date the calculaation was performed



These items are <u>not</u> required for a one- or two-family dwelling system [see exception of 706.15(C)]

52

NEC 706.15(C) – Disconnect Marking Continued…

706.15(C) continued:

- Where the line and load terminals of an ESS disconnect can be energized when in the off (open) position, there must be a sign on the disconnect(s) with the following words:

  "**Warning Electric Shock Hazard Terminals on the Line and Load Sides May be Energized in the Open Position**."

53

NEC 706.16 – Continued

706.16(F):

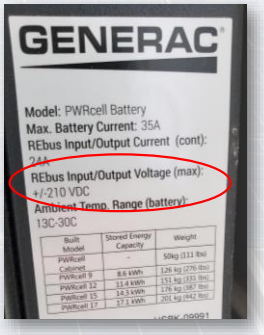
- When an ESS is capable of operating in stand-alone mode, the requirements of *NEC* 710.15 also apply.
  - Note: 710.15(A) states that a stand-alone system is permitted to have a capacity less than the calculated load.
  - The capacity of all combined sources of the stand-alone supply must be equal to or greater than the load of the largest single utilization equipment connected to the system.

54

NEC 706.20 – General Installation Req.

706.20(B):

- The voltage for a <u>one- and two-family dwelling</u> cannot exceed 100V.
  - Exception says that up to 600V is permitted when live parts are not accessible during routine ESS maintenance.



55

NEC 706.20 – Continued

706.20(C):

- Working space is required in front of equipment per *NEC* 110.26 and 110.34.
- Spacing in between ESS components is permitted to be in accordance with the manufacturer's instructions and listing.
  - However, more restrictive spacing requirements may be required per Section 1207 of the IFC, or Section R328 of the IRC.

56

Violations!

57

NEC 706.21 – Identification of Power Sources

706.21:

- Marking or labels for ESS must be per NEC 110.21(B).
- "Plaques or directories" are required per 705.10 and 710.10.

58

NEC 706.31 – OCPD Rating

706.31(B):

- Overcurrent protection devices (where required) for circuits serving an ESS must be rated not less **125%** of the current ratings per *NEC* 706.30(A).
  - The exception to the rule is assemblies with overcurrent devices which are rated for 100% continuous operation, in which case the overcurrent protection rating cannot be less than the current rating per *NEC* 706.30(**B**).

59

Example Plan and System Layouts of Energy Storage Systems (ESS)

60

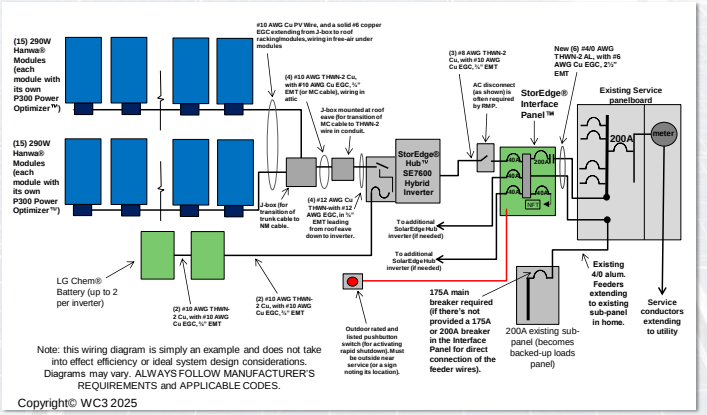
ESS Example System #1

SolarEdge® StorEdge HUB™ Battery Backup String Inverter with an LG Chem® DC Battery System

61

Example System (for an SolarEdge® Hub™ battery system

ESS Example Sys. #1

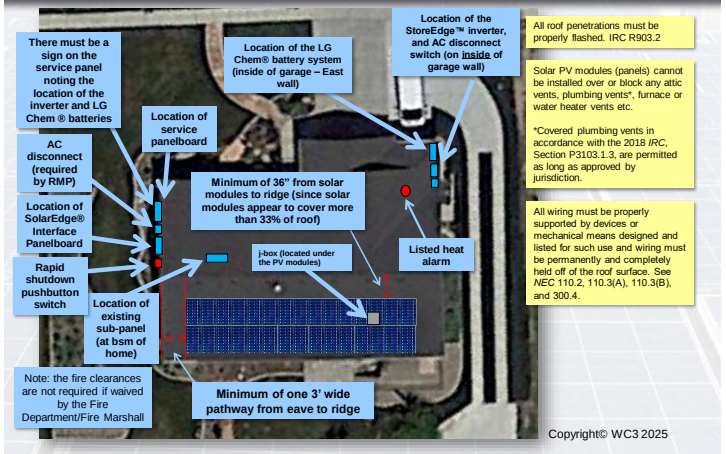


Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

62

Site Plan (gabled roof)

ESS Example Sys. #1



All roof penetrations must be properly flashed. IRC R903.2

Solar PV modules (panels) cannot be installed over or block any attic vents, plumbing vents*, furnace or water heater vents etc.

*Covered plumbing vents in accordance with the 2018 *IRC*, Section P3103.1.3, are permitted as long as approved by jurisdiction.

All wiring must be properly supported by devices or mechanical means designed and listed for such use and wiring must be permanently and completely held off of the roof surface. See *NEC* 110.2, 110.3(A), 110.3(B), and 300.4.

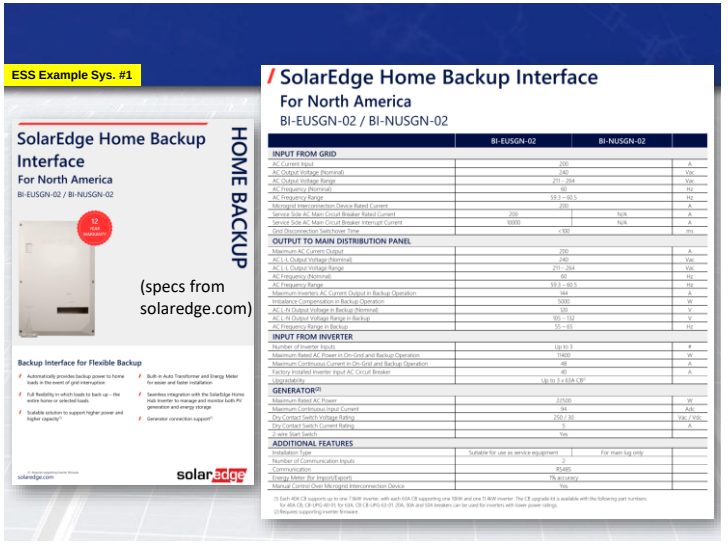
63

Photo of Service Panel

ESS Example Sys. #1

For this example, we are assuming that the service panel is rated for **200A** since the main service breaker is rated **200A**.

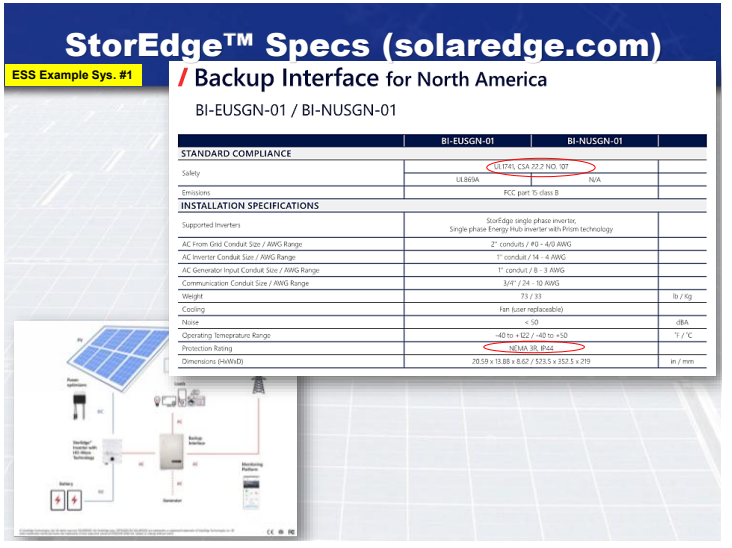
64



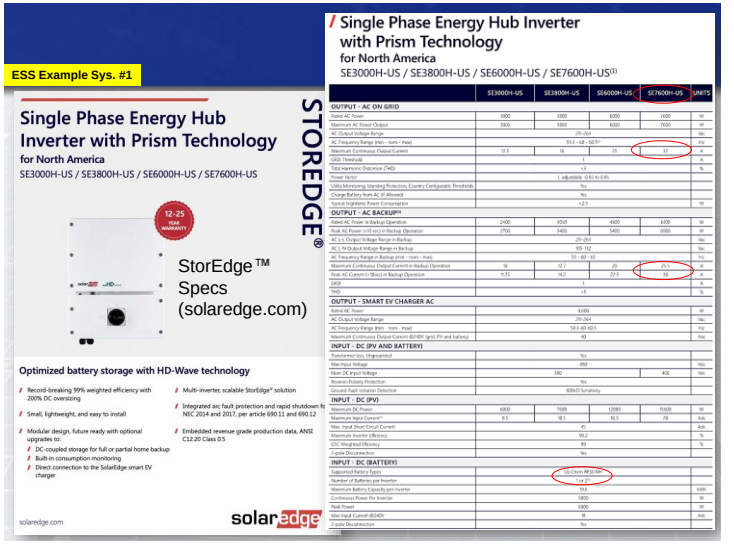
65

66

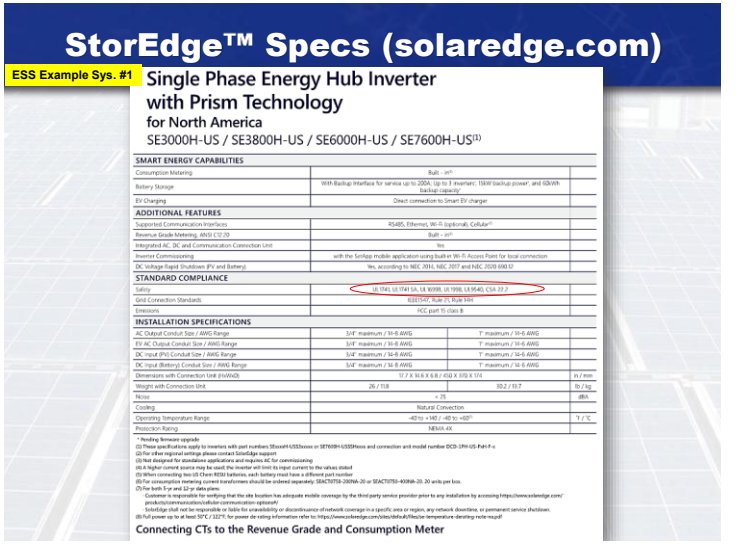
67



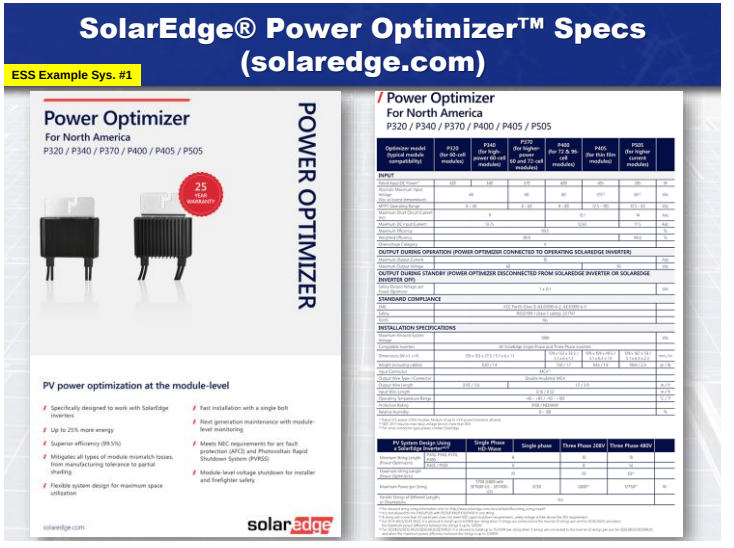
68


ESS Example Sys. #1
Single Phase Energy Hub Inverter with Prism Technology
for North America
SE3000H-US / SE3800H-US / SE6000H-US / SE7600H-US
STOREDGE
12-25 YEAR WARRANTY
StorEdge™ Specs (solaredge.com)
Optimized battery storage with HD-Wave technology
Single Phase Energy Hub Inverter with Prism Technology
for North America
SE3000H-US / SE3800H-US / SE6000H-US / SE7600H-US
SE3000H-US
SE3800H-US
SE6000H-US
SE7600H-US
UNITS
OUTPUT - AC ON GRID
OUTPUT - AC BACKUP
OUTPUT - SMART EV CHARGER AC
INPUT - DC (PV AND BATTERY)
INPUT - DC (PV)
INPUT - DC (BATTERY)
solaredge.com
solaredge

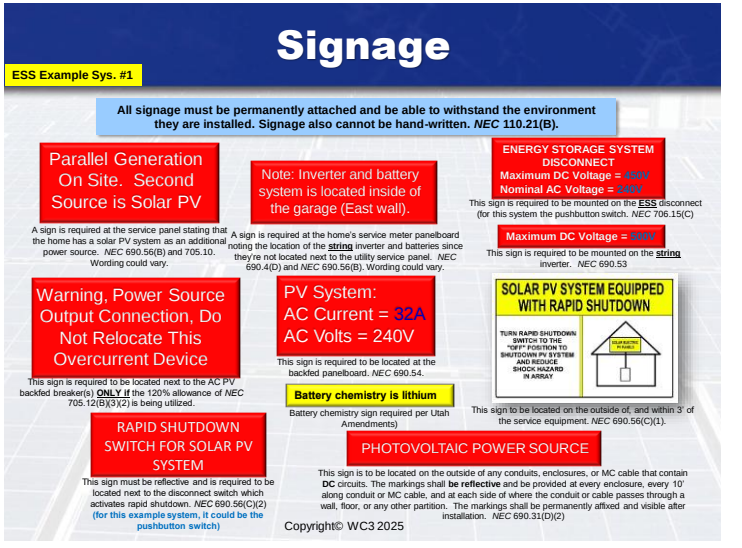
69


StorEdge™ Specs (solaredge.com)
ESS Example Sys. #1
Single Phase Energy Hub Inverter with Prism Technology
for North America
SE3000H-US / SE3800H-US / SE6000H-US / SE7600H-US
SMART ENERGY CAPABILITIES
ADDITIONAL FEATURES
STANDARD COMPLIANCE
INSTALLATION SPECIFICATIONS
Connecting CTs to the Revenue Grade and Consumption Meter

70


SolarEdge® Power Optimizer™ Specs (solaredge.com)
ESS Example Sys. #1
Power Optimizer
For North America
P320 / P340 / P370 / P400 / P405 / P505
POWER OPTIMIZER
25 YEAR WARRANTY
PV power optimization at the module-level
Power Optimizer
For North America
P320 / P340 / P370 / P400 / P405 / P505
solaredge.com
solaredge

71


Signage
ESS Example Sys. #1
All signage must be permanently attached and be able to withstand the environment they are installed. Signage also cannot be hand-written. NEC 110.21(B).
Parallel Generation On Site. Second Source is Solar PV
A sign is required at the service panel stating that the home has a solar PV system as an additional power source. NEC 690.56(B) and 705.10. Wording could vary:
Note: Inverter and battery system is located inside of the garage (East wall).
A sign is required at the home's service meter panelboard noting the location of the string inverter and batteries since they're not located next to the utility service panel. NEC 690.4(D) and NEC 690.56(B). Wording could vary.
ENERGY STORAGE SYSTEM DISCONNECT
Maximum DC Voltage = 400V
Nominal AC Voltage = 240V
This sign is required to be mounted on the ESS disconnect (for this system the pushbutton switch. NEC 706.15(C)
Maximum DC Voltage = 400V
This sign is required to be mounted on the string inverter. NEC 690.53
Warning, Power Source Output Connection, Do Not Relocate This Overcurrent Device
This sign is required to be located next to the AC PV backfed breaker(s) ONLY if the 120% allowance of NEC 705.12(B)(3)(2) is being utilized.
PV System: AC Current = 32A AC Volts = 240V
This sign is required to be located at the backfed panelboard. NEC 690.54.
SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN
TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUTDOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY
This sign to be located on the outside of, and within 3' of the service equipment. NEC 690.56(C)(1).
Battery chemistry is lithium
Battery chemistry sign required per Utah Amendments)
RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM
This sign must be reflective and is required to be located next to the disconnect switch which activates rapid shutdown. NEC 690.56(C)(2) (for this example system, it could be the pushbutton switch)
PHOTOVOLTAIC POWER SOURCE
This sign is to be located on the outside of any conduits, enclosures, or MC cable that contain DC circuits. The markings shall be reflective and be provided at every enclosure, every 10' along conduit or MC cable, and at each side of where the conduit or cable passes through a wall, floor, or any other partition. The markings shall be permanently affixed and visible after installation. NEC 690.31(D)(2)
Copyright© WC3 2025

72

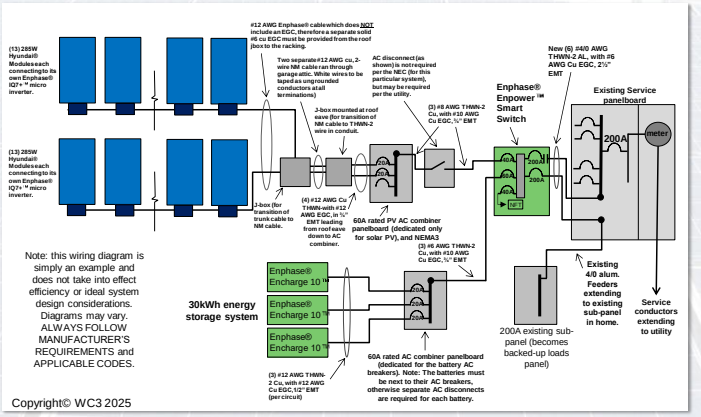
ESS Example System #2

Enphase® Encharge 10™ Energy Storage System with Enphase® Micro Inverters

73

Example System (for an Enphase® Encharge 10™ and IQ7+™ micro inverter system)

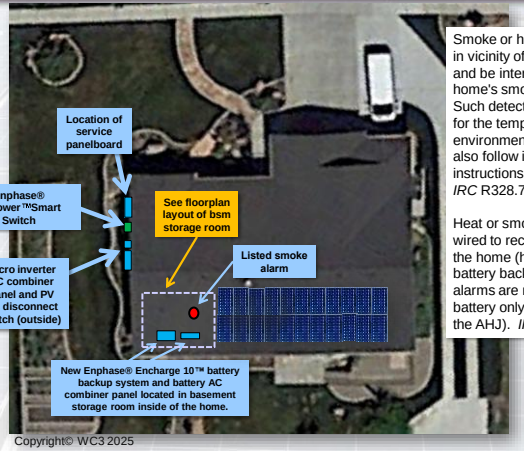
ESS Example Sys. #2



74

Site Plan

ESS Example Sys. #2

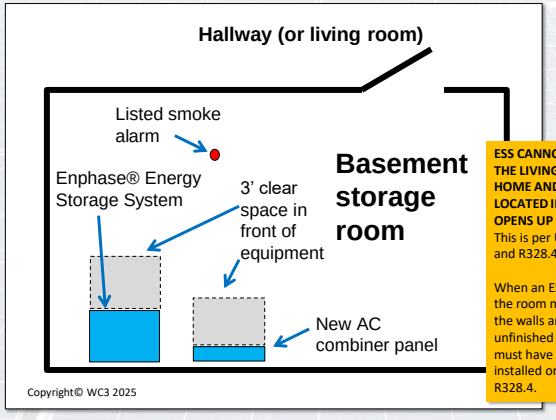


Smoke or heat alarm must be in vicinity of the battery system and be interconnected with home's smoke alarm system. Such detector must be rated for the temperature of the environment it's installed. Must also follow installation instructions for the alarm. Utah *IRC* R328.7.

Heat or smoke alarms must be wired to receive power from the home (hard wired) with battery backup. Heat or smoke alarms are not allowed to be battery only (unless allowed by the AHJ). *IRC* R314

75

Floorplan Layout



ESS CANNOT BE LOCATED IN THE LIVING SPACE OF THE HOME AND CANNOT BE LOCATED IN A ROOM THAT OPENS UP INTO A BEDROOM! This is per UL 9540 requirements and R328.4 of the 2021 *IRC*.

When an ESS is inside the home, the room must be finished on the walls and ceiling, or any unfinished walls and ceilings must have 5/8" Type X sheetrock installed on them. See *IRC* R328.4.

76

Photo of Service Panel

ESS Example Sys. #2

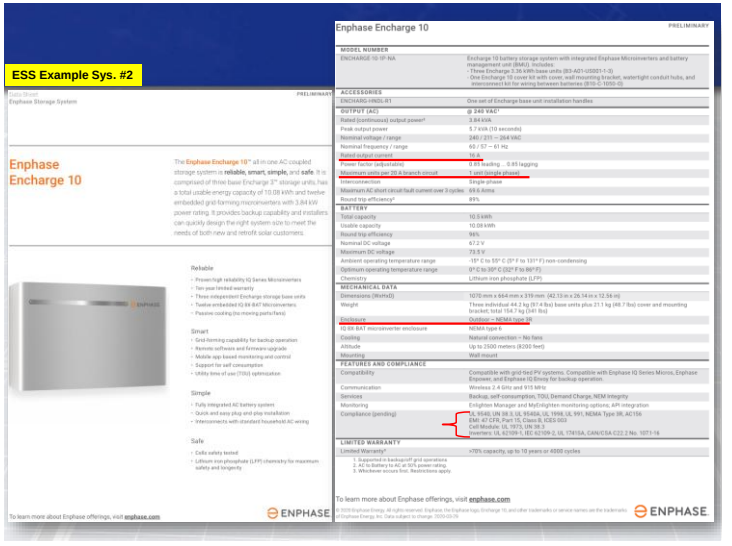
Typically, photos of the service panel label are needed in order to show the rating of the service (and rating of breaker slots).

Also, a clear photo showing the rating of the main service breaker(s) is usually required (in order to determine load-side connection rules).

For this example, we are assuming that the service panel is rated for **200A** since the main service breaker is rated **200A**.

77

ESS Example Sys. #2

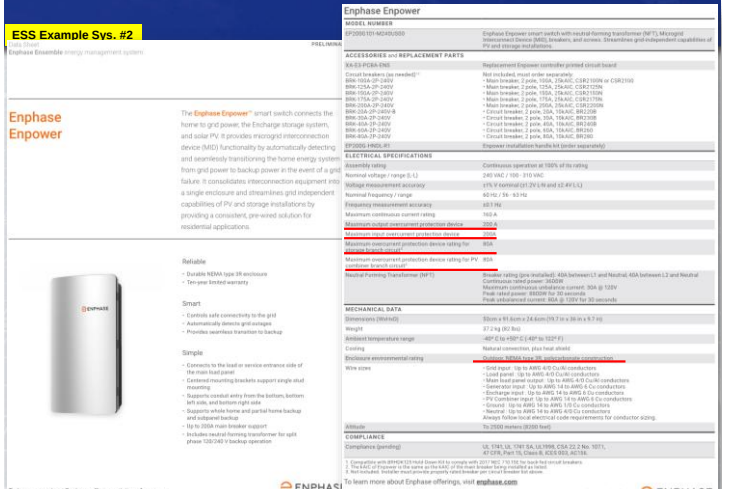


78

ESS Example Sys. #2

79

ESS Example Sys. #2



80

81

Signage

ESS Example Sys. #2

All signage must be permanently attached and be able to withstand the environment they are installed. Signage also cannot be hand-written. *NEC* 110.21(B).

Parallel Generation On Site. Second Source is Solar PV

A sign is required at the service panel stating that the home has a solar PV system as an additional power source. *NEC* 690.56(B) and 705.10. Wording could vary.

Note: Battery System is mounted at West wall, inside of garage.

A sign is required at the home's service meter panelboard noting the location of the **string** inverter and battery system. *NEC* 690.4(D), 706.21, and 705.10. Wording could vary.

Warning, Inverter Output Connection, Do Not Relocate This Overcurrent Device

Power Source

This sign is required to be located next to the PV backed breaker(s) **ONLY if** the 120% allowance of *NEC* 705.12(B)(3)(2) is being utilized.

PV System:
AC Current = 40A
AC Volts = 240V

This sign is required to be located at the backfed panelboard and AC disconnect switch. *NEC* 690.54.

SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN

TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUTDOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY

This sign to be located on the outside of, and within 3' of the service equipment. *NEC* 690.56(C)(1).

ENERGY STORAGE SYSTEM DISCONNECT
Maximum DC Voltage =
Nominal AC Voltage = 240V

This sign is required to be mounted on the **ESS** disconnect (for this system could be the Enphase Smart Switch shutoff). *NEC* 706.15(C)

Battery chemistry is lithium

Battery chemistry sign required per Utah Amendments)

WARNING ELECTRIC SHOCK HAZARD TERMINALS ON THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.

This sign is required at disconnects where terminals can be energized even when the disconnect is shut off. *NEC* 690.13(B).

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

This sign must be reflective and is required to be located next to the disconnect switch which activates rapid shutdown. *NEC* 690.56(C)(2)
(for this system, it could be at any AC breaker or AC disconnect that isolates the micro inverters from the Enphase Smart Switch)

Copyright© WC3 2025

82

ESS Example System #3

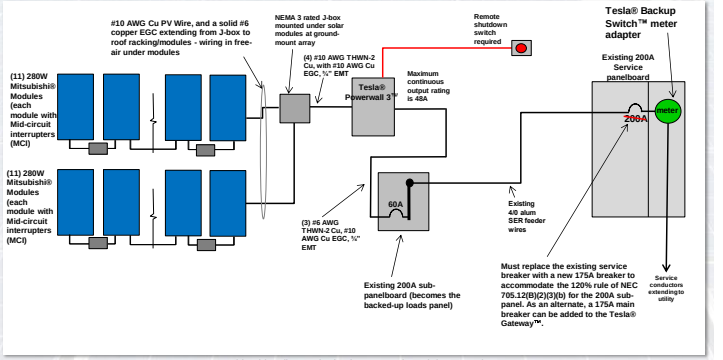
Tesla® AC Powerwall 3™

Copyright© WC3 2025

83

Tesla® Powerwall 3™ Battery System

ESS Example Sys. #3



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

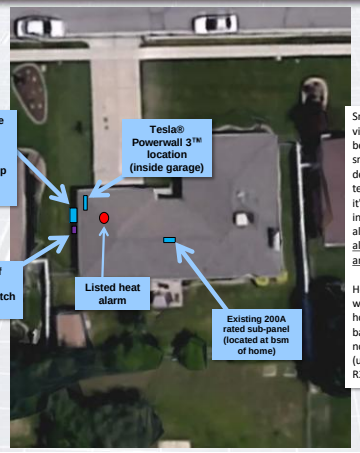
Copyright© WC3 2025

84

Site Plan

ESS Example Sys. #3

(Solar array not shown on this example site plan)



Smoke or heat alarm must be in vicinity of the battery system and be interconnected with home's smoke alarm system. Such detector must be rated for the temperature of the environment it's installed. Must also follow installation instructions for the alarm. Utah *IRC* R328.7. A heat alarm should be installed for ESS in an attached garage.

Heat or smoke alarms must be wired to receive power from the home (hard wired) with battery backup. Heat or smoke alarms are not allowed to be battery only (unless allowed by the AHJ). *IRC* R314

85

Photo of Service

ESS Example Sys. #3

86

Tesla® AC Powerwall™

ESS Example Sys. #3

For Tesla® Powerwall™ and Gateway™ Spec Sheets, see tesla.com.

87

Signage

ESS Example Sys. #3

All signage must be permanently attached and be able to withstand the environment they are installed. Signage also cannot be hand-written. *NEC* 110.21(B).

Parallel Generation On Site. Second Source is Solar PV

A sign is required at the service panel stating that the home has a solar PV system as an additional power source. *NEC* 690.56(B) and 705.10. Wording could vary.

Battery chemistry is lithium

Battery chemistry sign required per Utah Amendments)

Note: Battery System is mounted at West wall, inside of garage.

A sign is required at the home's service meter panelboard noting the location of the battery system. *NEC* 690.4(D), 706.21, and 705.10. Wording could vary.

ENERGY STORAGE SYSTEM DISCONNECT
Maximum DC Voltage =
Nominal AC Voltage = 240V

This sign is required to be mounted on the ESS disconnect (for this system the remote shutoff switch. *NEC* 706.15(C)

Maximum DC Voltage = 500V

This sign is required to be mounted on the string inverter (powerwall). *NEC* 690.53

Warning, Power Source Output Connection, Do Not Relocate This Overcurrent Device

This sign is required to be located next to the PV backfed breaker(s) **ONLY if** the 120% allowance of *NEC* 705.12(B)(3)(2) is being utilized.

PV System:
AC Current = 48A
AC Volts = 240V

This sign is required to be located at the backfed panelboard. *NEC* 690.54.

SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN

TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUTDOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY

This sign to be located on the outside of, and within 3' of the service equipment. *NEC* 690.56(C)(1).

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

This sign must be reflective and is required to be located next to the disconnect switch which activates rapid shutdown. *NEC* 690.56(C)(2) (which for this system will be the remote switch outside next to the service panel)

PHOTOVOLTAIC POWER SOURCE

This sign is to be located on the outside of any conduits, enclosures, or MC cable that contain **DC** circuits. The markings shall **be reflective** and be provided at every enclosure, every 10' along conduit or MC cable, and at each side of where the conduit or cable passes through a wall, floor, or any other partition. The markings shall be permanently affixed and visible after installation. *NEC* 690.31(D)(2)

88

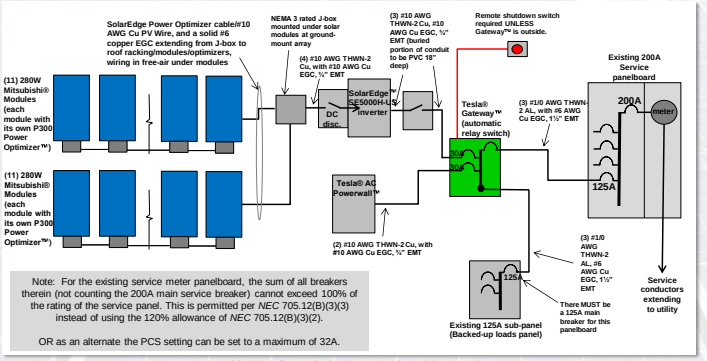
ESS Example System #4

Tesla® AC Powerwall™ with a SolarEdge® String Inverter System ALTERNATE LAYOUT

89

SolarEdge® String inverter with a Tesla® AC Powerwall™ Battery System

ESS Example Sys. #4

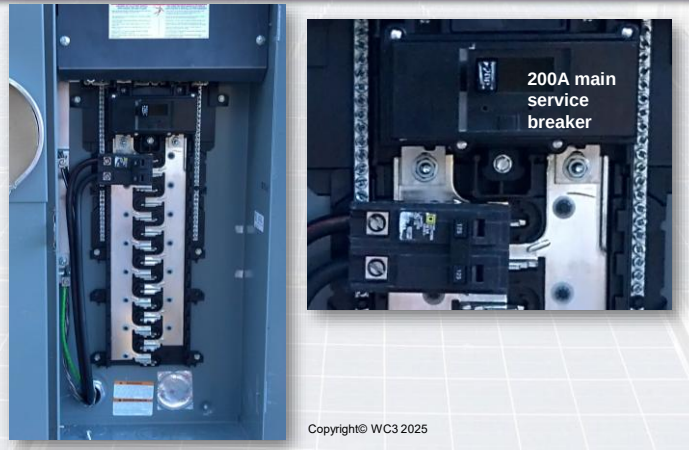


Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

90

Pictures of Service Panel

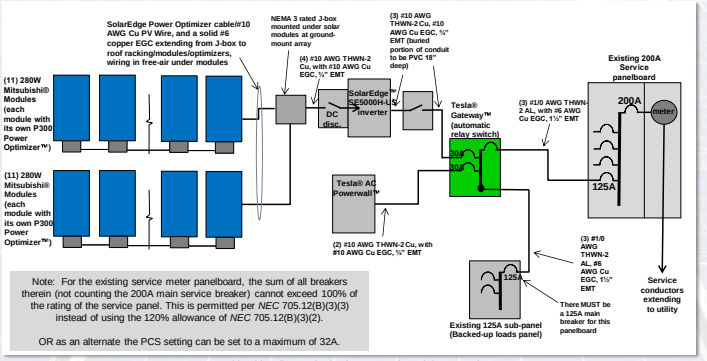
ESS Example Sys. #4



91

SolarEdge® String inverter with a Tesla® AC Powerwall™ Battery System

ESS Example Sys. #4

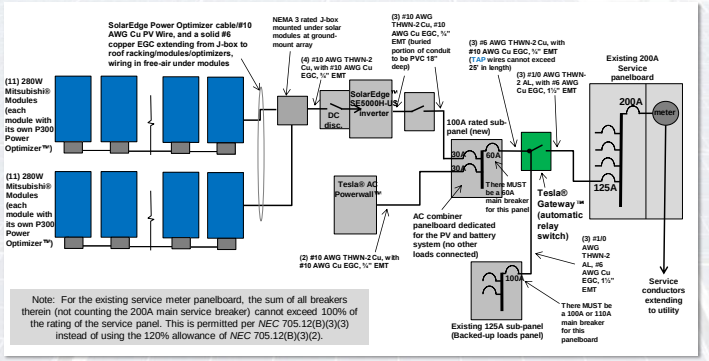


Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

92

Another Example of a Tesla® System Layout

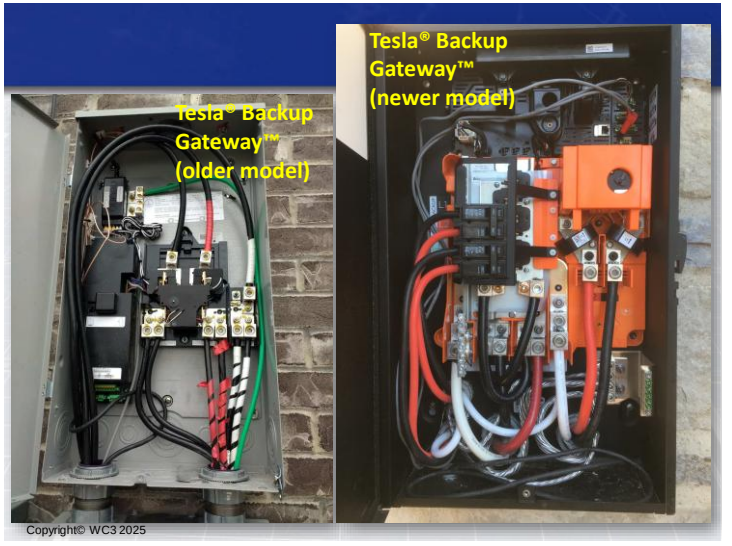
ESS Example Sys. #4



Note: For the existing service meter panelboard, the sum of all breakers therein (not counting the 200A main service breaker) cannot exceed 100% of the rating of the service panel. This is permitted per *NEC* 705.12(B)(3)(3) instead of using the 120% allowance of *NEC* 705.12(B)(3)(2).

Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

93



94

95

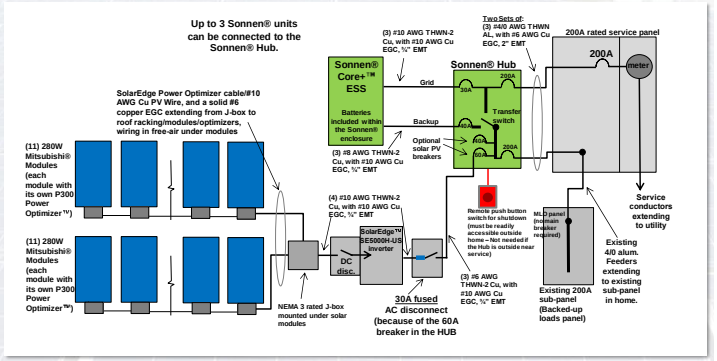
ESS Example System #5

Sonnen® Energy Storage System with a SolarEdge® String Inverter System

96

Sonnen® Core+™ Energy Storage System with a SolarEdge® String Inverter System

ESS Example Sys. #5



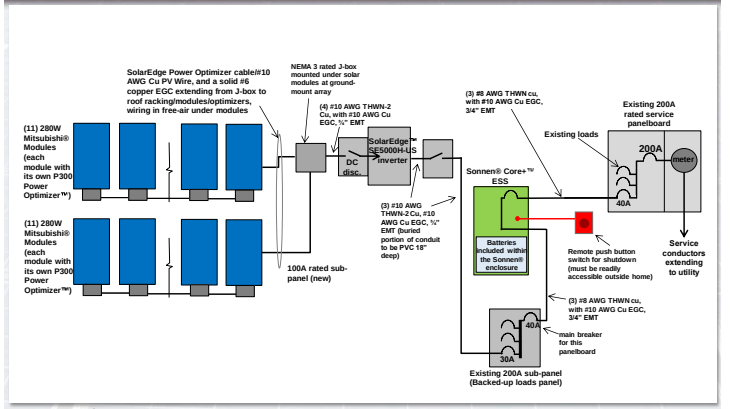
Copyright© WC3 2025

Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary.

97

Alternate layout

ESS Example Sys. #5



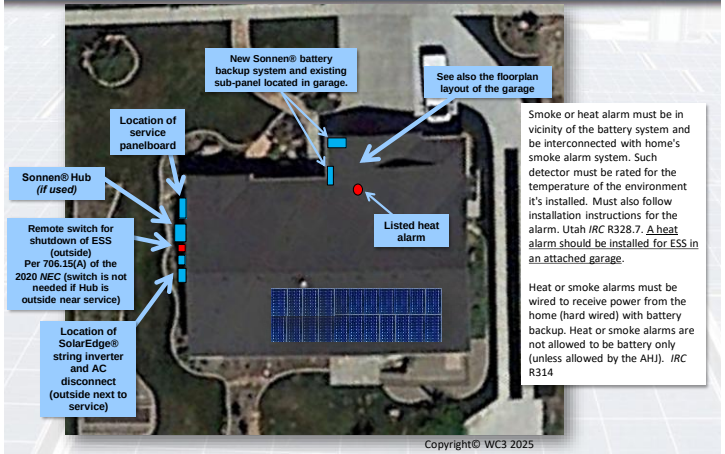
Copyright© WC3 2025

Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary.

98

Site Plan

ESS Example Sys. #5

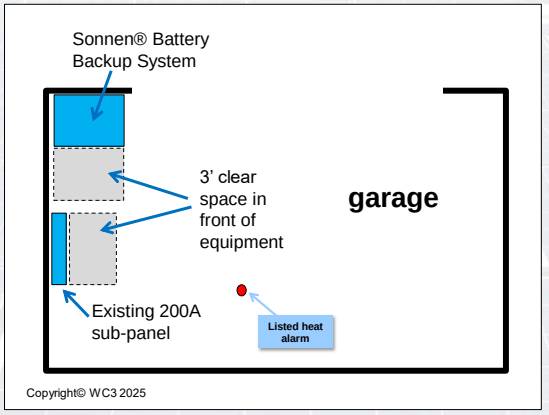


Copyright© WC3 2025

99

Floorplan Layout

ESS Example Sys. #5



Copyright© WC3 2025

100

ESS Example Sys. #5

Sonnen® Core+™ Specs (sonnen-batterie.com)

sonnen

Engineering Design Tech Specs - sonnenCore+

The sonnenCore+ is an intelligent energy storage solution that is safe, long-lasting and offers up to 20kWh of battery capacity. The sleek design combines smart energy management software with the safest and longest lasting batteries to efficiently manage home energy usage throughout the day, store excess solar power for use at night and provide reliable backup power during power outages.

	SCORE-P10	SCORE-P20
Model number		
Usable capacity	10 kWh	20 kWh
Weight (approximate)	408 lbs	514 lbs
Nominal power rating (Grid-tied output at 40°C)	4.8kW	
Dimensions W*H*D* (adjustable height from ground)	27 / 69.5 / 14	27 / 71.5 / 14 (with legs elevated)
Grid integration	AC coupled	
Applications	Time-of-use Virtual Power Plant Solar self-consumption Emergency backup power	
Usable capacity[1]	5 kWh per battery module	
Inverter efficiency	94.4% peak	
On-Grid pass-through	35 A	
Max round-trip efficiency[2]	85.8%	
Operation temperature range	14°F - 122°F 32°F - 104°F (MAX power)	
System cooling	Natural convection	
Comm. ports	Ethernet	
Communication protocols / Control	SunSpec Alliance / API available to select partners	
Noise emission	<25 dB	
Total harmonic distortion	<5%	
Maximum compatible PV inverter	6 kW	

sonnen

101

Sonnen® Core+™ Specs (sonnen-batterie.com)

ESS Example Sys. #5

Off-grid specifications

Nominal Off-Grid current (Continuous)	20 A / 4.8 KVA
Max AC Off-Grid current (Max 30min)	25 A / 5.52 KVA
Max AC Off-Grid current (Max 5s)	30 A / 7.2 KVA
Max AC Off-Grid current (Max 100ms)	36 A / 8.64 KVA

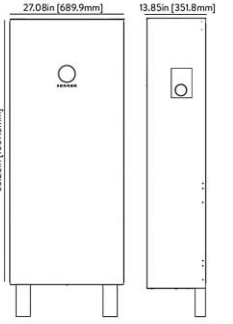
Compliance information

Certifications	UL1741, UL1741SA, UL1973, UL9540, UN38.3
Grid Connections	IEEE 1547, IEEE 2030.5, Rule 21
Emissions	FCC Part 15 Class B (inverter)
Transient protection	IEEE C62.41 Class B
Warranty*	10 year or 10,000 cycle system warranty – includes inverter, battery modules, cabinet and components
Enclosure rating	Type 12

Battery specification

Nominal DC voltage	102 VDC
DC battery input voltage	96 - 112 VDC
Max charge current	19 A per module
Cell discharge[1]	5 kWh with 100% DoD
Cell chemistry	Lithium iron phosphate
Over-current Protection	Fuse protection

Measurements

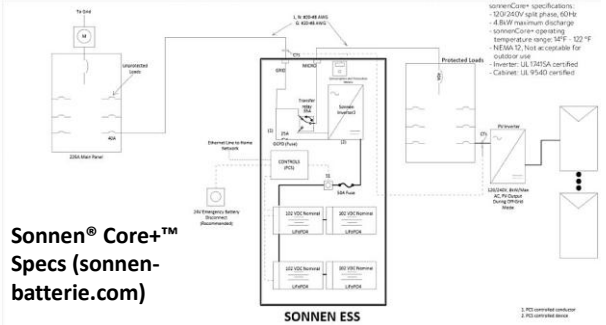


102

ESS Example Sys. #5

Single Line Diagram for System Design

Below is an overview of the design layout for a single sonnenCore+ system with a protected loads panel for backup power. Specific project design consultation for custom installations is available through sonnen Applications Engineering at design@sonnen-batterie.com.



Sonnen® Core+™ Specs (sonnen-batterie.com)

103

Sonnen® Battery-Backup System

ESS Example Sys. #5

104

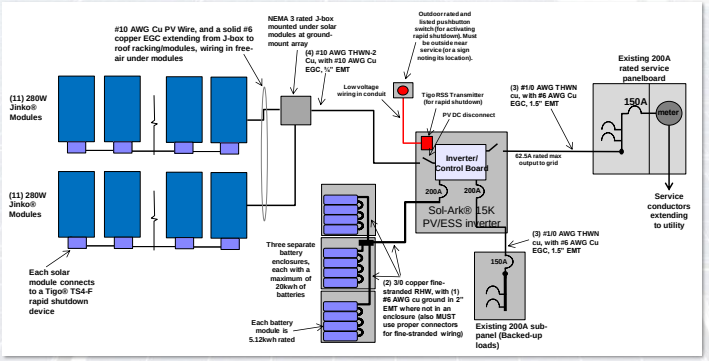
ESS Example System #6

Pytes® Energy Storage System with a Sol-Ark® 15K Inverter

105

Pytes® Energy Storage System with a Sol-Ark® 15K Inverter

ESS Example Sys. #6



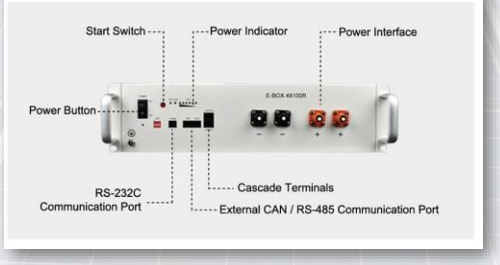
Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

106

Specs from Pytesusa.com

ESS Example Sys. #6

Operation Panel



107

Specs from Pytesusa.com

ESS Example Sys. #6

Technical Specifications

Battery Model	E-BOX-48100R	E-BOX-4850	E-BOX-48100C
Chemistry	LFP	LFP	LFP
Nominal Voltage	51.2V	48V	51.2V
Voltage Range	47.5V-58V	45V-54V	47.5V-58V
Nominal Capacity	100Ah	50Ah	100Ah
Nominal Energy	5.12kWh	2.4kWh	5.12kWh
Unit Dimension	440mm* 620mm *117mm 17.32in * 24.41in * 4.61in	440mm* 420mm * 89mm 17.32in * 16.54in * 3.50in	440mm* 480mm * 200mm 17.32in * 18.90in * 7.87in
Unit Weight	51kg/ 112.44lbs	25kg/ 55.12lbs	50.6kg/ 111.55lbs
Standard Charge Current	50A	50A	50A
Maximum Charge Current	50A	50A	50A
Standard Discharge	50A	50A	50A
Maximum Discharge Rate	50A	50A	50A
Round-Trip Efficiency	≥95%	≥95%	≥95%
Communication Protocol	RS232, RS485, CAN	RS232, RS485, CAN	RS232, RS485, CAN
Cycle Life	≥6000cycles	≥6000cycles	≥8000cycles
Calendar Life	≥10years	≥10years	≥10years
Operating Temperature	-10°C~50°C/ 14°F~122°F	-10°C~50°C/ 14°F~122°F	-10°C~50°C/ 14°F~122°F
Connect style	Parallel	Parallel	Parallel
Storage Temperature	< 1month: -20~55°C/ -4°F~131°F 1-3months: 0~35°C/ 32°F~95°F 3-12months: 20~25°C/ 68°F~77°F		

108

Specs from Sol-Ark.com

ESS Example Sys. #6

North America: 15K-2P-N

Datasheet	UL: Limitless 15K-LV
Input Data (PV)	
Max. Allowed PV Power (STC)	19,500W
Nominal Voltage Range	175 - 425V
Startup Voltage	125V
Max. Input Voltage	500V
Max. Input Current per MPPT	26A (self-limiting)
No. of MPP Trackers	3
No. of PV Strings per MPPT	2
Max. AC Coupled Input	19,200W
Output Data (AC)	
Nominal AC Voltage	120/240V, 120/208V, 220V
Grid Frequency	50 / 60Hz
Real Power, max continuous	15,000W
Max. Output Current	62.5A
Real Power, max continuous (batteries only, no PV)	12,000W (50A @ 240V)
Peak Apparent Power (10s, off-grid)	24,000VA @ 240V
Peak Apparent Power (100ms, off-grid)	30,000VA @ 240V
Max Output Fault Current (5s)	94A with PV, 75A (batteries only, no PV)
Max Output Fault Current (100ms)	120A
Max. Grid Passthrough Current	200A
Power Factor Output Range	+/- 0.9 adjustable
Backup Transfer Time	5ms
CEC Efficiency	96.5%
Max Efficiency	97.5%
Design (DC to AC)	Transformerless DC
Stackable	Up to 12 in parallel

109

Specs from Sol-Ark.com

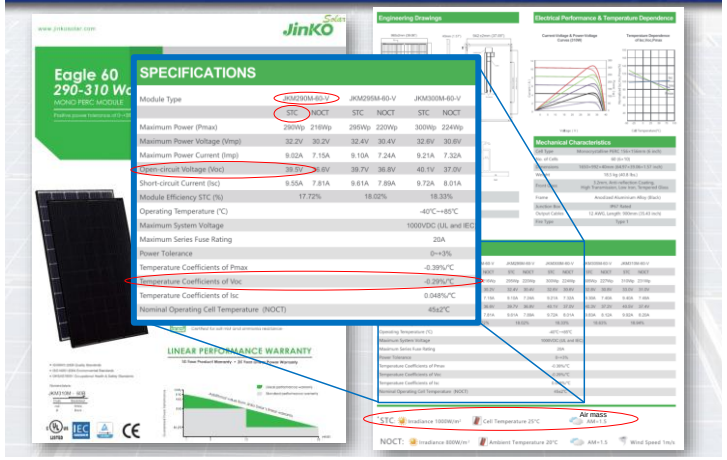
ESS Example Sys. #6

Battery Input Data (DC)	
Battery Technologies	Lithium / Lead Acid
Nominal DC Voltage	48V
Operating Voltage Range	43 - 63V
Capacity	50 – 9900Ah
Max. Battery Charge / Discharge Current	275A
Charging Controller	3-Stage with Equalization
Grid to Battery Charging Efficiency	96.0%
External Temperature Sensor	Included
Current Shunt for Accurate % SOC	Integrated
Automatic Generator Start	Integrated
Communication to Lithium	CANBus & RS485
General Data	
Dimensions (H x W x D)	807 x 494 x 306 mm / 31.8 x 19.4 x 12 in
Weight	61.2 Kg / 135 lb.
Enclosure	IP65 / NEMA 3R
Ambient Temperature	-25~55°C, > 45°C Derating
Noise	< 30 dB
Idle consumption - No Load	90W
Wi-Fi & LAN Communication	Included
Standard Warranty	10 Years
Protection and Certifications	
Electronics Certified Safety by SGS Labs to NEC & UL Specs - NEC 690.4B & NEC 705.4/6	Yes
Grid Sell Back – UL1741-2010/2018, IEEE1547a 2003/2014, FCC 15 Class B, UL1741SB, CA Rule 21, HECO Rule 14H	Yes
PV DC Disconnect Switch – NEC 240.15	Integrated
Ground Fault Detection – NEC 690.5	Integrated
PV Rapid Shutdown Control – NEC 690.12	Integrated
PV Arc Fault Detection – NEC 690.11	Integrated
PV Input Lightning Protection	Integrated
PV String Input Reverse Polarity Protection	Integrated
AC Output Breaker - 200A	Integrated
200A x 2 Battery Breaker / Disconnect	Integrated
Surge Protection	DC Type II / AC Type II

2023 Sol-Ark | Portable Solar LLC Support: (972) 575-8875 Ext. 2, support@sol-ark.com Sales: (972) 575-8875 Ext. 1, sales@sol-ark.com

110

Jinko® PV Module Specs (example) – Cold Temp dc voltages



111

Cold Temperature DC Voltage

Example

Maximum dc voltage of a solar PV system on residential premises cannot exceed 600V (*NEC* 690.7)

Maximum system DC voltage calculation:

Open Circuit Voltage (Voc) of modules= 39.5V DC (at 25°C or 77°F)

39.5V × **11 modules** on a dc string = **434.5V** (at 77°F)

If we use -28°C for our coldest temperature (which is noted in the ASHRAE Fundamentals Handbook for Bozeman, MT):

The difference in temperature drop from 25°C to -28°C is **53°C**.

Per the module's specs, the voltage of the modules increases by .29% for every 1°C drop in temperature.

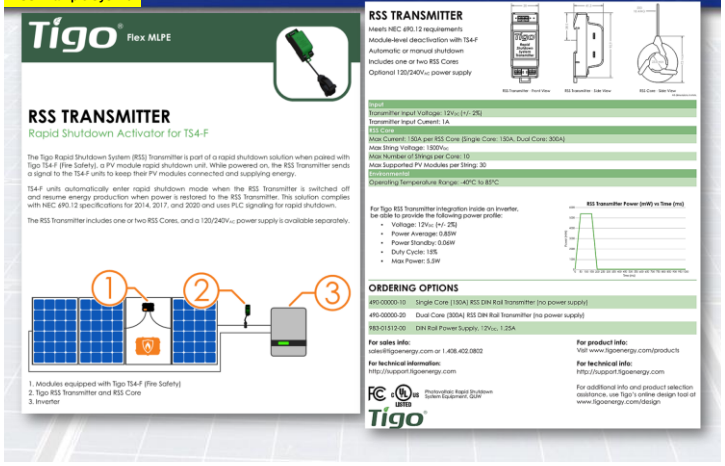
Take 53°C × .29 = a voltage increase of 15.37% at -28°C.

434.5V × 1.1537= a cold temperature voltage of **501V**.

112

Tigo® Rapid Shutdown Devices

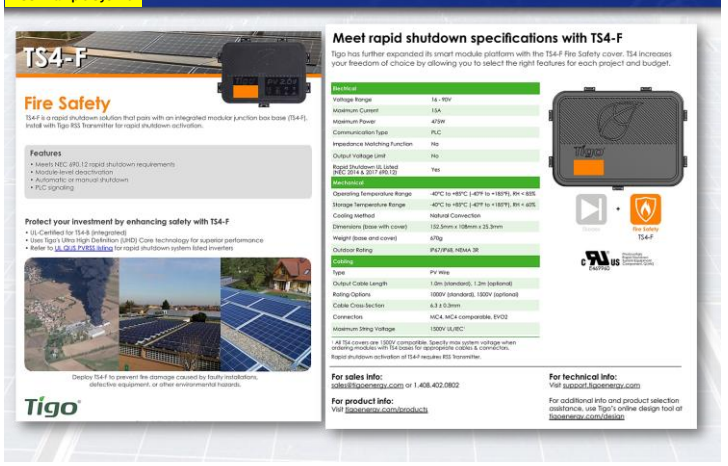
ESS Example Sys. #6



113

Tigo® Rapid Shutdown Devices

ESS Example Sys. #6

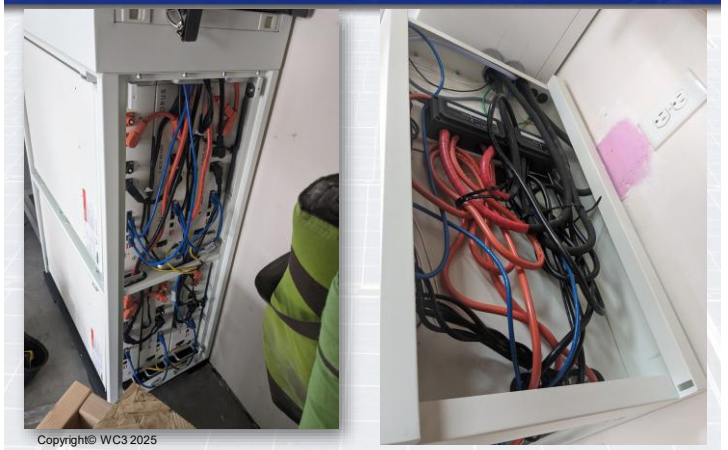


114

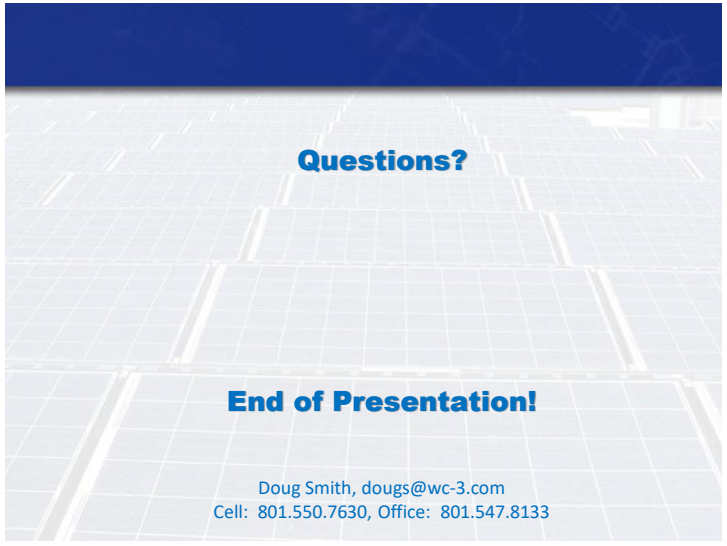
Violations?

115

Torrus® ESS



116



117