

GEORGIA ENVIRONMENTAL FINANCE AUTHORITY

Solar and Battery Resiliency Best Practices Guide

January 20, 2022

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1 Purpose and Objectives

This document has been developed for the Georgia Environmental Finance Authority (GEFA) to provide local governments a guide to planning and development of a solar power and battery storage system to provide electric service for critical facilities and shelters during power outages. For the purposes of this Guide, the term "Resiliency System" will refer to the combined solar and battery storage system and all ancillary components. GEFA's assessment of emergency operation needs of critical local government infrastructure during power outages finds the Resiliency System should be deigned to provide a minimum of 36-hours of electric service to critical electric loads needed during community emergency events.

This guide is intended to provide local governments best practices in the development of solar and battery storage systems, designed to provide electricity to critical infrastructure during emergency events over a 36-hour power outage.

Natural disasters and prolonged power outages can create displacement of residents and threaten the essential infrastructure on which a community thrives. This demands resilience, especially for critical facilities, like shelters, that are a city's first line of protection for residents displaced by disasters. Severe disasters such as hurricanes and forest fires have the potential to leave critical facilities exposed to long-term disruption, including those for maintaining essential services.

Solar and battery energy storage offer a flexible option for critical facility resilience. Solar and battery storage do not depend on traditional resources or regional infrastructure systems for operation. When properly sized and designed, they can reduced energy a facilities electric consumption during normal operation and provide emergency backup power during outages. Additionally, solar and battery storage are reliable resources with established supply chains, standardized designs, known construction techniques, and established operation and maintenance best practices.

For purposes of Resiliency Systems designed to ensure critical equipment and operate continuously during community emergency events, the solar portion is designed based on the critical load energy requirements and to provide battery charging. The battery storage system is designed with sufficient capacity to ensure operation of critical loads during non-daylight hours and during periods when the solar systema cannot meet load requirements. This Guide will focus on commercial scale systems for resiliency purposes. Solar capacity factors in Georgia range from 20%-30%, with many commercial scale systems designed with best practices achieving capacity factors in the 25%-28% range.

2 Facility Assessment

The first step in development of Resiliency System is to perform a Facility Assessment. The Facility Assessment will review the building use during community emergencies to define critical electric loads, capability to use solar power, and develop a preliminary sizing of the Resiliency System. The following discusses the key portions of a Facility Assessment.

2.1 BUILDING AND SITE ASSESSMENT

One of the first steps in planning the implementation of a Resiliency System is identifying the facility's function during community emergencies, key characteristics, and constraints. Considerations include the size of the building or facility itself, the size of the surrounding land and property, the layout and configuration of the facility, available space for solar arrays such as rooftops, parking lots, or other open land, available space for battery systems in utility closets, basements, or detached structures, existing electrical equipment, energy efficiency, and the use case of the facility. Each facility is unique and will serve a different purpose during an emergency outage. The Resiliency System should be designed to provide a minimum of 36 hours of uninterrupted power supply to critical electric loads. These factors affect the design and sizing of the solar and energy storage resiliency system, and they will vary by facility to meet specific needs.

Constraints to be considered may include limited rooftop space, unusual rooftop slope, shape, or orientation, shading, limited storage space, and inefficient electrical equipment. These factors can affect the design and sizing of the solar array and battery storage system. Solar array mounting configurations and system sizing are further discussed in Section 3.3, and additional construction considerations are discussed in Section 4.4.

2.2 CRITICAL ELECTRIC LOAD INFORMATION

A key step in the development of the Resiliency System is identifying and understanding the facility's critical electric load. Operational needs during a power outage event will fluctuate depending on the facility's purpose and uses. For example, facilities that operate as emergency shelters may reach full capacity for extended periods of time, so HVAC systems, lighting, computer systems, and kitchen equipment may need to operate under atypical patterns; while Emergency Services facilities would need to maintain normal functionality to serve the community during outage events, so fuel pumps, communications equipment, and computer and security systems may be considered critical.

Identification of critical electric loads, how they operate and how the facility can be operated in energy conservation mode during emergency events is critical in minimizing the size of the Resiliency System. The Facility Assessment needs to determine which building systems can be shut down and which areas of the building can be isolated to reduce electric loads during the emergency event. Reducing electric requirements by reducing lighting to minimum levels, changing thermostat settings, cycling HVAC equipment, turning off un-needed equipment, etc. should be used reviewed in the Facility Assessment process. Often times a buildings electric requirement can be reduced by 50% with proper energy management. The following discusses critical systems to be addressed in the Facility Assessment.

2.2.1 HVAC Systems

HVAC equipment is often one of the largest electricity uses in buildings, both on a kW demand basis and total kWh consumption basis. Determination of necessary critical loads during emergency events needs to start with review of building HVAC requirements based on the planned use of the facility during an emergency event. Buildings used as shelters will require sufficient HVAC to keep the building environment habitable based upon expected occupancy. Buildings with critical equipment or operations centers must ensure that changes in building environment does not cause equipment failures due to overheating. In emergency conditions, unused spaces should be isolated and HVAC systems should be shut down to reduce building load. Air movement is the priority, with space conditioning the second.

A 36-hour event is a relatively short period, and many building environments will not change significantly during that period. As part of the emergency plan, contingencies need to be included for recognizing limited HVAC use and allowance for turning off other building systems, such as lighting, to allow operation of HVAC systems for shorter periods to ensure the building envelope can meet its intended emergency use. Keep in mind, most HVAC systems are overdesigned to meet worst case external environment conditions and can be operated intermittently. In sizing your battery storage and inverters, ensure there is sufficient KW for motor starting loads and operation of the HVAC to properly condition the building envelope.

2.2.2 Lighting

Lighting systems are typically a large portion of a buildings continuous electric load. The facility assessment will determine the amount of normal lighting load, how to reduce the load during emergency events, and the remaining energy requirements. During the lighting assessment it may be beneficial to consider lighting efficiency upgrades in those areas needed during the community emergency to reduce electric loads.

2.2.3 Computer, Communication, Emergency Call Centers, etc.

Community emergency events during power outages can require various communication, information technology, call center, security, and other systems to remain operable. The electric requirements of these systems may include proper cooling of equipment. Modeling these electric loads is an important component of the Facility Assessment and needed for proper sizing of the Resiliency System.

2.2.4 Other Electric Loads

The Facility Assessment needs to include other potential electric loads that may require operation during emergency events, such as fuel pumps for government vehicles, kitchen equipment in shelters, electric operated doors and gates, sump and water pumps, etc.

2.3 UTILITY DATA

Historical load and energy consumption data can be acquired from the utility that serves the facility. These data patterns, along with nameplate information for critical equipment and industry standard technical reference variables, can be used to create the facility's emergency load profile. This profile is key for determining the proper size for the solar array and energy storage system, to provide sustained operation for the critical load, as well as charge the battery. Example energy and load data for a municipal office building in Savannah, Georgia is below.

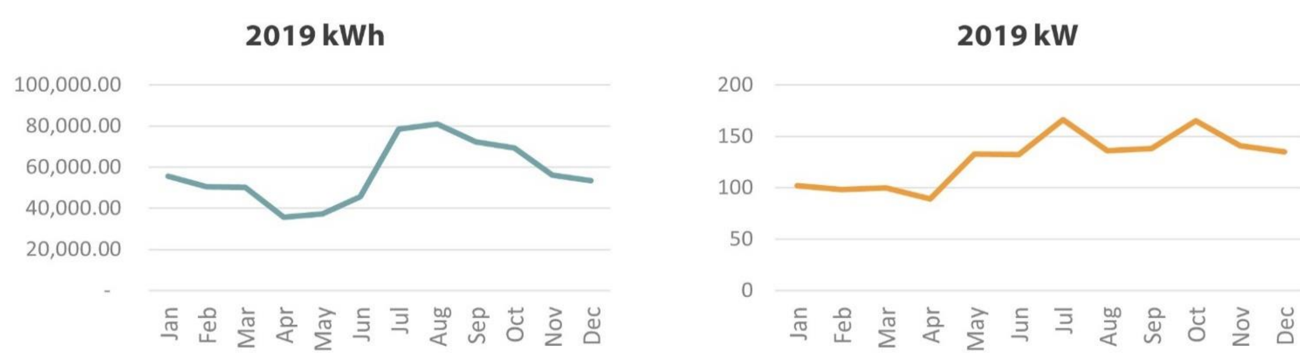


FIGURE 1 – 2019 ENERGY KWH CONSUMPTION AND BILLED KW DEMAND PATTERNS

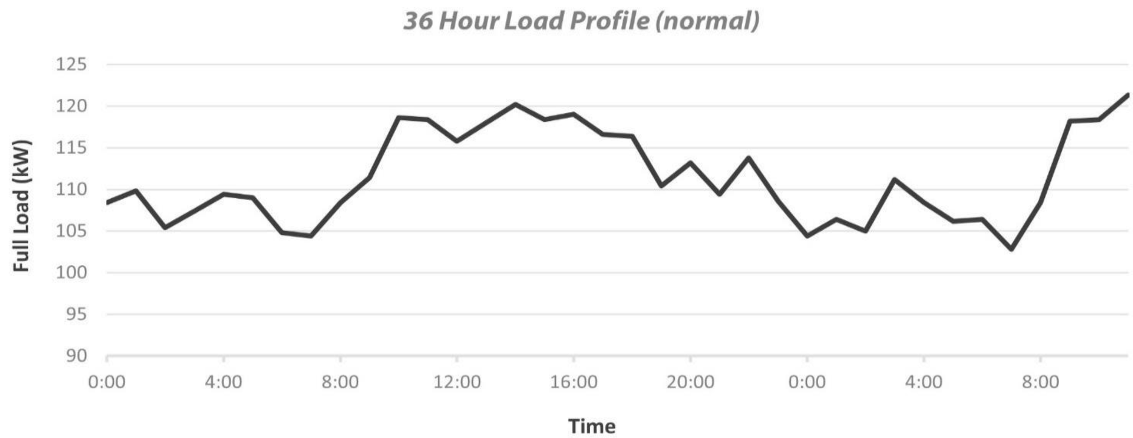


FIGURE 2 – NORMAL 36-HOUR FACILITY LOAD PROFILE

2.4 RESILIENCY SYSTEM MODELING AND SIZING

The Facility Assessment should provide modeling of the Resiliency System performance during a 36 hour power outage and provide estimates of the solar and battery system sizing. The following graph from a Facility Assessment for the city of Decatur performed under a GEFA grant is an example of how a Resiliency System performs during a 36 hour power outage. This Resiliency System was based upon a 78 kW solar PV system and 35 kW, 277 kWh lithium-ion battery storage designed project.

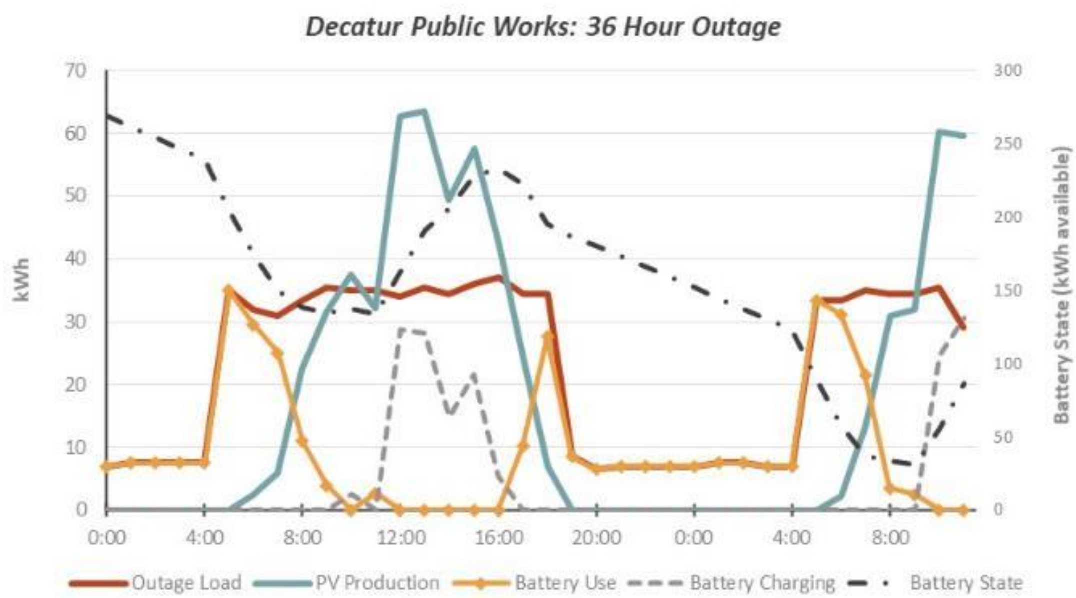


FIGURE 3 – EXAMPLE PERFORMANCE MODEL, 36-HOUR OUTAGE

Facility Assessment Best Practices

- ✓ Identify building and site characteristics and potential constraints.
- ✓ Understand critical electric loads during emergency outages.
- ✓ Develop the facility's emergency load profile.
- ✓ Provide preliminary sizing of Resiliency System.
- ✓ Provide Resiliency System performance modeling.

3 Technical Considerations

3.1 RESILIENT SOLAR POWER GENERATION SYSTEMS

Solar plus storage systems equipment is selected based on the connections with facility systems and other resilient resources (generators, etc.). In many cases, a solar generation system may already exist, and energy storage may be added at a later point. The specified components depend on a system's functional and operational requirements.

Commercial systems using solar plus energy storage may be integrated in several ways to provide services. The AC power produced supplies on-site electrical loads or is back fed to the grid when the PV system output is greater than the load demand. During periods when the electrical loads are greater than the PV system output, the power required is received from the electric utility.

Resilient systems are designed to be interactive with the grid and have the capability to disconnect from the grid during utility outages or disturbances and operate as the solar resource permits. Only special interactive equipment and controls can provide standalone power, or islanding-mode, for critical loads independent from the grid during outages. Smart inverters are the latest interactive technology that allows for the effective integration of distributed energy sources and controls power output based on operational needs and reliability events.

TABLE 1 – SPECTRUM OF COMMERCIAL SYSTEM RESILIENCY

No Resiliency	Partial Resiliency	Critical Load Resiliency	Fully Resilient
PV system requires grid connection to provide power to facility	PV system can disconnect from grid and island to provide power	Solar plus energy storage seamlessly provides services to critical loads during short outages	Robust solar plus energy storage resources to serve loads during resiliency events
Full loss of Power during loss of utility connection	Available power is limited to solar output during an outage	Seamless power during outages for critical loads for a limited duration	Multiple resources enhances reliability for up to 36 hours

A fully resilient Resiliency Systems is necessary to provide electricity during community emergency events when power outages occur. Thus, the remainder of this guide will focus on fully resilient systems.

Solar Resiliency Best Practices

- ✓ Use of solar plus energy storage can have resiliency value streams if the equipment and controls are designed for resiliency.
- ✓ Solar plus storage systems may be designed for partial resiliency, critical load resiliency, and full resiliency with the proper specifications.
- ✓ Appropriately specified inverters transfer loads from PV system operation to operate in stand-alone battery mode for the circuits designated for emergency load.
- ✓ Equipment should be capable of detecting grid-events and control of Resiliency System operations to meet critical electric load needs and provided continuous source of electricity.

3.2 SOLAR PLUS BATTERY SYSTEM ARCHITECTURE

Energy storage systems can be completed as stand-alone assets or coupled with solar PV using different electric configurations. A common configuration is to couple the energy storage and solar at the AC side, but hardware is becoming increasingly available that couple these resources on a shared DC-Bus or input bay on the inverter. Commercial inverter models may couple multiple PV strings or batteries at the inverter using multi-mode inverters. These inverters operate as charge controllers and dump excess PV energy to the grid when they are energized.

AC-coupled systems connect the battery and the PV array on the AC bus. As a result, PV-generated electricity can serve loads with a single conversion, but for PV to charge the batteries, it needs to flow back through a bi-directional inverter to be converted to DC (resulting in an efficiency loss). AC coupling is common when batteries are retrofitted to existing solar PV systems.

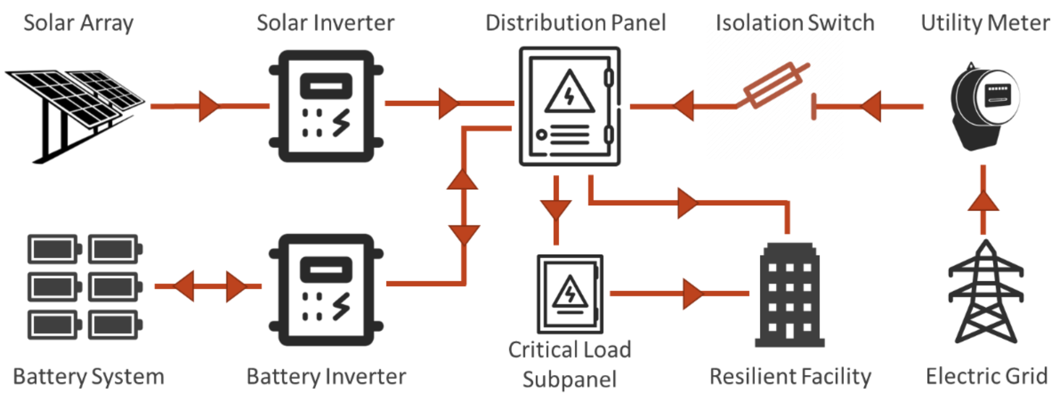


FIGURE 4 – AC COUPLED SOLAR PV PLUS ENERGY STORAGE DIAGRAM

DC-coupled systems link the PV and the battery on the DC side of an inverter and can charge from the grid when permissible. A charge controller is needed to manage the voltage of the DC electricity coming from the PV that is used for battery charging. The charge controller is generally an efficient conversion, but nonetheless it represents an additional component that affects overall system efficiency. This configuration is sometimes classified as "AC/DC-coupled" when the battery can be charged from the grid in addition to the PV array. For most Resiliency Systems, AC/DC-Coupled systems will be the preferred configuration because of lower costs and the resiliency benefits of grid battery charging capability.

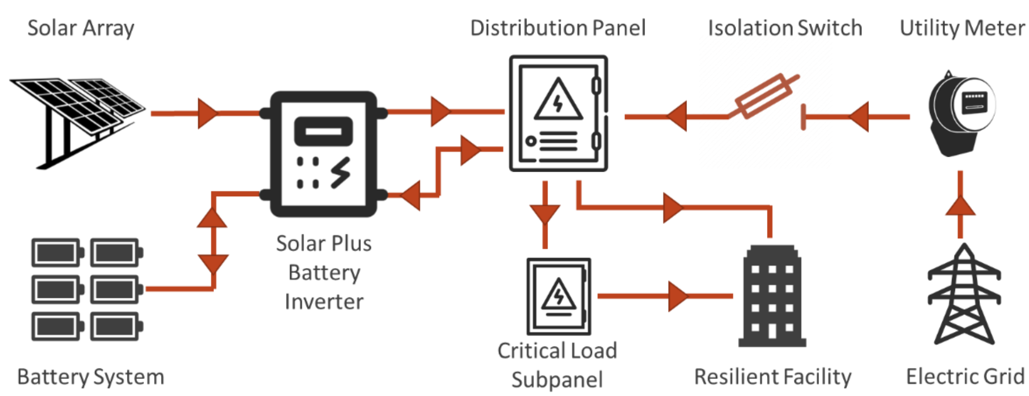


FIGURE 5 – DC COUPLED SOLAR PV PLUS ENERGY STORAGE DIAGRAM

3.3 MAJOR SYSTEM COMPONENTS

PV systems include different components that should be selected according to hardware requirements, site location and performance targets. The addition of an energy storage system (ESS) to an interactive system creates a more resilient system than solar alone and rides through most outage events. The major components to consider for a resilient solar PV plus ESS system are described at a high level below and should be configured according to ISO manufacturing standards[1,2].

PV Arrays: The PV Array is a collection of PV strings connected to the inverter comprised of PV modules that converts sunlight into DC electricity through a photovoltaic (PV) effect. Several modules are electrically connected to build up voltage and current in a string, and PV strings in array are combined before the current goes to the inverter. PV arrays with tracking subsystems are often deployed to track the sun to maximize the incident solar radiation.

***Inverters*:** Inverters convert DC power (direct current) to AC power (alternating current) and provide the control function to optimize Resiliency System output. Battery systems are also connected through an inverter and multiple product options exist to design hybrid systems consisting of solar plus energy storage systems. The inverter is a central component of the Resiliency System as it provides most of the control function required to optimize PV output and disconnect from the grid (island-mode) during power outages and emergency events. The inverter and the transformer internal to as the Power Conditioning System (PCS) as it is the job of this system to provide power to match grid, or electrical islanding, conditions.

System Protection: Several subsystems have protection practices. Utility owned equipment includes the transformer which provides galvanic isolation, step up/down the voltage, and transfers energy to the point of delivery, and protection relays and metering equipment data. Utility equipment is the first layer of protection; however, Resiliency Systems have their own set of requirements for protection. Critical equipment starts with an isolation switch that automatically responds when a grid events is detected. The inverter coordinates with the energy management system to provide a seamless transition to the Resiliency System. Instrumentation, network equipment, metering, relay protection, supervisory control and data acquisition (SCADA), interactive inverter controls are all critical components for fully resilient systems.

Battery Energy Storage System (BESS): Resiliency Systems will use battery systems, known as BESSs), to provide power when the solar panel generation is lower than the buildings emergency load. The BESS will be charged during power outages using the excess solar energy during the power outage. These systems, when paired with solar generation, provide a considerable resiliency enhancement over solar alone. Lithium-ion batteries currently dominate the energy storage industry, as such, their characteristics will be further explored in this Guide.

Equipment and contractor qualification: Preferred or qualified vendor lists are commonly maintained for organizations who procure Resiliency Systems frequently in order to standardize equipment portfolios and to assure synergistic maintenance programs. Likewise, qualified Contractors are also recommended for both installation, operation, and maintenance services over the life assets useful life. Major types of equipment manufacturers to either specify or consider during the procurement process include modules, inverters, tracking systems, protection and controls, batteries, and any site-specific auxiliary equipment necessary. Pre-qualification of products and services; however, may also limit technological choices and create limitations on procurement.

[1] https://www.iso.org/standard/62085.html
[2] https://www.iso.org/standard/60857.html

System Component Best Practices

- ✓ Qualified Contractor lists should be maintained for design, installation, and operation and maintenance services.
- ✓ Qualified Equipment list for all major system components (PV Module, Inverter, transformer, protection and controls equipment, and battery module/rack).
- ✓ Manufactured using an ISO-9001 quality management system
- ✓ Manufactured using an ISO-14001 Environmental Management System

3.3.1 Energy Management System

Resiliency System operation allows support of the facility with high-speed operations driven by the technology of the system components. All of the system components which need to be monitored and controlled are done so through the system's Energy Management System (EMS). The inverter is commanded from the EMS which accepts critical inputs from grid protection devices, grid monitoring, and other emergency signals sent to the EMS.

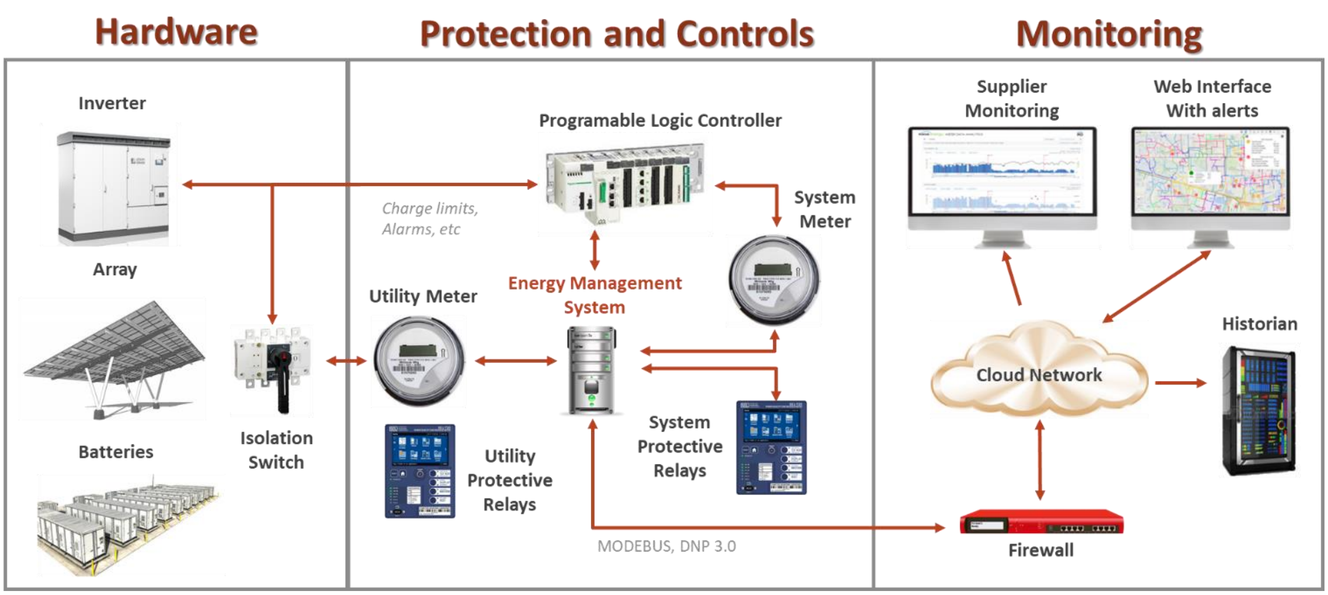


FIGURE 6 - THE ENERGY MANAGEMENT SYSTEM DRIVES CONTROL AND MONORI

While synced to the grid, resilient systems has proven to respond with critical load capability by opening the grid isolation switch, and commanding the inverter to islanding mode, where the batteries energy is also managed to provide adequate capability. When returning to normal operation, a system can sync to the grid and provide full power in less than 30 seconds, if not seamlessly, in most circumstances. The steps required to go from offline to an online state has a relatively simple control sequence and using the PCS to sync to the electrical characteristics of the grid.

Switching from grid-connected to different a grid could take place with the functionality of the typical PCS, as the power electronics are designed for rapid transitions. The limiting factor being the energization of the AC bus, closing and opening contactors, and subsequent syncing of the inverter. The semiconductor devices that provide the switching frequency for the power electronics can respond on a sub-second basis. When the switching is initiated, the BESS inverter is placed into and idle mode and AC contacts are opened.

3.3.2 Types of PV Modules

PV modules are the starting point to convert sunlight into electricity. Although there are many different types and variations of modules, the three most prevalent module types are mono-crystalline, poly-crystalline, and thin film.

Mono-crystalline silicon modules (preferred): Produced using semiconductor grade silicon cut into wafers. Monocrystalline has been the workhorse for the industry, with service life lengths of over 30 years being reported. Product performance and cost are the driving factors with product efficiencies of 20%-24%, which highest conversion efficiency for silicon-based technology.

Poly-crystalline silicon modules: Produced using lower grade silicon that is formed from a modified casting process and cut into wafers. These panels are often used in roadside lighting and remote transmitters and most production panels will have a service life of less than 20 years. Relatively lower efficiencies of 14%-16% leads to higher overall project costs on larger scale projects based on land usage and lifecycle expectations.

Thin Film modules: Includes Amorphous Silicon (a-Si), Cadmium Telluride (CdTe), Copper Indium Gallium Selenide (CIGS) and (CIS), and III-V Multi-junction cells. These various thin film products have a range of performance characteristics that may not suit utility solar but CdTe has historically had deployments which are becoming less common due to competing cost factors of mono-crystalline silicon. These lightweight panels can be attractive for rooftops where there are special loading constraints.

FIGURE 7 – IMAGES OF COMMON TYPES OF PV MODULES

Module Selection Best Practices

- ✓ Mono-crystalline silicon modules typically offer the best value of performance and cost.
- ✓ Thin Film Modules are lightweight and can be attractive for rooftop installations where there are special requirements or loading constraints.
- ✓ Manufactured to ISO9001:2000 and ISO 9001 quality and ISO14001:2004 environmental standards

3.3.3 Inverter Technologies

Inverters come in many form and function varieties to serve a broad range of applications. There are 3 types of form factors commonly deployed in solar systems (micro, string, and central inverters) as described below. String and central inverters are generally deployed when an ESS is specified due to the ability to electrically connect multiple inputs from PV strings or battery banks.

Micro inverters connect to every single module and produce AC power right at the panel. The upfront cost is typically high; however, may enhance energy production and eliminates impactful single point failures that may occur with a larger inverter.

String Inverter is a stand-alone unit that is connected to a string of PV panels which is generally less than 150 kW_{ac} output capacity per inverter (30kW is typical). These inverters have replacement and repair advantages as components need to be replaced over the PV plants useful life. Residential/commercial systems are well matched for string inverters, but they are also commonly deployed in small and medium size utility scale projects.

Central Inverters have inputs for multiple PV strings which tends to have upfront and maintenance cost advantages for medium to large scale projects. Power capacity for these products range from 500 kW_{ac} scale to several MW_{ac} of capacity in a single unit. These inverters typically have liquid or forced air cooled power electronics along with high voltage cabinets which can be supported by specialized technicians.

FIGURE 8 – IMAGES OF COMMON TYPES OF INVERTERS

Inverter Selection Best Practices

- ✓ String inverters are often preferred due to cost, reliability, ease of maintenance, and wide variety of configuration and product options.
- ✓ Central inverters provide cost advantages for projects >500 kW_{ac} but may require specialized maintenance to maintain reliability.

3.3.4 Orientation and PV Tracking Systems

Photovoltaic (PV) panels can be mounted at a fixed orientation; however, they can also be made to track the sun to maximize the incident solar irradiation. PV tracking systems are classified according to the number of axes of rotation and the frequency with which the adjustments are made. Most importantly, the frame and wiring harnesses must be appropriate for the application and follow recommended codes and standards. Types of panel orientation and tracking equipment:

Fixed Orientation: Panels are mounted at a fixed slope and azimuth. This is the simplest and most common case which can suit a wide variety of mounting configurations. Resilient solar installations may benefit from this design method due to the reduced maintenance and cost relative to PV with tracking systems.

Single Axis Tracking: Rotation is around a horizontal east-west axis and is adjusted continually to minimize the angle on incidence. Power production is higher than fixed orientation but has costs associated with the additional equipment. Larger installations with goals of enhancing the annual production of solar energy may benefit from this design.

Fixed Orientation

Single-Axis Tracking

FIGURE 9 – ILLUSTRATION OF COMMON SOLAR PANEL ORIENTATIONS

Dual Axis Tracking and tilted single axis tracking options also exist, but they tend to be costly with more reliability risk related to the moving parts. The modules can be rotated around both horizontal and vertical axes so that the sun's rays are always perpendicular to the surface in a dual axis arrangement. This type of tracking system maximizes the power production of the PV modules; however, is not a typical practice for systems where resiliency is the primary value stream due to reliability risks, higher costs, and insubstantial benefits.

PV Tracking and Orientation Best Practices

- ✓ Resilient solar installations benefit from a fixed orientation design method due to the reduced maintenance and cost relative to PV with tracking systems.
- ✓ Tracking systems maximize annual energy production and offer value in larger scale installations.

3.3.5 Mounting Configurations

Photovoltaic mounting configurations are used to fix solar panels on surfaces like roofs, building facades, or the ground with racking systems to hold multiple modules. The important factors to consider are land or roof availability and the use of multiple arrays and locations on the property to maximize production and meet resiliency goals. Modern mounting and racking systems generally enable retrofitting of solar on roofs or as part of the structure of the building.

Ground mount is ideal for installation flexibility as tilt and row spacing design can increase yields. Installed costs and operation and maintenance expenses are most economical of the different mounting configurations. The angle of the modules can be optimized for local conditions and is often paired with tracking technologies which can increase yields. About 50 ft^2 of area is required to set up 1 kW_{AC} ground mount solar system

Canopy installations are a good alternative in parking lots or where there are space restrictions. They do not need any extra land like a ground mounted system does and offer a far more efficient use of space; although, site-specific cost factors such as parking lot modifications may disadvantage this design in some installations. Areas required to install canopies greatly depend on the orientation of the parking lot and available space for canopy structures.

Rooftop solar works where space is limited and is very common in residential and commercial installations. Rooftop-mounted solar modules are restricted by multiple variables, including the type of roof, angle, and direction and require more caution and expense when it comes to maintenance. About 100 ft^2 area is required to for 1 kW_{AC} of rooftop solar system. *The design of existing building roofs needs to be reviewed to ensure the roof can support the added weight of the solar panels.*

Ground Mount | Rooftop | Canopy

FIGURE 10 – IMAGES OF SOLAR MOUNTING CONFIGURATIONS

Mounting Configuration Best Practices

- ✓ Multiple array mounting configurations should be considered and can be deployed in combination to provide the power and energy requirements.
- ✓ Ground mount systems offer the most cost-effective solution, where land is available, and designed for high wind loading experienced during many severe weather events.
- ✓ Rooftop mounted solar will require review of roof design to ensure it is capable of supporting the additional weight of the solar equipment.

3.3.6 Energy Storage Systems

When there is a loss of grid voltage, systems with a Battery Energy Storage System (BESS) are similar to uninterruptible power supplies and are capably of responding in fractions of a second. This sub-system is key to resiliency and can transfer loads from the solar PV system or grid to operate in stand-alone battery mode for the emergency load circuits.

The BESS is generally comprised of battery strings, a battery management system (BMS), and auxiliary equipment such as communication and the appropriate fire detection and suppression. The battery building blocks are shown below in Figure 11, which are commercially available from a growing landscape of lithium-ion suppliers and are often packaged together by the battery vendor.

Battery Selection: Although there are several varieties of batteries to consider such as lead-acid, zinc-based, flow batteries, and many more for large scale energy storage; lithium-ion batteries have emerged to become the battery of choice for many resilient installations due to factors such as reliability, longevity, low maintenance requirements, and total project costs. This Guide will focus on lithium-ion battery components and the best practices associated with their design, installation, and operation.

Battery Racks | Battery Management System | Battery Modules

FIGURE 11 – IMAGES OF BATTERY BUILDING BLOCKS IN A HYBRID SOLUTION

Solar Plus Storage Sizing Best Practices

- ✓ Commercially available lithium-ion varieties are commonly deployed due to factors such as reliability, longevity, low maintenance requirements, and total project costs.
- ✓ Questions to ask the Sellers include which battery they selected and a long-term strategy for replacing critical components such as battery modules and servicing the BMS.
- ✓ Multiple parallel strings of batteries are often recommended so that one may be taken out of service for maintenance while the other string provides higher reliability for critical operations.

4 Development Process

4.1 REQUEST FOR PROPOSALS (RFP)

When planning and procuring a solar and battery resiliency system, the recommended method for finding the best vendor/contractor for the project is via a Request for Proposals (RFP). Going through a competitive RFP process allows for the evaluation of multiple bids from various contractors. This section discusses best practices for an RFP solicitation and evaluation.

4.1.1 RFP Solicitation

An example RFP template is available from GEFA. The template provides recommended content to include in the solicitation for a solar and battery resiliency system, in order to improve project results.

Submitting a response to an RFP allows contractors to describe their approach to implementing a resiliency system, propose the pricing, design, and sizing details for a potential project, and provide information regarding the company's background and work on similar projects. Contractors may request a site visit prior to submitting a proposal in order to better understand the facility's needs.

Introduction and background: The RFP should include a description of the entity requesting proposals, information regarding the purpose of the resiliency system, and the desired project timeline.

Project details: The most important function of the RFP is to provide details about the facility/building itself and the surrounding owned property site, a description of potential space for solar and battery equipment, information about the facility's utility interconnection, and a list of equipment considered critical during an outage event.

Proposal content: It is recommended that the RFP include an outline or list of desired content for each respondent to provide in their proposal response. This ensures that each contractor provides the same information as the others, to aid in evaluation of the proposals.

Evaluation criteria: The RFP should list out the criteria that will be used to evaluate responses and explain the scoring/ranking process. Further information on recommended evaluation criteria is discussed in Section 4.1.2.

Administrative details: The RFP should also include administrative and logistical details for contractor responses. This includes contact information, proposal submittal instructions, and any other supplemental information.

4.1.2 RFP Evaluation

There are several key parameters required to evaluate proposals, including the immediate check that the proposal conform to the technical and commercial requirements of the project. A methodical checklist or scoring matrix is often used to screen proposals and rank based on Buyer priorities. Attachment C is offered as an example evaluation matrix which is based on sample ranking categories, on a gradable scale, and weighing those against pricing, commercial, and technical combined scores.

Pricing Score can be quantified by making comparisons of like systems offered by the Contractors who responded with conforming proposals. Assigning percentile rank to the quoted monthly payment provides a statistical representation of the price which can be converted to a gradable scale, as an example.

Commercial Score can also be quantified based on the financial history, development history of similar projects, conformance to terms and conditions, ability to meet disadvantaged and local businesses targets, and any other project specific requirements.

Technical Score can be quantified by grading technical categories on a predetermined grading scale similarly to commercial ranking categories. The information supplied in the Proposal Form such as PV module, battery, inverter, transformer, and communications and network equipment may be communicated through approved vendor lists and may be further qualified by ranking equipment preference.

Procurement and RFP Best Practices

- ✓ Entities should publish a Request for Proposals (RFP) in order to receive proposals from multiple vendors/contractors and be able to select the best option for the facility.
- ✓ The RFP should include an introduction of the facility, critical needs in an outage scenario, project details and electrical load information, and a list of content expected to be included in each proposal/response.
- ✓ Proposal evaluation should prioritize the project commercial and technical requirements, in addition to price, through a scoring process and then weighting the numerous evaluation criteria.
- ✓ The Proposal Form should include all evaluation metrics, while the proposal content allows the Buyer to explore detail and make informed decisions on how to properly evaluate the proposal. The Technical worksheet in the Proposal Form allows Contractors to input all the pertinent technical criteria while the General worksheet contains the pertinent financial metrics for proposal valuation.

4.2 DETERMINING THE BEST LOCATION

4.2.1 Site Placement

In addition to system design and sizing for energy requirements, site constraints can play an important role in the benefits to the community. The Facility Assessment (Section 2) determines basic parameters for loads and assessment of the capacity of the building property or available land determines deployments of solar and storage. This process will involve examining the site and the surrounding area since a site may pursue resilient solar and storage as a stand-alone project or as part of microgrid with other facilities.

Position of Solar Array can begin with mapping tools and satellite images as a starting point to assess if the building roof or site area are good for evaluating solar potential. Position of the roof, and site areas where solar and storage can be placed can be more thoroughly examined by a contractor using common software modeling tools as was described further in Section 3.3.4. For a ground mount system, geotechnical information and environmental impact will also need to be considered over the course of project development.

Shading analysis should be done if shading will impact production estimation. Adjacent properties with trees may also impact solar production as those trees reach maturity and elevate the shading losses. To simplify shading evaluations, several devices and software tools are commercially available. These tools are based on sun path charts and tracking the solar window at potential array locations. The process predicts obstructions in the solar window and estimates the net losses as an input to the production estimating process. Contractors should be familiar with these tools and how to obtain accurate results.

Balance of System Components placement includes identifying proposed locations for all components, including inverters, disconnects, overcurrent devices, charge controllers, batteries, junction boxes, raceways, conductors and any other electrical apparatus or mechanical equipment associated with the system. The PV installer must ensure that all equipment locations are suitable for the intended equipment such as non-habitable spaces such as utility rooms, garages, or using outdoor rated equipment.

System Placement Best Practices

- ✓ Commercially available site placement and modeling tools should be used for evaluating solar performance based on position on roof or other mounting configurations, inclusive of roof angles, module orientation, and other shading losses.
- ✓ Shading analysis should be done using on-site using analysis tools to predict and estimate shading losses over the life of the project.
- ✓ Electrical components such as distribution panels and energy storage systems should be in appropriate spaces such as utility rooms or using outdoor rated equipment to minimize operational and maintenance constraints.
- ✓ Ground mount systems require geotechnical analysis including topography, soil conditions, and any information inclusive of data regarding wetland buffer areas, conservation territory, natural protection territory, or other local constraints.

4.2.2 Production Estimates

The contractor should substantiate and have a reasonable basis for an energy production estimate based on the selected location and system. The proposed system's characteristics are generally assumed in the estimate phase such as hardware specifications, weather data, shading, tilt and positioning of panels, and long-term module performance. The production estimate shows a range of performance data based on sub-hourly, hourly, daily, and/or seasonal influences depending on the necessary complexity of analysis required to achieve project goals. It is recommended that the Contractor's estimated Resiliency System performance be verified by an independent consultant.

Key information to be obtained during this process is summer, winter and annual capacity factors, total production for the first year of operation and total production over the system's use life or contract term. The Contractor should provide a model of the Resiliency System performance during a 36 hour power outage that demonstrates it can meet the buildings electric requirements during a community emergency event with a power outage. Most importantly, Sellers should document and disclose changes as the project is developed including assumptions used during production estimates.

Production modeling software tools are available to generate estimated energy production for a proposed system design. There are several software options of varying complexity that can be utilized to generate production estimates. Commonly used software tools include Homer, PV Watts, PVsyst, SAM, Helioscope, and many others including many proprietary vendor tools. Preferable applications depend on the level of detail and scale of the proposed system. More detailed production estimates often produce sub-hourly energy production estimates which can be used to assume energy savings in a particular electrical usage profile.

Loss estimation of a specific system is important in addition to the production in the given location. All electrical systems have losses associated with their operation and typical system losses which models estimate is 12%-20%. Figure 16 in Appendix B illustrates outputs from a commonly used model, PV Watts[3] which was developed by the National Renewable Energy Laboratory for public use. This model was created using a 1 MW_{ac} and 1.35 MW_{dc} system size with a single axis tracking system and premium PV panels. Losses assumed in this analysis reflect default values and amounts to 14%-20% (soiling 2%, shading 3%, electrical mismatch 2%, PV wiring losses 2%, connections 0.5%, performance variability 1%, availability 3%, inverter efficiency 96%).

End-users can also perform preliminary estimates of their facilities to better focus contractor efforts and scope out the best options. SolarResilient[4] is an example of an online tool developed under a U.S. DOE grant that enables users to size resilient solar and/or storage systems. It uses the available solar area and emergency load profile to estimate solar and storage needs for a particular facility. The tool can be accessed at solarresilient.org. The tool provides the sizes of solar and storage installations required for a particular electrical emergency load profile. Different scenarios can be run to find the system that best suits the site.

Production Estimate Best Practices

- ✓ Use a database of local historical data or predicted weather data file.
- ✓ Site-specific issues factored in such as shading analysis or operational constraints.
- ✓ Component hardware specified in production estimate tool (tracking system, inverter, and PV modules).
- ✓ Array orientation specified in production estimate tool (azimuth and tilt) to include roofing orientation analysis as applicable.
- ✓ System loss factor assumptions noted (electrical losses, availability, soiling, etc.).
- ✓ Summary report that confirms annually, winter (December-February), and summer (June-August) seasonal capacity factors, total production for the first year of operation and over the system's use life or contract term.

4.2.3 System Design Planning

The emergency power loads discussed in Section 2.2 are the most important considerations in sizing a resilient solar plus energy storage system. The emergency load profile should be used by the contractor to size the energy storage power and energy requirements and the solar array size required to provide sustained operation for loads and to charge the battery for a minimum period of 36 hours.

Key questions to answer are how many hours or days the facility should withstand isolation from the grid. A typical goal in implementing a Resiliency System would be to provide power to critical electric loads during a 36-hour outage event. The system should be sized for average solar availability and/or worst-case conditions such as high cloud cover or rain that may be apparent during weather events. The best practice is to size and select the system based on worst-case weather scenarios that the facility would expect to happen.

Power and Energy Sizing: System should be expected to serve the emergency loads during the expected duration of the outage with the output from solar and storage, especially in low solar output conditions. Total maximum power at the required duration should ultimately determine the size of the energy storage system. The ability to

[3] https://pvwatts.nrel.gov/pvwatts.php

[4] The tool can be accessed at https://solarresilient.org/

charge a bank of batteries is the job of the PV system during a resiliency event. The PV array should be sized with sufficient capacity to supply critical loads and to charge the batteries, assuming average solar production, and the EES should be designed with enough storage to ensure critical loads are served for the entire 36-hour period even during weather events.

Design Validation: The Contractor is responsible for gathering relevant information such that the PV system designer can design a PV system appropriate for facility integration and resiliency purposes. The Contractor shall ensure that system design and production estimates are made using reliable data. The contractor needs to provide modeling data that demonstrates the Resiliency System, using the proposed equipment and community emergency critical electric loads, is adequate fro the full 36-hour event.

Efficiency Losses: Due to the round-trip efficiency losses associated with charging and then discharging a battery system, PV energy will ultimately be lost through these inefficiencies. The result of this includes any cost to buy energy from the grid or parasitic losses during operation and should be considered in performance analysis and operational decision making. A typical energy storage system is highly efficient with most losses resulting from the inverter component which is partially avoided in DC-coupled design architecture as discussed in Section 3.2. Frequent cycling of the battery will also result in more hour of operation and impact lifecycle management.

System Design Planning Best Practices

- ✓ Battery sizing should be based on the expected outage duration and critical load profile.
- ✓ Solar PV sizing should be adequate to provide the necessary charging energy to the battery and support critical loads during grid events.
- ✓ A detailed sizing analysis should be accomplished using commercially available software tools to estimate the impact low solar days have on battery charging.
- ✓ Model of Resiliency System performance showing system is capable of providing sufficient power to meet emergency critical loads over a 36-hour period, even in adverse weather conditions.
- ✓ Battery losses should be considered in the frequency of using the battery to manage efficiency losses and unnecessary cycling of the battery.

4.2.4 System Safety and Standards

There are numerous codes and standards that apply across the PV and ESS technological landscape and for interconnecting with distribution systems. Some of these standards apply across all the technologies such as electricity metering, inverters and electrical equipment, cyber security, building, and electric codes. Individual technologies, such as different battery chemistries or mechanical energy storage, may have specific standards that apply while emerging technologies are pushing these standards to be constantly evolving.

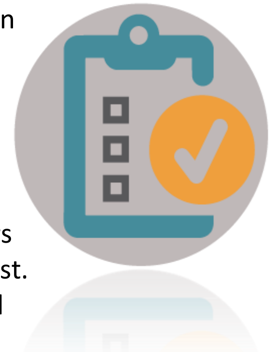
Good utility practice assures successful design, fabrication, procurement, and installation of a fully functional solar plus storage that meets or exceeds all technical requirements, including protective and reverse-power relaying, and connection to the inverter and step-up transformer secondary connections and the network and controls interface. All communications equipment/software, within the system, and equipment necessary for integration of the existing network are also driven by industry accepted methods and the preference of the customer. Electrical hazard signage on equipment (Inverter, transformer, combiner boxes), including arc flash hazard labels, are also recommended to allow technicians to navigate the appropriate personal protective equipment for the job. Electrical disconnects should be installed in accessible locations to isolate the PV system from the rest of a building's electrical system for the purpose of safety during installation, maintenance, service, and for first responders.

Codes and standards for solar PV and battery systems are well developed with best practices recently emerging in the battery component. Design and location of a battery cabinet should consider easy access to each battery module for service. The design should also include features to support battery O&M such as safety systems. There are several codes and standards that can be used to support specifying the system to assure safe and reliable operation during resiliency activities. The Institute of Electrical and Electronics Engineers (IEEE 1547 - interconnecting distributed resources) has developed and broadly accepted standard for distributed energy resources. Numerous other codes and standard are applicable depending on the system configuration (ground mount, canopy, rooftop, equipment specific factors, and purchaser preferences) and are listed below.

System Safety Best Practices

- ✓ Good utility practices can be used in selecting equipment to interconnect with the distribution grid to assure standardized construction and operation and maintenance
- ✓ American Society for Testing and Materials (Class F ASTM D3161 – Solar Shingles)
- ✓ American Society of Civil Engineers (ACSE - Guide for the Design of Steel Transmission Towers, Manual No. 52)
- ✓ American Institute of Steel Construction (AISC) "Manual of Steel Construction
- ✓ American Concrete Institute (ACI) (ACI 318 – Building Code, ACI 347 - Concrete Formwork)
- ✓ American National Standards Institute (ANSI 62.41 – Surge suppression, ANSI C12.1 – AC Electric Metering, ANSI - Design of Cold Formed Steel Structural Members)
- ✓ Communications (MODBUS, DNP3.0, SCADA, FCC Part 15A)
- ✓ Cyber Security Framework (NIST 800-171, ISO 27001)
- ✓ International Code Council "International Building Code", latest version.
- ✓ Institute of Electrical and Electronics Engineers (IEEE 1547 - Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE 519 - Harmonics)
- ✓ Georgia Building Code, latest version
- ✓ International Electric Code (IEC 62215 – mono or poly crystalline modules, IEC 61646 – Thin film modules, IEC 6130
- ✓ Local Building and Safety Codes, latest version
- ✓ Local Fire Marshal, or local authority, inspection and approval of system
- ✓ National Electrical Manufacturers Association (NEMA 4 – Exterior Enclosures and Combiner Boxes, NEMA "SG6" and "TT1" - Design of structural and miscellaneous steel)
- ✓ National Fire Protection Association (NFPA 855 - Standard for the Installation of Stationary Energy Storage Systems, NFPA 70E – Electrical Safety, NFPA 780 - Installation of Lightning Protection Systems, NFPA 241 – Fire Safety During Construction)
- ✓ National Electric Code, latest version
- ✓ Occupational Safety and Health Administration (OSHA) work safety practices
- ✓ Underwriters Laboratories (UL1741 – Inverter safety, UL 62109 – Inverter safety, UL1973 – Stationary Batteries, UL9540a – Thermal Runaway and Flame Propagation, UL 1642 Standard for Lithium Batteries, UL 790 – Solar Shingles, UL1703)

4.3 OWNERSHIP STRUCTURE



Ownership options come in many forms of commercial agreements which have their own benefits, as well as terms and conditions. Customer owned versus third-party owned decision making may be based on customer preferences and cash flows in many cases, but third-party financing options provide certainty to expenses related to a facility's energy and resiliency requirements. Third-party financing is a common solution in the solar industry as a method of deploying solar and may often take advantage of tax incentives such as the Federal Investment Tax Credit (ITC) available to Contractors installing leased system for tax exempt entities thereby reducing the overall levelized cost. Managing operation and maintenance is a function of the ownership model where leased system will have service and support structured into the contract.

Third-party financing predominantly occurs in two forms: leases and power purchase agreements (PPAs). In the lease model, a customer signs a contract with an installer/developer and pays for the use of a solar system over a specified period of time, rather than paying for the power generated. In the PPA model, the solar PV system offsets the customer's electric utility bill, and the developer sells the power generated to the customer at a predetermined rate, typically lower than the local utility. Third party financed commercial scale systems tend to follow lease models and the usage will follow operational agreements structured into the lease.

Performance guaranties for system availability and the energy storage capacity may make third-party operating agreements and leases attractive. A common practice is to structure damages into the lease based on underperformance or reliability responses. Solar plus storage systems are highly reliable and can be expected to be available > 95% of the time annually. System outages may result in partial or full deratings and the response time for the service providers depends on the criticality and situation.

Energy Capacity Guaranties for the energy storage system assures that the batteries will discharge for the required duration over the term of the agreement. Battery degradation is typically 2%-5% of energy capacity annually for a resiliency application resulting the maximum duration a battery can discharge being reduced by this amount. Cost related to degradation of batteries and energy capacity lifecycle management can be structured into the contract with this type of performance guaranty, which is sometimes offered as an additional service to product warranties.

Lease payments are typically levelized over the entire term of the agreement, can be fixed or escalated annually, to budget for servicing and end of life disposal of equipment. Pricing for systems is often given in dollar per kilowatt-month ($/kw-mo) to compare the pricing of different size system over a common metric. Monthly payments are calculated based on multiplying this rate by the available kW during the month of operation, with excusable outages for standard operation and maintenance practices.

Term lengths for contracts are based on the project's useful life and also the contractor's strategy to recover the cost of the system. Leased systems are often offered in 10-, or 20-year intervals with options to extend the term in many cases. A system that is customer owned can choose to self-perform maintenance or sign a contract with a service provider through a Long Term Service Agreement (LTSA) which may have 5-year, 10-year, or longer terms as required.

Ownership Structure Best Practices

- ✓ Third-party financing options provide certainty to expenses related to a facility's energy and resiliency requirements
- ✓ Performance guarantees are commonly structured into third-party ownership scenarios based on equipment availability and response times for technical support.
- ✓ Energy capacity guarantees provide certainty around the duration that the battery can provide service.

4.4 CONSTRUCTION CONSIDERATIONS

Structural considerations: Structural considerations for solar and battery storage resiliency systems revolve around roof mounted PV equipment. Other PV mounting configurations were discussed in more detail in Section 3.3.5. Modern mounting and racking systems generally enable retrofitting of solar on roofs as part of the existing structure of the building, but care should be taken to confirm that the weight of such an installation can be fully supported.

The design process should consider roof condition as well as additional weight of the PV modules and racking. The roof should be adequately constructed or otherwise reinforced to allow for the additional weight, including both the weight of the solar system itself and the dynamic loading impact of wind and snow. Solar PV systems add 2 to 4 pounds per ft^2 to the dead load of a roof, and substantially more at specific attachment points. A ballasted system, which is becoming a common installation method, may add much more weight to a system. A structural engineer should be consulted to examine the additional weight being added.

Contractor should determine local code requirements for seismic and wind design loads. It is the Contractor's sole responsibility to ensure that the project structural and architectural facilities comply with all federal, state, and local code requirements and all industry codes and standards.

Historical building considerations: Some facilities may be designated as historical buildings in national or local registries. Such facilities are often subject to more specific or strict building codes and regulations. Solar panels can usually be installed on the rooftops of historic properties if they are unobtrusive and cannot be seen from the ground, but this may vary by location and care should be taken to obtain the proper construction permits.

Obstacles: For roof mounted PV installations, space availability may be limited by obstacles such as skylights and HVAC equipment, or from shading caused by nearby trees and taller buildings. For canopy PV installations over parking lots or other areas, ensure proper height clearance.

Construction Best Practices

- ✓ Care must be taken to ensure roof mounted PV equipment can be fully supported by the existing building or structure.
- ✓ If a facility is designated as a historical building, verify building codes/regulations regarding installation of PV modules.
- ✓ Review building HVAC requirements based on the planned use of the facility during an emergency event.

4.5 OPERATION AND MAINTENANCE

An effective Operation and Maintenance (O&M) program provides certainty that a system will perform at or above its production estimate and costs over the useful life. Therefore, a long-term performance management strategy will assure the expected benefits of an asset and should be properly considered in the budgeting phase of the project and sustained over time through monitoring and performance guaranties. This guide is not intended to provide a full set of O&M best practices, but this section is offered to provide a context for considering contractor qualification to operate and maintain the systems.

O&M Plans: Strategies exist to provide O&M services to manage the desired performance expectations. The ownership model largely determines the maintenance approach of the system over the useful life. Solar and energy storage service and maintenance programs are well developed throughout industry which should be presented by the contractor including regular maintenance tasks to maintain the warranties of equipment.

4.5.1 Battery Lifecycle

Lifecycle Management strategies are necessary to deal with the certainty of decaying battery performance. Battery degradation occurs every time there is a charge or discharge cycle, and it is a function of depth of discharge, current rate, and average state of charge. The battery's energy capacity, the duration that the battery can serve the load, fades overtime which can be managed by proper initial sizing and a strategy to maintain the system performance over the life. Typically, the battery is slightly oversized to account for degradation and allow the system to provide the appropriate duration over the contract term. Tier One lithium-ion suppliers offer up to 10-year warranties and LTSAs with contractors can help manage those warranties and act as the guaranteeing party for the term of the agreement.

Mechanisms of Degradation in lithium-ion batteries are primarily due to the innate chemical reactions that occur between the electrolyte and anode as well as mechanical breakdown of the electrodes due to usage. The two primary mechanisms of battery aging are resultant of usage and the passage of time. It is worth noting that cycle life and discharge throughput through a lithium-ion battery are directly proportional, but not in a linear fashion, and the relationship differs by cell based on the exacerbating variables.

Cycling degradation from charging and discharging of a lithium-ion battery results in the repeated intercalation and deintercalation of lithium ions into and out of the crystalline electrode structures forcing repeated expansion and contraction of such electrodes with each cycle. As with any mechanical movement, over time the underlying electrode materials or the composite electrode structure will become fatigued from stress and fail and/or a current collector can separate from its electrode. As discussed under Exacerbating Factors below, the rate at which mechanical damage occurs increases under certain conditions. Under controlled cycling, the mechanical damage develops over time and manifests as an increase in internal resistance and reduced charge-carrying capacity; however, accelerated degradation can occur if such fatigue breaks through the solid electrolyte interface (SEI) layer and wear through the separator shorting the electrodes

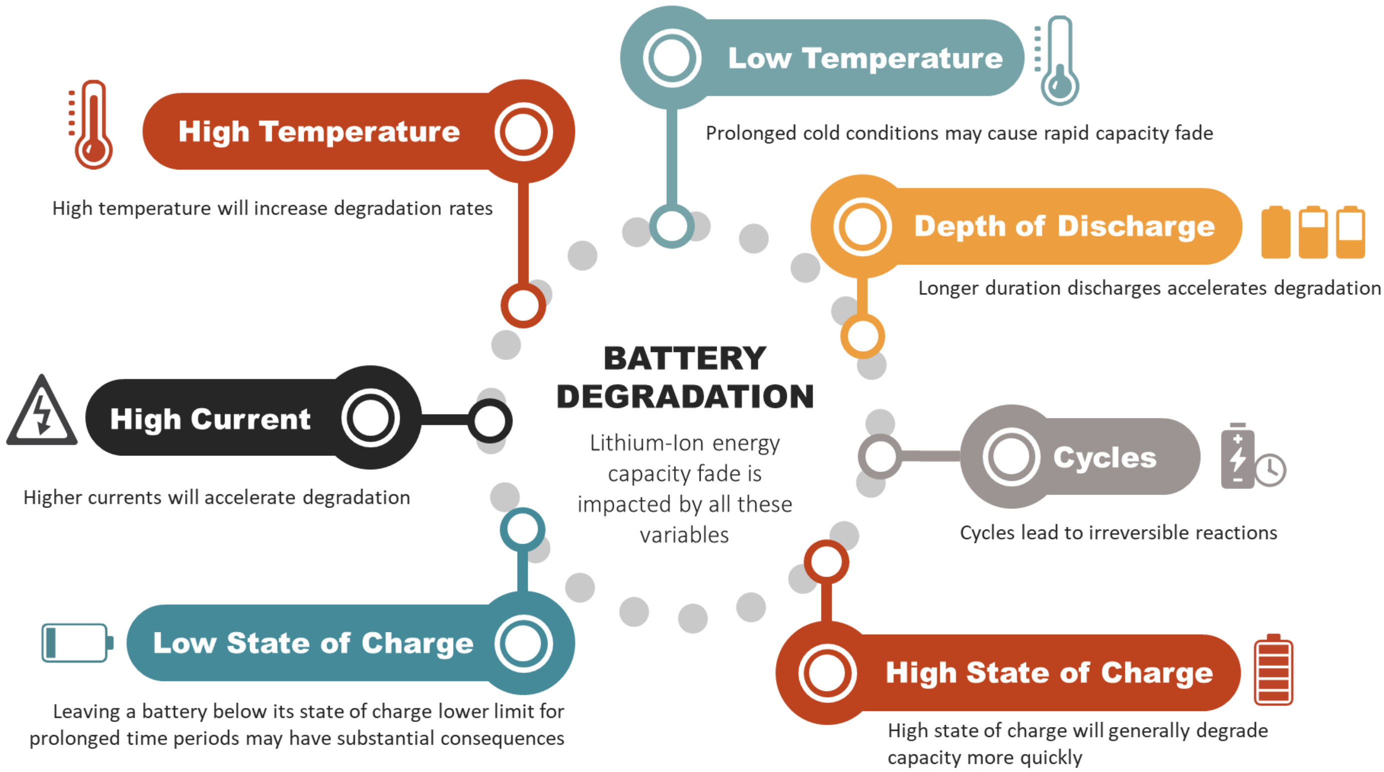


FIGURE 12 - BATTERY DEGRADATION EXACERBATING FACTORS

Calendar fade degradation results from a battery sitting idle. The carbon anodes used in lithium-ion batteries require a passivation layer (impervious to electrons) to moderate the flow of lithium-ions into and out of the anode's structure. Passivation is accomplished via the formation of an initial SEI layer formed at the factory via a charging procedure applied after battery assembly. While essential for stable battery operation, with the passage of time (and compounded by cycling) the SEI layer continues to thicken (a non-reversible reaction), reducing the quantity of active chemicals in the cell and increasing the battery's internal resistance. Such changes reduce the usable capacity of the cell and restrict the flow of lithium ions, thus increasing heat generation at a given power (i.e. – the current flowing through the battery) and reducing charge and discharge energy efficiency. The rate at which SEI formation occurs increases under certain conditions. In addition to SEI formation, over time, corrosion will consume active materials within a cell, increasing internal resistance and reducing energy capacity. Exacerbating factors from both cycling degradation and calendar fade can be exacerbated by battery operation and storage conditions, the key factors of which are highlights in **Error! Reference source not found.**.

High and low temperatures can be harmful to a lithium-ion battery. Given temperature's key contribution to degradation, battery thermal management is critical to lifecycle management. When a battery is not operating, low-temperature storage slows the rate of chemical reactions that can degrade a battery; however, it is generally not advised to store a lithium-ion battery at or below freezing (we typically see OEM-prescribed storage temperature minimum limits just below 20°C). Low-temperature charging (less than 10°C) causes lithium to plate over the anode, rapidly reducing (in as little as a few cycles) the amount of lithium available to carry charge. If failure is not near-immediate, such reaction generally continues over time, thickening the lithium layer, further reducing charge-holding capacity of the cell. Charging below freezing highly accelerates the lithium-plating reaction, possibly forming dendrites that can pierce the separator between electrodes, shorting the battery resulting in permanent failure, and perhaps, an unsafe thermal event.

Higher cell operational and storage temperatures increase the effects of cycling degradation as well as calendar fade. This occurs because (as with low temperature) the speed of chemical reactions is directly proportional to temperature, including the chemical reactions that cause a battery to degrade. Lithium-ion batteries follow Arrhenius' law, which for most lithium ion chemistries mans that for every 10°C of temperature increase, the rate of calendar fade doubles.

Differential temperature is also important to consider as a cause of cell mismatch over time is un-even operational temperatures resultant of inadequate cooling systems, and it's worth noting that even the best cooling systems are imperfect. Battery performance is limited by its weakest cells, so it is of key importance that the temperature gradient throughout a battery rack be as uniform as possible.

State of charge (SOC) is the amount of energy contained in the battery which is represented by a percentage (0%-100%) of how full the battery is or simply indicating the available energy available for discharge (watt-hours). Lithium-ion batteries are impacted by both high and low SOC and is managed over the uselife of the project.

Low SOC operation can result in dissolution of the anode's copper current collector into the electrolyte. When the battery is then charged above the dissolution voltage threshold, such dissolved copper then precipitates in places that can short the electrodes of the battery. Cathodes will additionally breakdown over time when cycled under low SOC scenarios (although the speed of cathode degradation at low voltage varies by lithium-ion sub-chemistry). Severe under-SOC situations are rare in the stationary energy storage industry as most modern BMSs will not allow battery operation below such threshold; however, driven by wider allowable SOC swings, or depth of discharge (DOD) from cell manufacturers, and when a wide DOD is allowed, momentary operation at low voltage will take an incremental toll on the cycle life of a cell, compounding over time.

High SOC operation also has lifecycle impacts. Unlike some non-lithium-ion battery chemistries that are more tolerant to sustaining a full charge, lithium-ion is susceptible to such, and the effects are very similar to that discussed in high current below. Like low SOC situations, severe high SOC situations are rare in the stationary energy storage industry for the same reasons. While the phenomenon varies based on sub chemistry, it has also been shown that cathodes can suffer from accelerated electrolyte oxidation at higher SOCs. As noted in low SOC operation, since a different reaction can cause accelerated degradation at lower voltages, each battery has a "sweet spot" for SOC (as well as "swing", or DOD, around such SOC) where degradation is minimized. This is why most lithium-ion battery manufacturers will specify an ideal average SOC range usually greater than 10 percent, but less than 60 percent (often averaging just below 50 percent); however, it's worth noting that independent battery testing has shown that several common battery cells deployed in the stationary energy storage industry today have highly variable ideal SoCs and SoC-swings, so "rules of thumb" do not always apply.

Current also has impact as lithium-ion batteries generally degrade faster with higher power operation and slower with low power operation; however, when discussing the effects of power on battery degradation, we're primarily referring to relative current. High-current charging rapidly expands the anode, which can result in mechanical stress on the anode's physical components. Under such situation, charging current may also exceed the current tolerance of the anode (ability of the battery materials to accommodate lithium ions quickly enough), resulting in permanent plating of lithium on the anode and associated reduction in the cell's charge-carrying capacity or complete failure (and potentially, dendritic growth puncturing the separator, leading to an internal short circuit and an unsafe thermal event).

High-current operation (both charging and discharging) also results in rapid heating of the cell which may exceed the heat-rejection capabilities of the thermal management system leading to high-temperature battery operation (of which as discussed above, increases both cycling and calendar fade degradation). This is the primary reason that several high-power stationary energy storage projects have degraded pre-maturely.

4.5.2 PV Lifecycle

PV Module Maintenance tends to be minimal with typical tasks consisting of physical inspections that complement performance monitoring. PV modules should be inspected along with an appropriate performance monitoring program to detect underperformance which may be caused by module failure and more commonly soiling on the PV modules. Soiling reduces the energy output of the PV array and can lead to localized "hot-spot failures" if the soiling is uneven. Efforts should be taken to reduce uneven soiling, for example, from bird droppings. Care must be taken with array cleaning to avoid damaging the components per the PV module manufacturer's recommendations, so cleaning is often not executed due to the increased risk. Cleaning the soiling from PV modules is strictly based on condition-based maintenance tasks and is typically not a concern in higher precipitation areas, such as Georgia, and when the panels are properly located and environmental conditions (bird populations, dust, agriculture, etc.) are not extreme.

FIGURE 13 - PERFORMANCE OF PV PANELS CAN BE IMPACTED BY ENVIRONMENTAL FACTORS

Inverter Maintenance: Inverter reliability continues to increase for all types of inverters, with 10-year warranties now commonly available and 20-year extended warranties/service plans also supported through LTSAs, PPAs, or ESSAs. However, a sound O&M plan should account for inverter failure because it is one of the most frequent causes of PV system performance loss.

Vegetation Management: Just as equipment O&M issues should be considered in the design phase, the long-term maintenance of the grounds and drainage should be considered in the design, civil engineering, and construction phases of ground-mounted systems to reduce O&M risks and costs. In many areas of Georgia, grass cutting and vegetation control costs can equal or exceed equipment O&M costs. Initial design assumptions can significantly impact O&M costs for ground-mounted systems include ensuring that panels are mounted with sufficient and uniform clearance from the ground and between rows. Gravel grounds is well suited for many installations.

End of Life: End-of-life disposal of solar products in the US is governed by the Federal Resource Conservation and Recovery Act (RCRA), and state policies that govern waste disposal or other disposition. Recycling is available for most of the equipment in a PV plant along with other environmentally friendly disposal methods. Likewise, battery equipment is commonly recycled which represents a cost at the end of life. Removal and disposal of equipment should be budgeted and planned for over the life of the project.

4.6 INTERCONNECTION

4.6.1 Utility Interconnection Requirements

Georgia Power Company (GPC) is the largest utility in the state, so this section will focus on interconnection details for GPC. There are also over 40 electric member cooperatives (EMCs) and over 50 municipally owned electric systems that provide power to various parts of Georgia. Each may have varying rates or regulations regarding interconnected solar systems, so entities served by utilities other than Georgia Power should verify details with the appropriate representative during the planning stages of a solar and battery storage resiliency project. In general, utility interconnection standards include IEEE 1547:2018 and UL 1741 SB.

Georgia Power offers a few different behind-the-meter solar programs depending on the system's size. For small generators under 250 kW, the Renewable & Nonrenewable tariff (RNR)[5] allows excess energy generated at a facility to be credited at the annual Solar Avoided Energy Cost Rate per kWh, summed monthly and used to reduce the customer's total monthly bill. For larger generators over 250 kW, customers may sell their electricity as a Qualifying Facility (QF). Generators participating in the QF program will be paid Georgia Power's hourly avoided cost rate.

Another program called Energy Offset (EO) is designed for customers who would like to maximize the size of their solar installation in order to offset their energy usage, in systems that are not designed to push energy back to the grid. This program is automatically applied to customers who have solar installed behind their meter and have not elected to participate in one of Georgia Power's other solar programs.

Georgia Power offers a Solar Adviser tool[6] that can help assess considerations and estimated costs for PV installations. Further details on the interconnection process with Georgia Power, including application and agreement information, can be found in GPC's "Operation of Distributed Energy Resources (DER) in Parallel with the Distribution System" Policy.[7]

4.6.2 Existing Emergency Generator Interface

Buildings with existing emergency generators can be an advantage in the design of a solar and battery resiliency project. Utilities usually require buildings with emergency generators to have isolation switches which disconnect the utility grid from the building during power outages. This isolation system can be used to perform the same purpose of isolating the solar and battery resiliency project from the grid. The design of the project needs to ensure the existing grid isolation systems are compatible with the new systems.

Generator control systems will need to ensure the emergency generators do not start on loss of power. Upon loss of utility power, the resiliency system needs to be designed such that the inverters have a frequency signal to maintain proper AC frequency while the utility feed is being isolated and switch to operation with the resiliency system. This control system should interface with the emergency generator controls to make sure it does not startup upon loss of the utility feed unless the resiliency system fails.

Interconnection Best Practices

- ✓ In general, utility interconnection standards include IEEE 1547:2018 and UL 1741 SB.
- ✓ Verify interconnection requirements and the potential for selling energy back to the grid with the utility that serves the facility.

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[5] Georgia Power RNR Tariff Schedule https://www.georgiapower.com/content/dam/georgia-power/pdfs/residential-pdfs/residential-rate-plans/RNR-10-1.pdf

[6] Georgia Power Solar Adviser tool https://www.georgiapower.com/company/energy-industry/energy-sources/solar-energy/solar/solar-adviser-tool.html

[7] Georgia Power Interconnection Policy https://www.georgiapower.com/content/dam/georgia-power/pdfs/company-pdfs/solar-pdfs/SOCO_Interconnection_Policy_Binder_06-15-2021.pdf

5 Project Economics

Numerous facilities are candidates for resilient backup power. and ideally could install solar and storage. The budgeting and finance are often barriers to widespread adoption. Solar and storage have benefits of reducing electric costs in everyday, normal operation, opening the door for combined public and private financing to achieve adoption of solar and storage systems resiliency measures. The project costs are driven based on providing sufficient electricity to power critical loads during a community emergency event over a 36-hour power outage. Economic assessment of the project should include the benefits of electric cost savings from the solar system reducing utility supplied power during normal operations. If the building is on a utility time of day rate, there may also be a benefit of charging the batteries with low cost power during off-peak periods and using the batteries to reduce load during on-peak periods.

5.1 COSTS

5.1.1 Project Cost

Preliminary cost estimates are typically based on industry trends and nominal rules of thumb for larger scale PV and battery storage installations. A preliminary cost estimate from a Feasibility Assessment should be used as a benchmark for project costs, understanding its level of accuracy. There are also associated infrastructure costs to consider, defined as costs outside of the PV or battery components and other required material to connect the battery to an existing distribution panel. The costs of these infrastructure components, required to isolate the building from the electric grid in a critical event, are typically estimated at 30% of the project costs, subject to the detailed design phase at the onset of the project.

Project Cost Example: For a 50% critical load outage for a 36-hour event at a municipal office building and emergency relief shelter in Savannah, Georgia, the battery specified to cover this outage would have an ideal nominal capacity of 949 kWh and a power capacity of 63 kW. The battery would dispatch power to serve critical loads in a behavior pattern similar to the chart below, for a summertime outage. The estimated cost of this 36-hour battery solution is based on industry trends and nominal rules of thumb for larger scale storage. The turnkey installation costs for the battery system described above are estimated between $850,000 and $950,000.

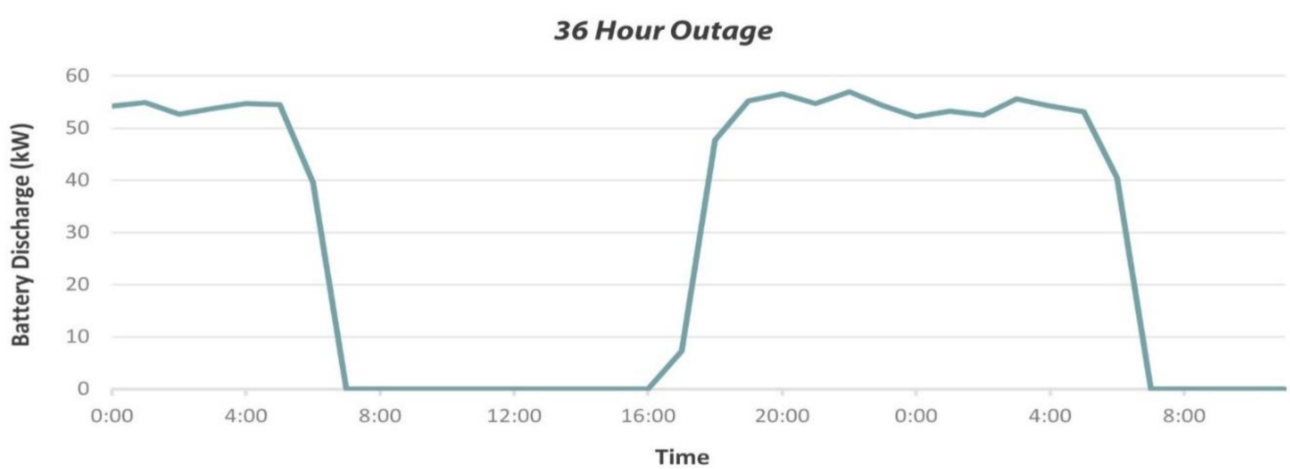


FIGURE 14 – 36-HOUR BATTERY DISPATCH PATTERN

5.2 BENEFITS

5.2.1 Avoided Outage Costs

The overall economics for a resiliency system incorporate certain non-energy (non-quantifiable) benefits to the community in a critical event, such as having climate-controlled shelter, lighting, and basic food preparatory functionality, or continued communications/operations of emergency medical services. These benefits, called avoided outage costs, are aggregated into a single benefit dollar amount per kWh that the user places on the unmet site load during grid outages, or the losses that the site would experience if the load were not met. The value of lost load (VoLL) is used to determine the avoided outage costs by multiplying VoLL ($/kWh) with the average number of hours that the critical load can be met by the energy system, then multiplying by the mean critical load.

5.2.2 Electric Cost Reduction

While this guide focuses on resiliency during outages, it is common for facilities to utilize solar and energy storage systems to reduce the peak demand of the facility. Many of the major equipment manufacturers allow for intelligent utility rate integration into the battery control software or inverters, allowing for a semi-autonomous approach to battery utilization for peak shaving. For the most effective utilization of this feature, it is necessary to perform an analysis of peak demand rate impacts in existing and possible scenarios, assuming a battery installation with the appropriate capabilities.

For facilities with large available land or roof space with minimal shading, the potential economic benefits may influence a larger PV installation than what would typically be considered from a resiliency perspective alone. In these cases, additional analysis should be performed regarding net metering benefits, and entities should coordinate with the utility that serves the facility to determine if excess energy can be sold back to the grid, as was described earlier in Section 4.6.1.

Electric Cost Reduction Example: The potential output of a 370 kW PV system in Savannah, Georgia is modeled below. The energy produced by such a system could be used to charge the battery system, serve the building's load, or be sold back to the utility.

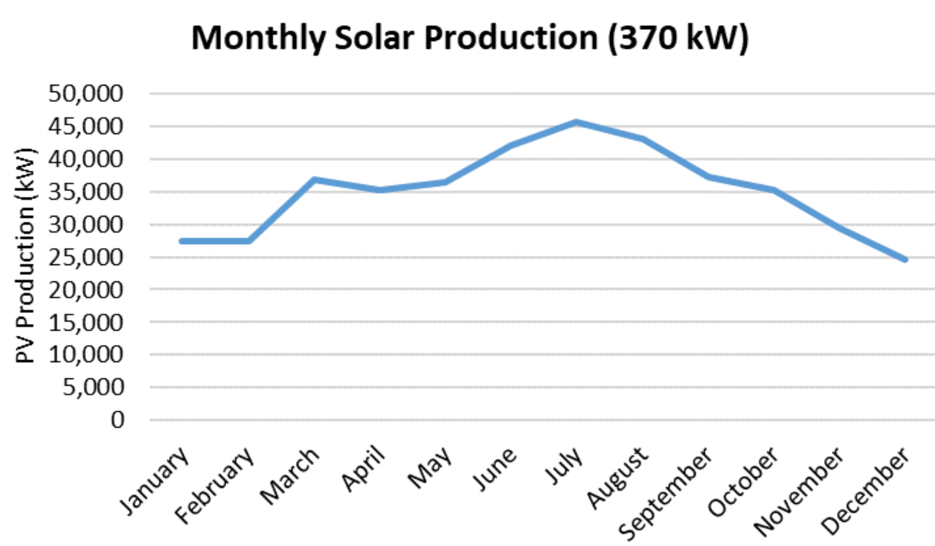


FIGURE 15 – MONTHLY SOLAR PRODUCTION ESTIMATE

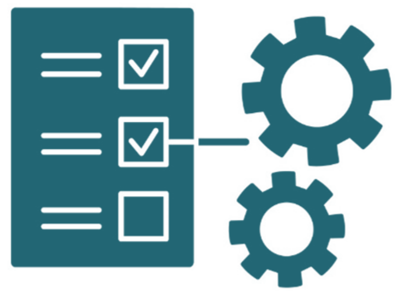
6 Testing

6.1 TESTING REQUIREMENTS

A PV commissioning and acceptance testing program is outlined that will assure that the system meets the requirements and is capable of performing as expected. Commissioning documentation that GDS recommends includes certificates of code compliance, performance, and electrical testing, and a first responder orientation record. Numerous other start-up tests are expected by the contractor to assure the system meets design characteristics including electrical measurements and performance testing. In tracking systems, array tracker operation test is used to verify panels are at the correct position for the time of day. Each tracker tested to verify that it is controlling the array angle to within OEM specification of the scheduled angle.

6.1.1 PV System Performance Testing

Performance testing is an important technical requirement to provide assurance to stakeholders, and the results of these tests are typically tied to guarantees, liquidated damages, and provisions set in financing agreements.



There are several industry accepted test standards including ASTM protocols (ASTM E2339 and E2848) which are the industry standards for capacity test procedure and instrumentation and measurement requirements. Baseline test and annual tests can be planned as part of an annual performance measurement. The ASTM standard proposes regression-based approach with a rigorous data validation process, which helps reduce the uncertainties associated with the short-term nature of solar PV plant acceptance testing. An illustrative example of ASTM data captured during a test is represented in Appendix C. System output and a system performance degradation rate can be captured annually. Updated weather adjusted models can be agreed upon in cases where the production guaranty is disputed. Performance Ratio tests are also a viable alternative to ASTM methods as IEC has an accepted method for measuring and accepting new power plants.

The test procedure should reference a standard or otherwise agreed upon test to determine of plant will be capable of delivering production estimates and stand-up against future warranty claims. Performance measurement and record is a best practice that is often agreed upon during contract negotiations and operational agreements may exist to periodically test the system for unexpected degradation of output.

6.1.2 Energy Storage System Performance Testing

An ESS commissioning and acceptance testing program is outlined that will assure that the system meets the requirements and is capable of performing as expected. Commissioning documentation that GDS recommends may include certificates of code compliance, performance and electrical testing, functional testing of fire detection and suppression systems, and a first responder orientation record.

6.2 ELECTRICAL INTERCONNECTION TESTING

The utility serving the facility will typically require testing of the system while operating in parallel with the utility's distribution system. For example, Georgia Power may require arranging for GPC staff to visit the facility and observe testing of the interconnection protection and control devices. Testing includes injection of test voltage and current to trigger tripping and closing of the interconnection breaker.

Further details on GPC interconnection testing requirements can be found in the GPC's "Operation of Distributed Energy Resources (DER) in Parallel with the Distribution System" Policy.[Error! Bookmark not defined.] Further testing may be r equired at various intervals throughout the life of the system.

Testing Best Practices

- ✓ Recommended commissioning documentation includes certificates of code compliance, performance, and electrical testing, and a first responder orientation record.
- ✓ Numerous start-up tests are expected by the contractor to assure the system meets design characteristics, including electrical measurements and performance testing.
- ✓ Verify electrical interconnection testing requirements with the utility that serves the facility.
- ✓ ASTM E2939 is the standard for determining measurement conditions and modeling parameters.
- ✓ ASTM E2848 provides guidelines for executing the test in the field and reporting standards.

Appendix A. Best Practices Summary

There are several checkpoints that the Project Manager can use to supervise the contractor to assure best practices are implemented during the course of the project. These checkpoints are listed below, summarizing the best practices for solar plus energy storage resiliency systems that have been detailed throughout this guide.

Facility Assessment (Section 2)

- ✓ Identify building and site characteristics and potential constraints.
- ✓ Understand critical electric loads during emergency outages.
- ✓ Develop the facility's emergency load profile.
- ✓ Provide preliminary sizing of Resiliency System.
- ✓ Provide Resiliency System performance modeling.

Solar Resiliency (Section 3.1)

- ✓ Use of solar plus energy storage can have resiliency value streams if the equipment and controls are designed for resiliency.
- ✓ Solar plus storage systems may be designed for partial resiliency, critical load resiliency, and full resiliency with the proper specifications.
- ✓ Appropriately specified inverters transfer loads from PV system operation to operate in stand-alone battery mode for the circuits designated for emergency load.
- ✓ Equipment should be capable of detecting grid-events and control of Resiliency System operations to meet critical electric load needs and provided continuous source of electricity.

System Components (Section 3.33.3)

- ✓ Qualified Contractor lists should be maintained for design, installation, and operation and maintenance services.
- ✓ Qualified Equipment list for all major system components (PV Module, Inverter, transformer, protection and controls equipment, and battery module/rack).
- ✓ Manufactured using an ISO-9001 quality management system
- ✓ Manufactured using an ISO-14001 Environmental Management System

PV Module Selection (Section 3.3.2)

- ✓ Mono-crystalline silicon modules typically offer the best value of performance and cost.
- ✓ Thin Film Modules are lightweight and can be attractive for rooftop installations where there are special requirements or loading constraints.
- ✓ Manufactured to ISO9001:2000 and ISO 9001 quality and ISO14001:2004 environmental standards.

Inverter Selection (Section 00)

- ✓ String inverters are often preferred due to cost, reliability, ease of maintenance, and wide variety of configuration and product options.
- ✓ Central inverters provide cost advantages for projects >500 kW_{ac} but may require specialized maintenance to maintain reliability.

PV Tracking and Orientation (Section 3.3.4)

- ✓ Resilient solar installations benefit from a fixed orientation design method due to the reduced maintenance and cost relative to PV with tracking systems.
- ✓ Tracking systems maximize annual energy production and offer value in larger scale installations.

Mounting Configuration (Section 3.3.5)

- ✓ Multiple array mounting configurations should be considered and can be deployed in combination to provide the power and energy requirements.
- ✓ Ground mount systems offer the most cost-effective solution, where land is available, and designed for high wind loading experienced during many severe weather events.
- ✓ Rooftop mounted solar will require review of roof design to ensure it is capable of supporting the additional weight of the solar equipment.

Solar Plus Storage Sizing (Section 3.3.6)

- ✓ Commercially available lithium-ion varieties are commonly deployed due to factors such as reliability, longevity, low maintenance requirements, and total project costs.
- ✓ Questions to ask the Sellers include which battery they selected and a long-term strategy for replacing critical components such as battery modules and servicing the BMS.
- ✓ Multiple parallel strings of batteries are often recommended so that one may be taken out of service for maintenance while the other string provides higher reliability for critical operations.

Procurement and RFP (Section 4.1)

- ✓ Entities should publish a Request for Proposals (RFP) in order to receive proposals from multiple vendors/contractors and be able to select the best option for the facility.
- ✓ The RFP should include an introduction of the facility, critical needs in an outage scenario, project details and electrical load information, and a list of content expected to be included in each proposal/response.
- ✓ Proposal evaluation should prioritize the project commercial and technical requirements, in addition to price, through a scoring process and then weighting the numerous evaluation criteria.
- ✓ The Proposal Form should include all evaluation metrics, while the proposal content allows the Buyer to explore detail and make informed decisions on how to properly evaluate the proposal. The Technical worksheet in the Proposal Form allows Contractors to input all the pertinent technical criteria while the General worksheet contains the pertinent financial metrics for proposal valuation.

System Placement (Section 4.2.1)

- ✓ Commercially available site placement and modeling tools should be used for evaluating solar performance based on position on roof or other mounting configurations, inclusive of roof angles, module orientation, and other shading losses.
- ✓ Shading analysis should be done using on-site using analysis tools to predict and estimate shading losses over the life of the project.
- ✓ Electrical components such as distribution panels and energy storage systems should be in appropriate spaces such as utility rooms or using outdoor rated equipment to minimize operational and maintenance constraints.
- ✓ Ground mount systems require geotechnical analysis including topography, soil conditions, and any information inclusive of data regarding wetland buffer areas, conservation territory, natural protection territory, or other local constraints.

Production Estimates (Section 4.2.2)

- ✓ Use a database of local historical data or predicted weather data file.
- ✓ Site-specific issues factored in such as shading analysis or operational constraints.
- ✓ Component hardware specified in production estimate tool (tracking system, inverter, and PV modules).

- ✓ Array orientation specified in production estimate tool (azimuth and tilt) to include roofing orientation analysis as applicable.
- ✓ System loss factor assumptions noted (electrical losses, availability, soiling, etc.).
- ✓ Summary report that confirms annually, winter (December-February), and summer (June-August) seasonal capacity factors, total production for the first year of operation and over the system's use life or contract term.

System Design and Planning (Section 4.2.3)

- ✓ Battery sizing should be based on the expected outage duration and critical load profile.
- ✓ Solar PV sizing should be adequate to provide the necessary charging energy to the battery and support critical loads during grid events.
- ✓ A detailed sizing analysis should be accomplished using commercially available software tools to estimate the impact low solar days have on battery charging.
- ✓ Model of Resiliency System performance showing system is capable of providing sufficient power to meet emergency critical loads over a 36-hour period, even in adverse weather conditions.
- ✓ Battery losses should be considered in the frequency of using the battery to manage efficiency losses and unnecessary cycling of the battery.

System Safety (Section 4.2.4)

- ✓ Good utility practices can be used in selecting equipment to interconnect with the distribution grid to assure standardized construction and operation and maintenance
- ✓ American Society for Testing and Materials (Class F ASTM D3161 – Solar Shingles)
- ✓ American Society of Civil Engineers (ACSE - Guide for the Design of Steel Transmission Towers, Manual No. 52)
- ✓ American Institute of Steel Construction (AISC) "Manual of Steel Construction
- ✓ American Concrete Institute (ACI) (ACI 318 – Building Code, ACI 347 - Concrete Formwork)
- ✓ American National Standards Institute (ANSI 62.41 – Surge suppression, ANSI C12.1 – AC Electric Metering, ANSI - Design of Cold Formed Steel Structural Members)
- ✓ Communications (MODBUS, DNP3.0, SCADA, FCC Part 15A)
- ✓ Cyber Security Framework (NIST 800-171, ISO 27001)
- ✓ International Code Council "International Building Code", latest version.
- ✓ Institute of Electrical and Electronics Engineers (IEEE 1547 - Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE 519 - Harmonics)
- ✓ Georgia Building Code, latest version
- ✓ International Electric Code (IEC 62215 – mono or poly crystalline modules, IEC 61646 – Thin film modules, IEC 6130
- ✓ Local Building and Safety Codes, latest version
- ✓ Local Fire Marshal, or local authority, inspection and approval of system
- ✓ National Electrical Manufacturers Association (NEMA 4 – Exterior Enclosures and Combiner Boxes, NEMA "SG6" and "TT1" - Design of structural and miscellaneous steel)
- ✓ National Fire Protection Association (NFPA 855 - Standard for the Installation of Stationary Energy Storage Systems, NFPA 70E – Electrical Safety, NFPA 780 - Installation of Lightning Protection Systems, NFPA 241 – Fire Safety During Construction)
- ✓ National Electric Code, latest version
- ✓ Occupational Safety and Health Administration (OSHA) work safety practices
- ✓ Underwriters Laboratories (UL1741 – Inverter safety, UL 62109 – Inverter safety, UL1973 – Stationary Batteries, UL9540a – Thermal Runaway and Flame Propagation, UL 1642 Standard for Lithium Batteries, UL 790 – Solar Shingles, UL1703)

Ownership Structure (Section 4.3)

- ✓ Third-party financing options provide certainty to expenses related to a facility's energy and resiliency requirements
- ✓ Performance guaranties are commonly structured into third-party ownership scenarios based on equipment availability and response times for technical support.
- ✓ Energy capacity guaranties provide certainty around the duration that the battery can provide service.

Construction (Section 4.4)

- ✓ Care must be taken to ensure roof mounted PV equipment can be fully supported by the existing building or structure.
- ✓ If a facility is designated as a historical building, verify building codes/regulations regarding installation of PV modules.
- ✓ Review building HVAC requirements based on the planned use of the facility during an emergency event.

Interconnection (Section 4.6)

- ✓ In general, utility interconnection standards include IEEE 1547:2018 and UL 1741 SB.
- ✓ Verify interconnection requirements and the potential for selling energy back to the grid with the utility that serves the facility.

Testing (Section 6)

- ✓ Recommended commissioning documentation includes certificates of code compliance, performance, and electrical testing, and a first responder orientation record.
- ✓ Numerous start-up tests are expected by the contractor to assure the system meets design characteristics, including electrical measurements and performance testing.
- ✓ Verify electrical interconnection testing requirements with the utility that serves the facility.
- ✓ ASTM E2939 is the standard for determining measurement conditions and modeling parameters.
- ✓ ASTM E2848 provides guidelines for executing the test in the field and reporting standards.

Appendix B. Example Production Estimate

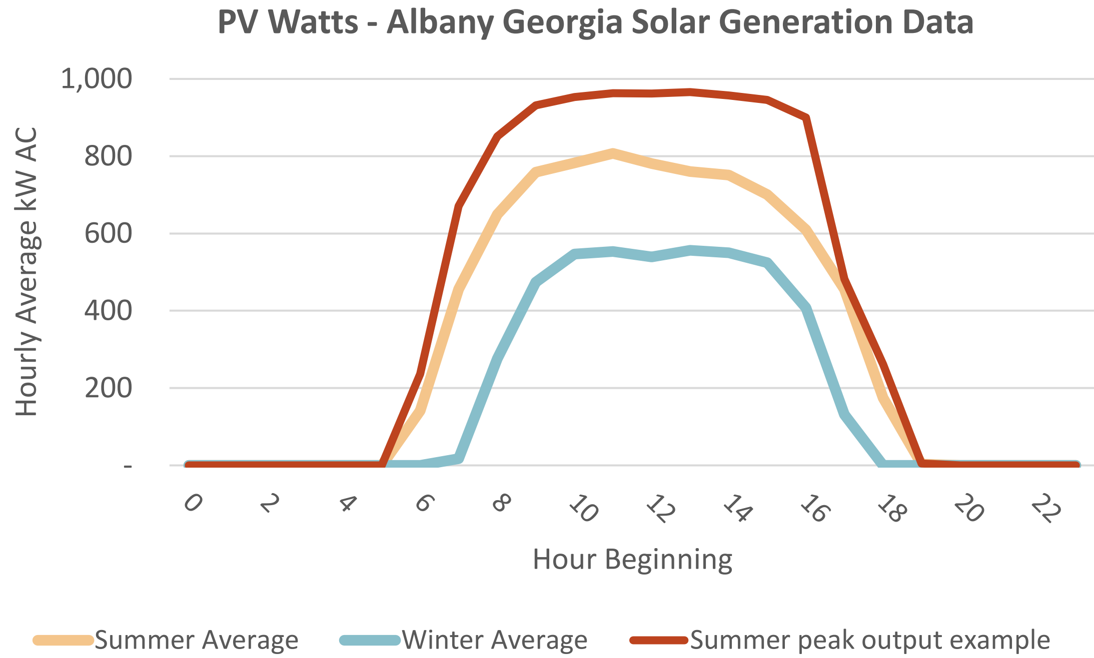


FIGURE 16 – PV WATTS SOLAR SIMULATION EXAMPLE

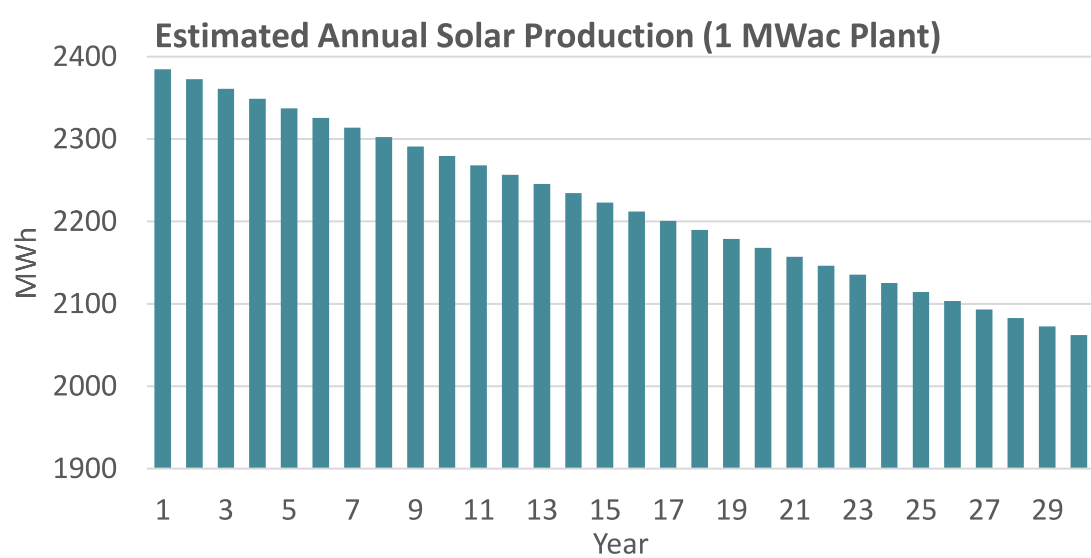


FIGURE 17 – ESTIMATED ANNUAL SOLAR PRODUCTION FOR A 1MW$_{AC}$ FACILITY[8]

[8] open System Performance and Reliability Clearinghouse (oSPARC); Estimates 0.5% system degradation annually, SunSpec Alliance; Accessed September 14, 2018.

Appendix C. Example ASTM Solar Testing Results

The ASTM standard proposes regression-based approach, which helps reduce the uncertainties capacity measurement. The data in this Appendix is provided to point out common issues with precise and accurate solar performance testing. Depending on the time of year the solar plant is commissioned, environmental conditions will determine the output of the solar plant based on the irradiance, ambient temperature, and wind speed. The ASTM2848 standard outline a method for determining which data to use for capacity measurement over a multi-day period (Figure 18). The process expects that 3 days will be able to produce the appropriate number of data point to measure power capacity and model what the plant output would be in ideal conditions. This “ideal condition” is when irradiance, ambient temperature, and wind speed match what the equipment manufacturer uses to rate the system. The data collected is then modeled (Figure 19) with guidelines from ASTM E2939 to understand if the solar plant is capable of producing the expected power at variable environmental conditions, and thereby producing the expected annual energy provided in the production estimate.

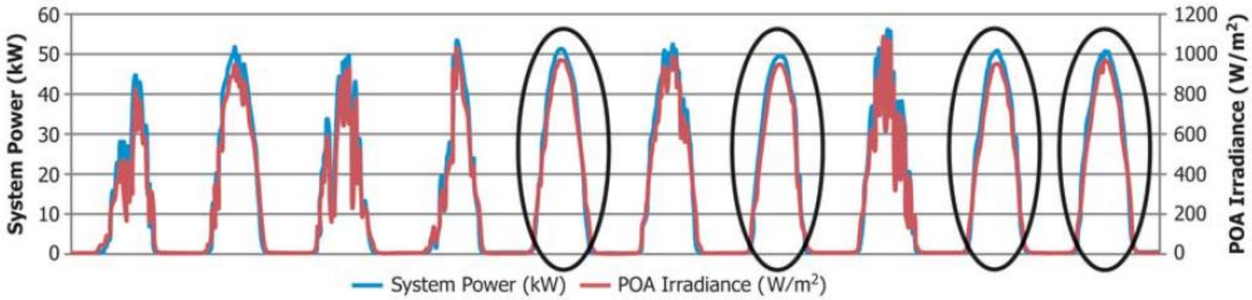


FIGURE 18 - ASTM2848 SETS STANDARD FOR DETERMINING WHICH DAYS TO USE FOR TEST DATA

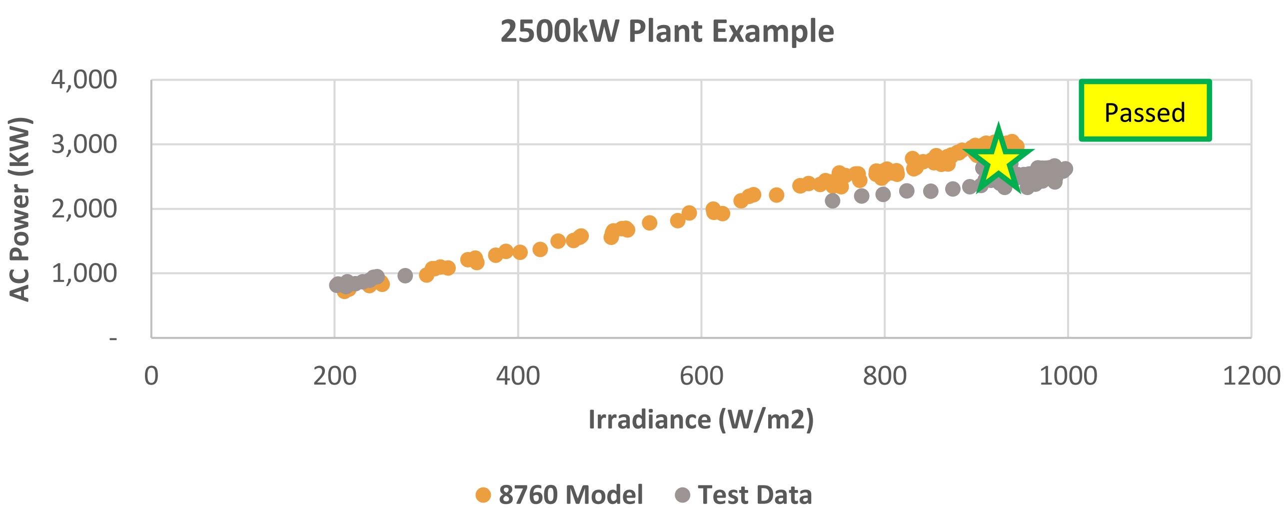


FIGURE 19 - ASTM2939 CREATES CRITERIA FOR MEASUREMENT AND MODELING