SEAC
Sustainable Energy Action Committee

Energy Storage-Ready Concepts for Residential Design and Construction

Introduction

This document presents guidelines and suggestions for the future adaptation of conventional electrical services in single-family homes to include Battery Energy Storage Systems (BESS), often referred to as Energy Storage Systems (ESS). This document is not intended to address code issues or requirements. Additional research and knowledge of these systems is recommended. This document is intended to address one- and two-family dwellings and townhouses not more than three stories, though many of the concerns addressed are applicable to other building types, such as multifamily and commercial buildings. Future versions of this document will include updates and address other items, such as multifamily and commercial systems.

For more information, please contact your local building department or solar and electrical contractor. There is also extensive information at the Sustainable Energy Action Committee website and the Interstate Renewable Energy Council website.

Why Storage?

A continuously dependable source of electric power has become a necessity in modern life. BESS can mitigate the effects of brownouts or power outages by providing a reliable source of power when electric utility power becomes unavailable. In addition to providing household energy resilience, BESS can provide valuable services for the utility and potential revenue for the system owner by helping to equalize energy demand through peak shaving or load shifting. When aggregated, these services can provide meaningful support for the resilience of the utility power grid.

Why Storage-Ready?

The largest expense to homeowners retrofitting BESS occurs when replacing existing equipment to accommodate a new storage system. To avoid passing unnecessary costs to future homeowners, builders should consider storage-ready construction to enable simple addition of BESS and mitigate the replacement of serviceable equipment. In retrofits, these guidelines and suggestions can aid in the design of a flexible system to provide the energy resilience needed now and in the future.

The example configurations below should help architects, designers, engineers, and contractors make homes more conducive to the addition of ESS. The diagrams show two typical approaches, partial-load backup and whole-home backup. Partial load backup might be more practical for most homes. Whole-home backup might be best for large batteries or homes with modest electrical requirements. The recent introduction of programmable demand load controls may make whole-home backup solutions more practical for the average homeowner. This document addresses many variables that affect the choice between partial-load and whole-home backup, a decision for the homeowner.

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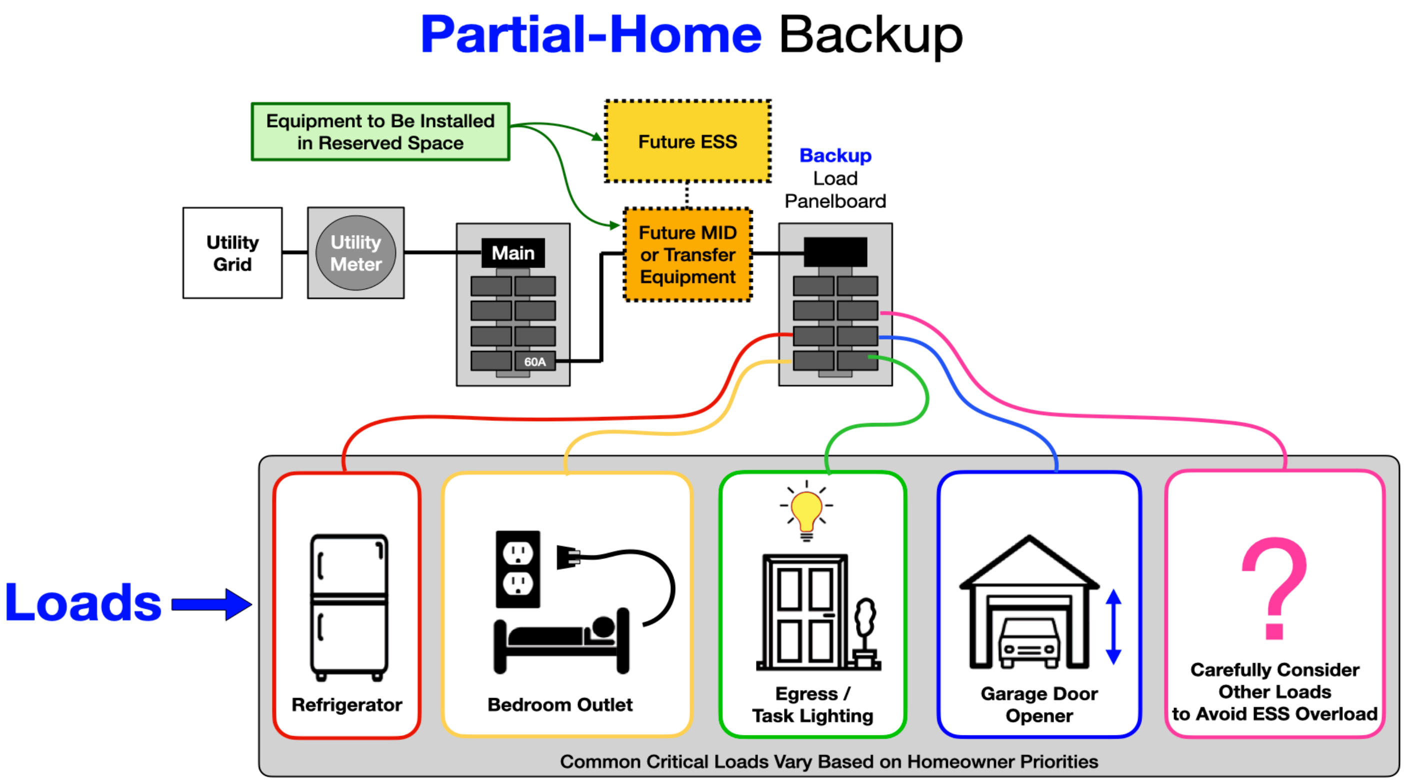
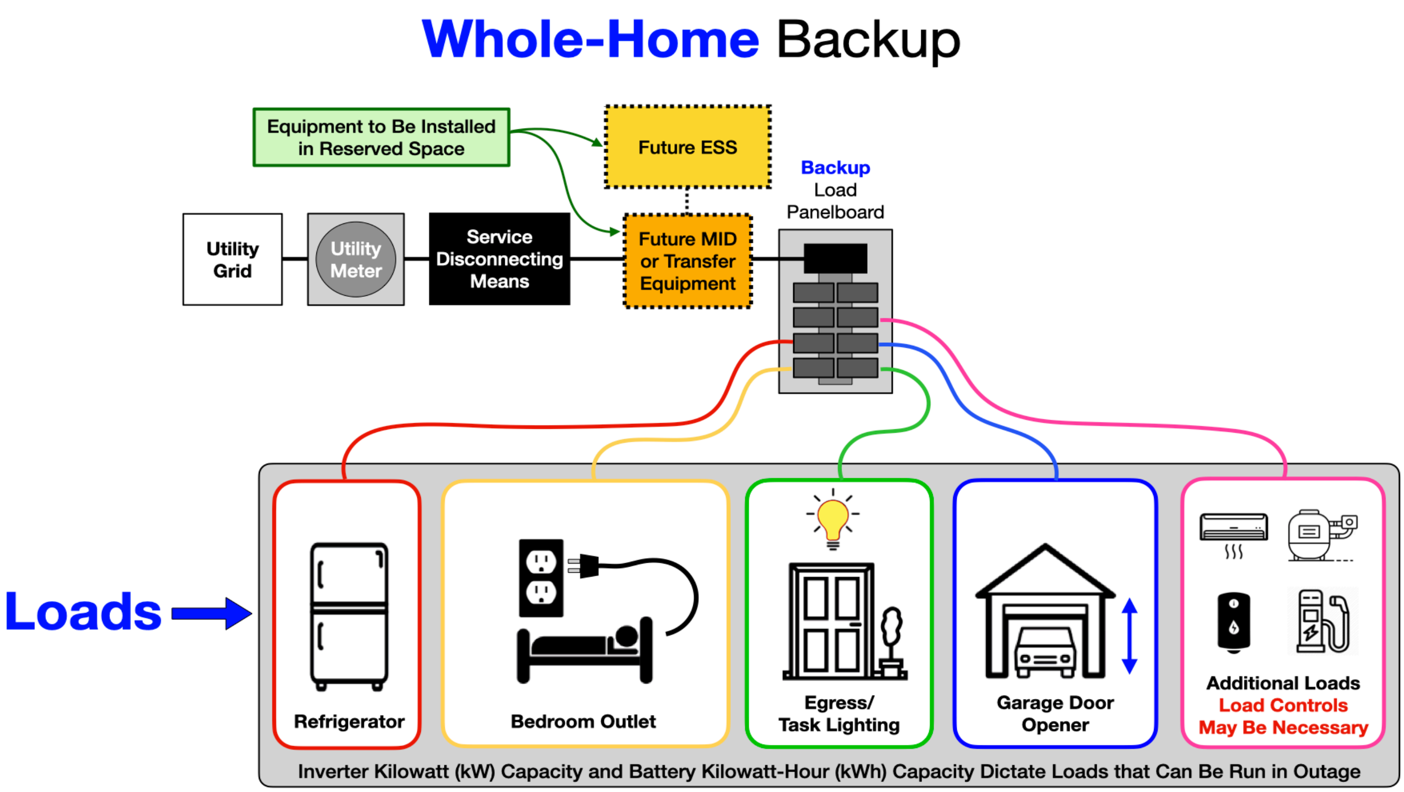
Example Configurations





Definitions

Automatic Transfer Switch: An electrical device that disconnects one power supply and connects it to another power supply in a self-acting mode.

Backup Initiation Device (BID): An electronic control that isolates local power production devices from the electrical grid supply.

Backup Mode: A situation where on-site power generation equipment and/or the BESS is powering a building or structure's premise wiring system, or a portion of the premise wiring.

Battery Energy Storage System (BESS): Typically rated in kilowatt-hour (kWh) storage capacity.

Demand Load Control: A device that automatically turns off specific circuits in a grid outage and allows the user to selectively control items that are powered or disconnected. These devices can reduce loads to be sure storage systems and inverters are not overloaded or set to provide power for a longer time at a lower demand. A programmable load center provides load control and additional capabilities.

Distributed Energy Resource (DER): Small-scale energy resources, such as rooftop solar photovoltaic (PV) panels and BESS, usually situated near sites of electricity use.

Energy Management System (EMS): A system to monitor, control, and optimize DER usage.

Energy Storage System (ESS): One or more components assembled or connected to store energy.

Inverter: A device that converts electricity from direct current (DC) to alternating current (AC). A grid-following inverter provides electrical power synchronized in phase with the utility power at its point of interconnection. A grid-forming inverter, like the high-inertia synchronous generators employed by the utility power network, can actively control their frequency output to support system frequency and share a portion of the load change required to maintain the system frequency. Grid-forming inverters are required in areas with high penetrations of DERs.

Islanding: An electrical service operational condition where the premises wiring system is powered by an on-site power source such as BESS and an inverter without providing power back to a second source, such as the utility grid. See the definition of Anti-Islanding in the UL 1741 Standard for Inverters, Converters, Controllers and Interconnection System Requirements for Use with Distributed Energy Resources for more information.

Isolation (Islanding) Equipment: A device that allows an interface with the utility where electrical loads can be safely connected to or disconnected from different sources of electrical power. Used in power backup applications to disconnect household loads, such as a BESS backup-load panel or programmable load center, from the electric utility and connect them to a backup source of power, such as a local BESS or bi-directional inverter connected to the battery management system of an electric vehicle. The household is now an electric island, completely disconnected from the utility grid.

Load Shifting: Load shifting can occur on the customer side of the electric meter or the utility side of the meter. Behind the meter, load shifting provides loads with multiple power sources and the ability to choose the source, such as a PV system when available, or change the time of use of stored energy or relieve demand on the grid. Load shifting may also be referred to as on-site use of power, or self-consumption. Reasons for load shifting include cost savings and convenience. In front of the meter, load shifting refers to an energy management strategy that encourages discharging stored energy in times of peak demand when electricity prices are high and charging BESS in off-peak times when electricity prices are low.

Microgrid Interconnection Device (MID): A microgrid interconnection device, as stated in the National Electrical Code (NEC), enables a microgrid system to separate from a primary power source and reconnect to operate in parallel with it. The MID may be internal or external to the inverter or BESS. For additional information and relevant standards, refer to the definitions in NEC Section 705.2.

Programmable Load Center: Programmable load centers allow for the remote control of electrical supply to various circuits. Some load centers allow for circuits to be turned on or off through a computer or smartphone. Through programmable control of active circuits, any circuit in a household has the potential to be activated, eliminating the restrictions of an essential loads panel and the expense of rewiring an essential loads panel as needs and priorities change. Many of these load centers also provide programmable prioritization of loads when energy resources become limited, less important loads can be automatically shed thus preserving power backup capability over longer periods.

Parallel Power Production: Two or more power sources combined and controlled on site.

Peak Shaving: An energy management strategy that avoids additional energy usage fees in periods of high demand by curtailment of loads (sometimes called "load shedding") or the self-consumption of on-site power, such as from rooftop solar panels or BESS.

What Does It Mean to Be Energy Storage-Ready?

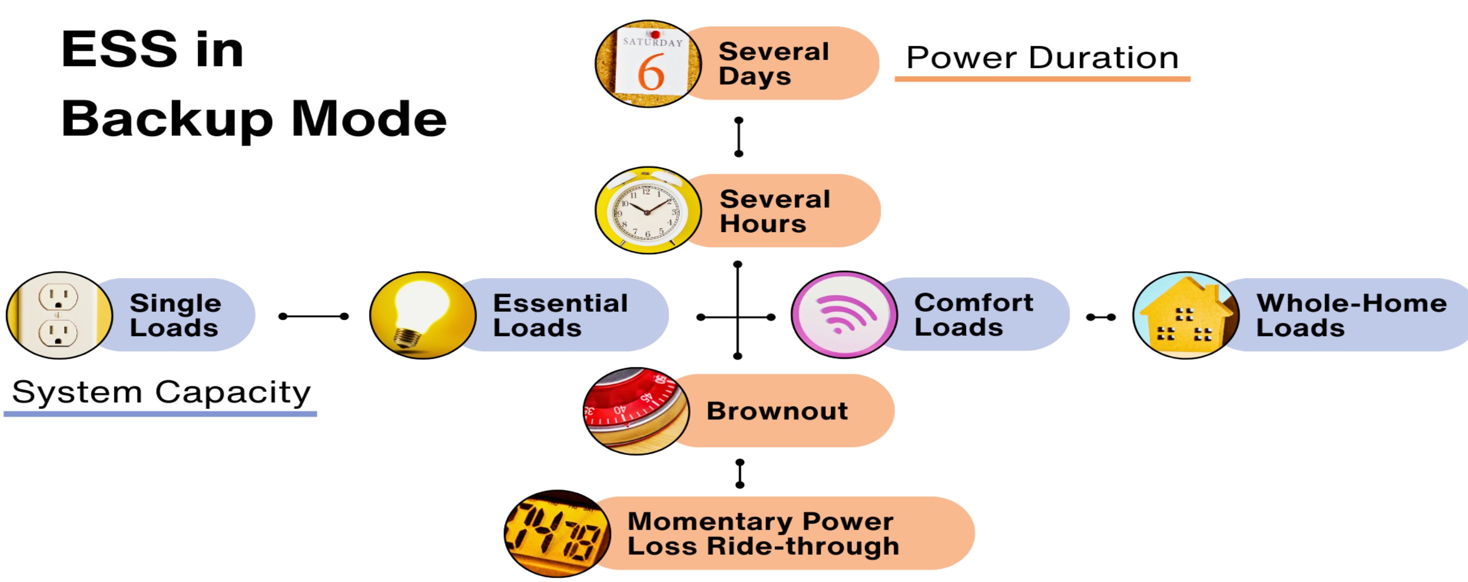
Battery Energy Storage-Ready is a term that has been introduced into construction practice where space is provided during construction for the placement of BESS, control, and electrical interconnection components, such as batteries, inverters, conduits, and raceways that allow for future wiring to be connected from an electric service panelboard to the BESS space and to probable locations for PV panels and other renewable energy generation equipment.

BESS has a broad spectrum of usage in residential design. It may range from load sharing or shifting to large power backup of essential loads and whole-home backup to continuous off-grid home power supply. These applications use the same set of components in varying sizes and configurations: batteries, inverters, wiring, load control (electrical breaker panels), load switching and energy sources (utility power, PV panels, etc.). The new components for home construction or retrofit are batteries, inverters, and load switching. In simple terms, batteries store DC power and inverters convert it to the AC power required by household loads. Additional equipment controls the power flow to the utility, generation sources, and the loads.

When considering local energy storage, the question is: What are you trying to accomplish? The answer defines the scope of the project. The scope also depends on whether power is available from electric vehicles associated with the household and what future system upgrades must be considered.

Be sure to address peak power requirements and duration of the required power.

The BESS-supplied circuits appear as a single load at the left of the diagram below. A backup load panel,



electrically separate from the household load circuit breaker panel, and switchable between sources of utility power or battery power, can provide a minimal home backup power solution. The comfort loads area to the right side of this diagram represents a larger-scale version of the backup load panel. The configuration of a whole-home backup power solution at the right side of the diagram provides a switchable source of power to the main load circuit breaker panel and all household loads from either utility power or battery backup power.

For required power, consider the consequences of power loss, particularly in an emergency. Are there loads that must be supported for safety or health reasons? Will damage occur if power is lost? Will living conditions become difficult in an outage? Note that loads incorporating motors require additional power, surge power, during startup.

Suggestion: Make a list of the electrical power loads in your household.

Split the list into four categories: required loads, essential loads, comfort loads, and optional loads. See an example list below.

Required Loads

Medical equipment

Essential Loads

Refrigeration

Lighting (egress and task lighting)

Electronic locks, security systems (especially fire protection systems), garage door openers

Well, sump and septic pumps, pressure tanks

Comfort Loads

Air conditioning and heating (including heat pumps)[1]

Important appliances, such as electric water heaters and microwaves

Communications and entertainment (internet modems, routers, switches, computers, TV, etc.)

Optional Loads

Other appliances (disposal, dishwasher, stove, washer, dryer, etc.)

Swimming pool pump

Everything else

These are personal or business decisions based on your needs, location, and circumstances. For some, a fish tank may be treated as an essential load. Many of us would also consider internet routers and computers to be essential, especially if they are used to control the door locks. Another consideration is the flexibility of load control as priorities change.

At a minimum, there should be a separate panel rated at least 60 amps capable of having at least four circuits to be used as a backup or standby to be powered by the BESS. These circuits typically include the refrigerator, a general-purpose receptacle, a light or lighting outlet in the living space, and egress lighting. Communications, including internet connection, a bedroom receptacle for oxygen generators or medical devices may be important. Return to the Example Configurations for more ideas.

Affordability drives decisions about duration of backup power. If several minutes without power is acceptable, one simple and relatively inexpensive approach is to use backup power from an electric vehicle.

Suggestion: In new home construction, provide space and wiring for a bi-directional inverter, and a backup loads panel with transfer equipment, ideally located near the service panelboard.

1 Backup heating, such as a fireplace insert with a fan for heat distribution, could be considered an essential load.

In a power outage, this enables you to provide household essential-load backup from the bi-directional inverter connected to the battery management system of an electric vehicle.

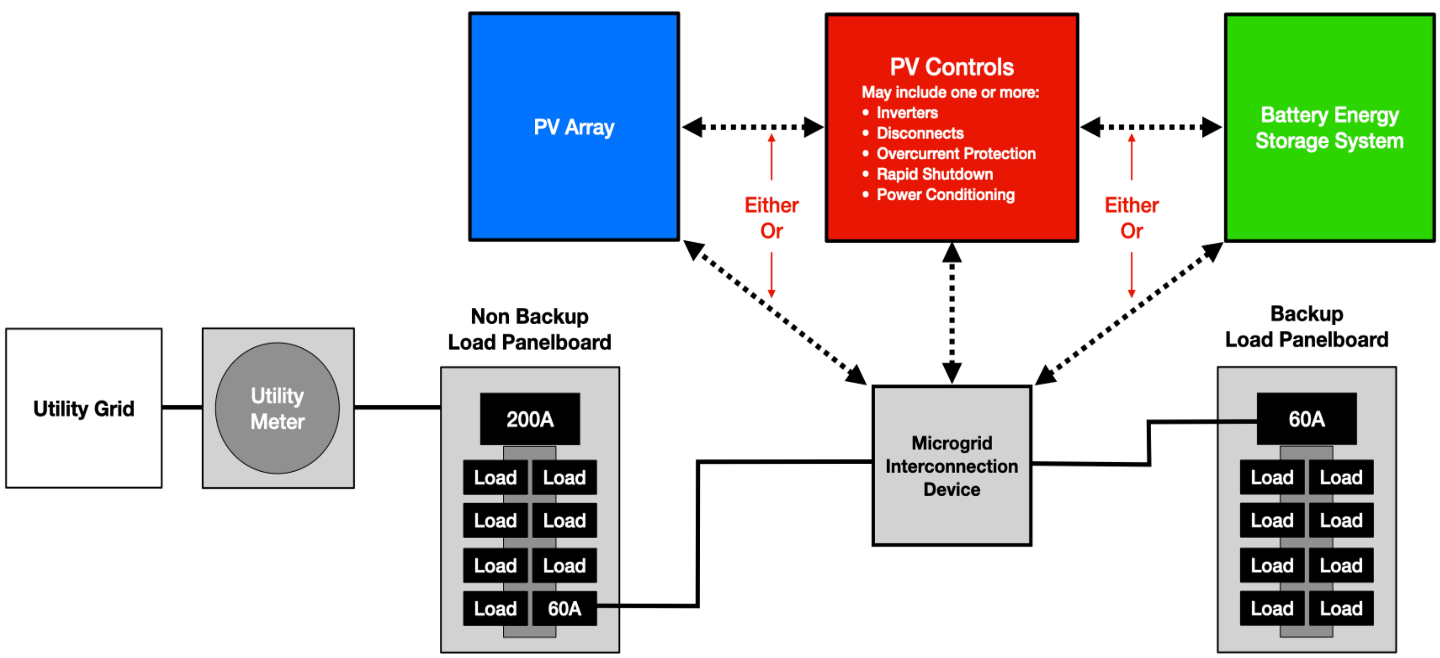
You can use programmable circuit breakers and a load center to migrate from a small backup load configuration to whole-home backup. Include a disconnecting bypass switch, a type of transfer equipment, in case of system failure. Some systems have these devices built in.

Suggestion: Consider an electrical load center design that uses dual panels or a programmable load center with the flexibility to match backup load requirements, which change with time and circumstance, to the backup power capability of the BESS.

This avoids costly re-routing of household wiring and other electrical system changes as the list of essential loads changes or increases. It also gives the homeowner control over loads to support as circumstances change and ride through during lengthy power outages.

See the sample electrical diagram below. There are many solar-and-storage configurations for whole-home and partial-load backup. This diagram shows one common configuration for partial-load backup in a residential electrical service.

Battery Energy Storage System with Partial-Load Backup



Battery Technology

At the time of this writing, the most common battery technologies being deployed are lithium chemistries or lead-acid batteries. New battery technologies are in the works and will appear on the market in time. As battery technology changes, and standards evolve, space and ventilation requirements may also change. Check the common battery types in the area you are designing for and use the most current information.

Building Codes, Electric Codes, and Fire Codes

Code adoption varies widely across the country and the world. Several code-making bodies address building safety in their own way. Understand the code-adoption process in your area to know which codes—building, residential, electrical, fire, zoning, local amendments, and more—are used for compliance. Information in this document is based on the International Code Council's family of codes. See the Appendix for more details.

System Design

BESS installation includes planning for the type of battery technology, the system's structure, and exposure to the elements. Often the best location may be outdoors due to air flow, separating the batteries from the building interior, and saving indoor space. Always follow the installation instructions. Outdoors might mean exposure to the elements. It could be a protected area that is not heated or cooled and remains separated from the habitable area. It could also be an area that only has a shed roof. In cold and very hot climates, consider insulating batteries, providing temperature control, and protecting the batteries from direct sunlight, any of which may damage or shorten the life of the system. Plan for locations with working temperatures between 40° and 115° Fahrenheit with no direct sun. Some systems may stop charging outside their temperature range. Check the manufacturer's instructions. If you don't know a structure's orientation, consider non-habitable indoor space, a garage, or a carport. Also consider if the location will be in a flood plain, a seismic zone, or a high-wind area. Batteries are a heavy dead load. Consider mass when mounting equipment to the structure.

Requirements such as ventilation, clearances, and location depend on site variables. Installed equipment should adhere to local codes and standards and manufacturer's instructions. Design flexibility will lower the cost of future changes to address system sizing, resiliency, and the important loads.

For system design, consider required power and backup power duration, factors that determine location and electrical design, the ratings of system components, required codes, standards and test results, and utility power interconnection practice.

The latest codes and standards account for many advances and safety enhancements. Refer to the most recent editions, even if your jurisdiction has not adopted them. Older versions may not address safety considerations and other key criteria. See governing codes and standards in the Appendix.

Location

When selecting a location for BESS, consider the following factors affecting safety, comfort, and system performance.

- Available space and required space
  - Note spacing on the site plan or plot plan
- Climate zone and ambient temperature
  - Outdoor systems in cold climates often require battery warming and temperature control
  - Systems in hot climates may require protection from heating by direct sunlight
- Dead load added to the structure
- Local building and fire codes
- Fire resistant-rated construction
- Fire detection or heat detection, fire alarms or heat alarms
- Protection from physical damage
  - As applicable per NEC and IRC 328.8
- Location of load centers, distance limits to storage units, utility disconnection (e.g., MID)
- Distance to obstructions, vehicles, other equipment, chemicals, working clearances
- Orientation and exposure to direct heat, radiant heat, and ultraviolet light
- Type of mounting
  - Outdoor systems may be wall mount, ground mount, in an out building
  - Indoor systems may be in non-habitable space, as required by building code
- Protection against water intrusion
- Resistance to snow loads and wind loads
- Seismic design criteria
- Required spacing from doors, windows, and storage units
- Vehicle impact protection[2]
  - Proximity to the garage door increases safety
- Location and space requirements of EMS, demand load control systems
- Setbacks and easements
  - Generally for local considerations, Plat survey

2 See Sustainable Energy Action Committee's recommendations to clarify vehicle impact protection requirements in the 2021 International Fire Code at https://sustainableenergyaction.org/resources/vehicle-impact/

Point of Interconnection

One significant consideration for storage-ready construction starts with planning for interconnection with the utility service. Generally, BESS connections go beyond the main disconnect. When installing BESS, consider busbar and load values and ratings percentages. Flexible allowances simplify system design.

As you connect more equipment and run the system for extended periods without recharging, increase amperage and dedicated space. Keeping BESS sources isolated from the utility during backup operation, and interconnected in parallel with the grid, requires a BID or an MID and overcurrent protection devices (OCPDs) protecting each system and the loads. Once again, consider flexibility for system modification when reserving space, sizing the system, and installing interconnecting raceways.

Meter-main electrical service equipment may complicate BESS projects later on.

Suggestion: Separate the utility meter and the main load distribution center.

Don't install a meter-main combination panel. If one is required, leave access to the conductor points between the utility meter and the main breaker. One way to design storage-ready electrical service is to connect a separate meter to a junction box, then the main disconnect and service panel.

Some meter-main combinations provide options, including feed-through lugs or split busbars. This way, you can more easily add connections for grid-tie systems and BESS systems and avoid a service change.

Make space for a MID at the main electric service during initial construction. This will speed later BESS installation and decrease overall cost. Also note that parallel power production technology is advancing, especially with automated controls.

Here are some other point of interconnection (POI) considerations.

- System type and future plans
  - Partial-home backup, grid resiliency, whole-home backup, functionality with utility
- Total system capacity
- Methods of interconnection
  - Loads on line side of service disconnect typically not allowed
  - Sum of breakers capacities as found in NEC calculations
  - Load-panel busbar rating using NEC 120% rule
  - Tap on load-panel feeders with properly sized conductors and OCPD on line and load side as required by the NEC
  - Isolation device and BID
- Common POIs include load-side taps on feeder, circuit breaker in panelboard
- Number of storage units, recommended space, spacing for power, capacity requirements
- Manual, automatic control
- Flexibility of panelboard equipment
  - Easy interception of feeders
  - Impact protection
  - Backup circuitry
  - Load management, flexibility of load controllers
- Type of technology
  - Energy storage is a fast-growing, continually changing industry
- Setbacks, easements, other restrictions
- Future-resilient design
  - Allowances for standby generator connection, easy utility interconnection, isolation, transfer and control; charging, use of Electric Vehicles for backup power, migration to whole-home backup with capacity increases, flexible load management
  - Incorporation of solar, wind, other renewable energy sources; incorporation of EMS with charging flexibility, islanding, utility support
- Compliance with current, future editions of codes[3]
- Manufacturer listings and instructions, especially AHJ interpretation of UL 9540A safety test results[4]
- Storage charged from grid, solar-only
- Wiring, routing, accessibility
  - Conduit size, installation of sleeves under paved surfaces, future expandability

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3 Refer to the Appendix

4 Consult local code officials about UL 9540A and NFPA 855. See more information on UL 9540A at the UL website and the Interstate Renewable Energy Council website.

Reserved Space

Reserve appropriate space for future BESS, including equipment and clearances according to NEC 110.26. Designers and installers, check with the local jurisdiction for specific installation requirements, especially for clearances from doors and windows.

At a minimum, follow the spacing suggested in the tables below and summarized here.

- Reserve a minimum protected vertical wall space from finished floor to ceiling
- Get a qualified person to establish horizontal wall space with at least six feet for the battery or other storage medium. If the equipment is known, use manufacturer's instructions for minimum spacing.
- Install electrical raceway with at least one-inch diameter from storage area to electrical distribution panel.
- Leave sufficient protected space near the main load panel to accommodate BESS integration and provide a viable path for future system upgrades, including MID or transfer equipment and a junction box.[5]
- During BESS installation, leave adequate space for the system, interconnection equipment or BID, raceways, and a backup load panel.

One piece of equipment may fill multiple roles. Check with manufacturers for component sizing and ventilation clearance requirements.

Provide a clear area of wall and floor space with sufficient working clearances for mounting load and source switching controls, interconnection equipment, and other controls, as well as the BESS, per NEC 110.26. Once again, check with your local jurisdiction for specific requirements.

Refer back to the Point of Interconnection section when considering the type of electric panel to install.

Suggested space requirements are based on allowances for a system rated for up to 60 amps at 120/240 single phase and a battery capacity of approximately 20 kWh.

Consider the user's needs. Minimum required spacing may leave no room for future expansion. In new construction, the decision rests with designers and builders. In retrofits, with the homeowner.

See a list of common BESS equipment below. Some equipment may be combined within the same enclosure.

The tables below show a wide variety of space requirements and a wide range of energy capacities. Each table uses a different manufacturer's safety and installation instructions. The depth specification (add 36 inches to the values in the table) includes the NEC-required, three-foot working clearance in front of electrical equipment, based on not more than 150 volts to ground. For installations that may exceed 150 volts to ground, refer to NEC Table 110.26 (A)(1).

Suggested Reserved Space

Manufacturer 1.

BESS Usable Capacity	Width	Height	Height Including Inverter[6]	Depth[7]	Duration at 4 kW Load	Area
5 kWh	54 in.	32 in.	76 in.	16 in.	1 hr.	28.5 ft^2
10 kWh	54 in.	37.25 in.	81.25 in.	16 in.	2 hr.	30.5 ft^2
20 kWh	54 in.	47.75 in.	91.75 in.	16 in.	4 hr.	34.4 ft^2
30 kWh	84.5 in.	58.25 in.	**	16 in.	6 hr.	34.2 ft^2

5 See suggested sizing tables. This should allow for a system of 60–100 amps in most cases.

6 Sizing appears in the Height Including Inverter column when the inverter is located above the BESS. A double asterisk (**) indicates that the manufacturer suggests locating the inverter beside the BESS.

7 Allow for sufficient working clearance per NEC Table 110.26 (A)(1)

BESS Usable Capacity	Width	Height	Height Including Inverter[6]	Depth[7]	Duration at 4 kW Load	Area
40 kWh	84.5 in.	68.75 in.	**	16 in.	8 hr.	40.3 ft^2
50 kWh	126.5 in.	53 in.	**	16 in.	10 hr.	46.6 ft^2
60 kWh	126.5 in.	58.25 in.	**	16 in.	12 hr.	51.2 ft^2
70 kWh	126.5 in.	63.5 in.	**	16 in.	14 hr.	55.8 ft^2
80 kWh	126.5 in.	68.75 in.	**	16 in.	16 hr.	60.4 ft^2
90 kWh	168.5 in.	68.75 in.	**	16 in.	18 hr.	80.4 ft^2
105 kWh	168.5 in.	63.5 in.	**	16 in.	20 hr.	74.3 ft^2
120 kWh	168.5 in.	68.75 in.	**	16 in.	24 hr.	80.4 ft^2
140 kWh	210.5 in.	63.5 in.	**	16 in.	28 hr.	92.8 ft^2
160 kWh	210.5 in.	68.75 in.	**	16 in.	32 hr.	100.5 ft^2

Manufacturer 2.

BESS Usable Capacity	Width	Width Including Inverter[8]	Height Including Inverter	Depth[9]	Duration at 4 kW Load	Area
5 kWh	47 in.	76 in.	49 in.	8.5 in.	1 hr.	16.0 ft^2
10 kWh	78 in.	107 in.	49 in.	8.5 in.	2 hr.	26.5 ft^2
20 kWh	140 in.	169 in.	49 in.	8.5 in.	4 hr.	47.6 ft^2
40 kWh	140 in.	169 in.	78 in.	8.5 in.	8 hr.	75.8 ft^2
60 kWh	140 in.	169 in.	109 in.	8.5 in.	12 hr.	106.0 ft^2

Manufacturer 3.

BESS Usable Capacity	Width	Height	Height Including Inverter[10]	Depth[11]	Duration at 4 kW Load	Area
4 kWh	42.5 in.	26 in.	70 in.	16 in.	0.8 hr.	20.7 ft^2
8 kWh	42.5 in.	26 in.	70 in.	16 in.	1.5 hr.	20.7 ft^2
12 kWh	48 in.	26 in.	70 in.	16 in.	2.3 hr.	23.3 ft^2
23 kWh	60 in.	36 in.	80 in.	16 in.	4.5 hr.	33.3 ft^2
46 kWh	72.5 in.	76 in.	**	16 in.	9.1 hr.	38.3 ft^2
92 kWh	102.5 in.	76 in.	**	16 in.	18.2 hr.	54.1 ft^2
137 kWh	132.5 in.	76 in.	**	16 in.	27.4 hr.	69.9 ft^2

8 At each configuration, this manufacturer suggests locating the inverter beside the BESS.

9 Allow for sufficient working clearance per NEC Table 110.26 (A)(1)

10 Sizing appears in the Height Including Inverter column when the inverter is located above the BESS. A double asterisk (**) indicates that the manufacturer suggests locating the inverter beside the BESS.

11 Allow for sufficient working clearance per NEC Table 110.26 (A)(1)

Appendix: Governing Codes and Standards

Division	Concern	Recommended Authority	Governing Codes and Standards [12]
Fire	1. Burn wall ratings and fire resistance construction 2. Fire detection 3. Maximum storage per building - Unit size and total system capacity - Typically governed by building and fire codes - Number of storage units - Units in multiple locations 4. Spacing from egress doors, windows, and individual units	Local Jurisdiction, Fire Authority	Locally adopted building, residential, and fire codes.[13] Safety standards, such as UL 9540,[14] UL 539/521, and NFPA 855 UL 9540A test standard
Civil Structural	1. Equipment attachment and supporting structure can meet environmental loading criteria - Wind, seismic, and snow loads 2. Vehicle impact protection	Local Building Authority, Licensed Civil Engineer	Codes: IRC and IBC Standard: ASCE 7
Electrical	1. NEMA ratings for environmental conditions 2. Protection from physical damage per NEC 110.27 (B) 3. Ratings manufacturers listing and instructions 4. Electrical hazards and working clearances	Local Electrical Authority, Licensed Electrical Engineer	Adopted version of the NEC (NFPA 70)
Designer/Installer	1. Sunlight, exposure allowances, and protection 2. Historical maximum and minimum ambient temperature at storage unit's installed location 3. Spacing from doors, windows, individual units 4. Distance to obstructions, other equipment, working clearances for installation, operation 5. Location of load centers and distance limits to storage units and MID 6. Protection against water intrusion from rain, snow, lawn sprinklers and flooding	Architect, Other Designer, Contractor's Design	Manufacturer's guidelines and installation instructions

12 Acronyms used throughout this document in reference to codes and standards include IBC (International Building Code, IRC (International Residential Code), IFC (International Fire Code), NFPA (National Fire Protection Association), NEC (National Electrical Code), UL (formerly Underwriters Laboratories, now UL Solutions), AHJ (Authority Having Jurisdiction), and NRTL (Nationally Recognized Testing Laboratory).
Standards and testing requirements ensure the safety of products in the marketplace. NRTL evaluation and certification to the proper standard, a UL 9540A report approved by the local AHJ (when applicable), and the manufacturer's instructions helps to ensure that products will perform safely. Product labels may show a test agency name and test standard or safety standard to indicate compliance.

13 In many cases, local codes are based on model codes and adapted for local conditions or legal requirements. Model codes include NFPA 1, the IFC, the IRC, and the IBC.

14 For more information about UL 9540, see the UL website.