Solar Readiness Design Guide

This guide provides design and architectural teams with everything needed to effectively incorporate onsite solar energy production and battery storage preparedness into hotels, resorts, and residences of the future.

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Marriott INTERNATIONAL

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1.0 INTENT

The following pages comprise the set of considerations necessary for including photovoltaic (PV) system and energy storage design provisions in the construction coordination process of new buildings falling under Marriott International brands. These guidelines provide direction on the structural, electrical, and mechanical considerations for installing PV arrays onsite. While local regulating bodies and code compliance will vary by geography and government, these standards universalize tested methods for PV and battery considerations during building development. Where applicable, they provide context and direction for where to look when customizing for a given continent or region and offer guidance on the best metering regime for your circumstance.

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2.0 INTRODUCTION

Solar power can be delivered to a hotel in several ways. Solar energy can be generated on site via a rooftop or carport canopy system or be generated at a remote location and delivered through the existing utility lines. Solar power generated remotely is purchased through virtual or synthetic power purchase agreements, through community solar projects, or directly from a utility. This Design Guide focuses on developing and preparing a building for an onsite solar project which generates power at the point of usage.

A decision to develop onsite solar usually centers on three criteria:

- The level of solar irradiance, or sunshine
- Local policies and incentives that promote solar power
- The cost of standard utility power

Onsite solar projects that meet an owner's financial requirements are usually in locations with good amounts of sunshine, favorable solar policies, and a high cost of power. When those three factors combine, an onsite solar project can deliver financial returns that are accretive to the financial return of the hotel. Most owners are seeking minimum rates above 10% for onsite energy projects. This return can normally be achieved in areas of the globe with above average sunshine and electricity costs above US $0.20/kWhr.

There are three primary methods of financing solar projects, each of which are described below.

1. **Direct Ownership** – The hotel owner invests capital to develop an onsite solar project and realizes all of the energy savings. With this approach, the building owner gains the benefit of any local incentives and keeps the environmental benefits.
2. **Lease** – Leasing, or lease-to-own programs allow development of a solar project with little to no capital investment from the building owner. Leases can be structured for the life of the equipment or for a shorter period with an option to purchase at the end of the lease term.
3. **Power Purchase Agreements (PPA)** – In this approach, a third party develops and owns the PV solar system at the property. PPA's can be attractive because the owner does not provide any capital and they can simply enter into an agreement to purchase the power generated by the onsite system at a discount compared with the local utility rate. The downside is that the building owner does not own the PV solar system and

they must enter into a 15-20 year agreement to purchase power from the third party PV owner. In a PPA, the third party owner usually maintains ownership of any environmental attributes so the solar generated cannot be counted towards any corporate ESG goals.

Hotels in the design development phase can make provisions for the future installation of onsite solar and battery systems at minimal cost to the initial building construction. These provisions include considering structural loads of rooftop solar, or garage mounted solar in the form of solar carports, providing connection points for future solar, installing empty conduits, and locating mechanical equipment to allow for future rooftop solar construction. These considerations, among others, are reviewed in detail in this guide.

Onsite solar projects are the most efficient way to deliver solar energy because they are located at the point of use (thus eliminating transmission requirements), and present an opportunity for a high return on investment. Onsite solar projects redirect revenue that would have gone to the local utility back to the building owner, thus increasing net operating income. One real-world example is presented below.

Case Study

PROJECT SIZE

450 kilowatts

PROJECTED SAVINGS

$230,000 USD First Year

$8.4M USD over 25 Years

PROJECTED IRR

18%-20%

ENERGY PRODUCTION

712,000 kWH First Year

17,800,000 kWH over 25 Years

Metering

There are several metering structures that may apply based on utility regulation:

1. Net Metering: With solar generated onsite, energy is first consumed locally, and ownership is given credits towards electricity bills for any energy sent to the grid on a monthly or yearly basis. Valuation for credits varies widely from the full retail value of the electricity when delivered from the grid, to just a fraction of full value. It is common for local offset to be

limited to common area load in the building, whether that is carried by one or several building meters on site.

   a. These conditions are subject to change. For example, in the United States some utilities are moving to a “Net Billing” standard in which the net energy billing frequency is instantaneous rather than monthly or yearly, and rates for compensation are often lower.

2. Virtual Net Metering: Sometimes known as *Geographic Compensation,* this structure is similar to Net Metering, except credits given for exported power at a single meter can be applied to multiple meters on the property, which offers far more value in most cases than the value of credits for simply exporting to the grid. This increases returns because solar systems can be built to offset a larger portion of building electricity producing higher avoided costs of power.
   a. At present, this structure is extremely limited and is allowed in only two U.S. states. However, there is growing interest in this mechanism including new programs in India, Greece and Brazil to allow for bill crediting from offsite solar generation.
3. Virtual Power Plant (VPP): Under this structure, the onsite solar acts as a production facility, fulfilling nearby electrical demand by exporting all production to the grid with no onsite consumption. This may offer favorable returns if the purchase price for the energy produced is sufficiently high.
4. Community Solar: Also known as “Shared Solar” or “Solar Farms” Community Solar programs allow utility customers to “subscribe” to a portion of the generation of an offsite solar array. The power is delivered through existing utility company distribution and the customer is given a credit on their utility bill for the value of power provided by the Community Solar array. The customer enters into a separate agreement with the Community Solar provider to purchase the generated solar power.

3.0 BUILDING PREPARATION GUIDELINES

This section provides general guidance for the design of new buildings which may incorporate future solar development.

MI Design Standards

Chapter 1: Site and Building Exterior
Building Structure

Solar Readiness: Adjust preliminary roof dead loads to include the roof loading needs of the solar (PV) system in the process of construction coordination.

- Pitched Roofs: A mechanically attached racking system will typically require additional support accommodations of 0.144 kN/m² - 0.192kN/m² (3 to 4 pounds per square foot (psf)).
- Flat Roof: If using a ballasted fixed tilt racking system, the weight requirements increase as the height of the building increases. Up to building heights of 15.24m (50 feet) loading requirements are typically between 0.383 and 0.574 Kn/m² (8 to 12 psf).
- Elevated racking will require coordination with an engineering firm to provide a point load analysis on a case-by-case basis.

Chapter 1: Site and Building Exterior
Building Exterior and Features

Service & Mechanical Equipment: Avoid placing equipment on roof.

- Where required, screen the roof top equipment from guest view, including when standing at grade level
- Paint visible roof vents, stack and other roof devices to blend with roof color where applicable. Provide walk pads for service equipment.
- Anchor roof top equipment to withstand the maximum wind speeds.
- Arrange rooftop mechanical and plumbing equipment in a way that is favorable for a solar layout. This may include consolidating towards the center or the edges of the rooftop.
- Route condensate piping and other rooftop equipment piping to drop down through the roof at the unit in lieu of routing across the roof surface

Roof: Solar Readiness: Coordinate exterior building maintenance requirements (window washing equipment, fall protection, etc.) to minimizing the impact on the available roof space for solar equipment.

Chapter 15C: Electrical Systems
Distribution

Solar PV Readiness: Design for solar PV readiness which includes structural, architectural, and electrical provisions. Coordinate electrical service and distribution with the following.

- Allocate 70% of the roof space for solar PV.

3.1 Structural

a. Adjust preliminary roof deadloads to include the roof loading needs of the solar system in the process of construction coordination. (See Figure 1 in section 6 for an example).
   i. The installation method of the PV system will determine what additional structural loading provisions may be required during construction.
      1. For pitched roofs, a mechanically attached racking system will typically require additional support accommodations[1] of 3 to 4 pounds per square foot (psf) (14.6 - 19.5kg/m^2).
      2. If using a ballasted fixed tilt racking system on a flat roof, the weight requirements increase as the height of the building increases. Up to building heights of 50 feet (15.24m) loading requirements are typically between 8-12 psf (39.1 and 58.6 kg/m^2).
         a. Above 50 feet (15.24m) in building height, the system requires additional loading analysis and loading may exceed the amount of ballast weight feasible to install in a ballast tray, or may exceed the maximum load support able to be incorporated into the roof structure for solar installation. If so, the use of mechanical attachments to secure solar racking to the roof structure may be required to supplement ballast. (See Structural Loading section 4.1 below for more information)

3.2 Mechanical/Plumbing

a. Arrange rooftop Mechanical and Plumbing equipment in a way that is favorable for a solar layout. (See Figure 6 in section 6 for an example).
   i. Plumbing vents should be located outside potential array areas or as near to walkways as possible.
   ii. HAVAC Condensing units and other rooftop mechanical equipment should be consolidated and located in the middle of roof sections or at the perimeter wherever possible.
      1. Condenser unit cabling should be planned to drop down through the roof rather than crossing roof space, and other mechanical equipment should be consolidated to the greatest extent possible to allow for optimized solar array layouts.
      2. Understand mechanical equipment setback clearances to ensure solar does not impede installation and maintenance requirements.
         a. Note: Multiple iterations of the layout are often required as more detailed levels of mechanical, plumbing and electrical equipment locations are included in the development drawings.

3.3 Architectural

a. Coordinate with the respective design teams on minimizing the impact on the available space for solar from Exterior Building Maintenance (EBM) requirements (window washing equipment, etc.) and any required fall protection equipment, including tie-off anchors, will also impact the available space for solar. Coordinate with the respective design teams on minimizing these impacts.

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[1] Support accommodations may include such things as increasing the size of roof framing members, adding additional reinforcement to roof framing, including additional vertical supports or increasing decking thickness

i. Additional rooftop design considerations can be found in section 4.2.

3.4 Electrical

a. Include provisions for equipment space and transmission of PV power via rough in of conduits on building design drawings (See Figures 2-4 in section 6 for examples).
    i. Conduit: Identify vertical pathways within the building that remain consistent in relative function and location between rooftop and main electrical rooms (or relevant point of interconnection) for conduit installation.
        - Additional conduit provisions should be included to facilitate PV transmission from suitably productive non-rooftop spaces. (See section 4.3 for more details).
        1. Sizing and Quantity
            a. At a minimum it is recommended that (2) 4” conduits be stubbed up at roof level at all suitable rooftop regions for solar transmission, with their origins near the point of interconnection.
                i. Consider future use cases for the PV system in terms of expanding the system or increasing module output such that additional or larger conductors are required.
                ii. It may be necessary to bring in a solar contractor to determine sizing and quantity of conduits based on a proposed solar layout.
            b. Include a 1” conduit between the solar communication equipment at each distinct PV array and the telecommunications room distributing internet throughout the building.
        - Include conduit paths on drawing sets to accommodate solar transmission in future iterations. (See Section 4.3 Electrical Design for more information).
    ii. Electrical Equipment
        1. Reserve space in electrical rooms for PV equipment by indicating the approximate space required on the building drawings, with appropriately sized illustrations and the location of this equipment.
            a. Equipment could include solar panelboards, solar monitoring equipment and solar disconnects. (See section 4.3 for more details).
        2. Include the quantity and location of conduit stub-ups where they tie into solar equipment or the electrical room where interconnection will occur.
    iii. Interconnection
        1. To produce as many options for interconnection as possible ahead of solar construction, include provisions for both line side and load side connections on the electrical single line diagrams and panel schedules.
            a. To include Load Side interconnection provisions: Add the requirements to single line diagrams indicating the frame rating needed at the bottom of the busbar (or opposite the service entrance in cases where that is required by code) to accommodate the PV power. (See section 4.3 for further information)

b. To include Line Side, or Utility Side interconnection provisions: Switchgear can be specified to have lug provisions installed during manufacturing which allows for connection between the utility meter and the main circuit breaker (MCB) for multiple parallel conductors carrying the PV system output.
    i. Request a suitable number of parallel barrel lug additions to the bussing to accommodate the number of parallel circuits carrying the full PV system output to the switchgear selected. (See section 4.3 for further information)

iv. Auxiliary Power
    1. Provide an access point (junction box) at roof level near the conduit stub ups to allow for power to solar communication equipment. Typically, 110-120V in the U.S.

4.0 GENERAL SOLAR AND STORAGE INFORMATION

This section expands on the Building Preparation Guidelines. Whereas the Building Preparation Guidelines provide information on the preparation of buildings for solar and storage development, this section offers details and information for the actual design and implementation of solar PV and energy storage systems.

4.1 Structural Loading

This section includes guidelines for the structural assessment and load-bearing capacity of building rooftops to ensure they can support solar PV installation.

a. Structural Assessment:
   i. Assess the structural load capacity of the rooftop to determine its ability to support the additional weight of the solar PV system. This should be done by evaluating the architectural and structural drawing sets generated as construction details are being evaluated.
   ii. Battery Energy Storage Solutions (BESS) will require additional considerations whether installed on the wall with mounting equipment, on the floor or roof of a structure, or on grade. This could include distributing batteries across the roof or upper stories of the building.
   iii. Identify any potential structural modifications or reinforcements that may be required to accommodate the solar PV system.
      1. In some scenarios it will be necessary to lay out where PV racking anchors or attachment points will land on the roof ahead of time, to ensure that structural supports exist within the maximum span of the racking equipment as laid out by the manufacturer and structural engineer.

b. Roof Load Capacity:
   i. Determine the minimum roof loading capacity based on building height and construction, local regulations, and environmental conditions.
   ii. Assess the dead load, live load, and other potential loads such as snow accumulation and wind forces.
   iii. Consider the dynamic load factors, such as wind uplift and seismic loads, to ensure the system can withstand various weather conditions.
      - Expanded Information
         a. Dead Loads: This refers to the weight of the BESS and PV system components, including the modules, racking, and wiring. Dead loads typically range from 3 to 12 pounds per square foot (psf) (14.6 to 58.6 kg/m^2), depending on the specific components used and means of attachment, and contribute to roof loading for the life of the system.
         b. Live Loads: This refers to temporary loads on the roof due to maintenance personnel, snow, and other factors. Loads generally range from 20 to 30 psf (97.6 to 146.5 kg/m^2). However, in snow-prone areas, the live load requirement may be significantly higher to account for snow accumulation. Live loads contribute to roof loading only when foot-traffic is present, or snow has accumulated.
         c. Wind Loads: The wind load requirements are determined based on the location of the installation and local wind speed considerations. Wind loads can range from 10 to 30 psf (48.8 to

146.5 kg/m^2) or higher, depending on the wind zone and the specific site conditions.

d. Seismic Loads: In seismic-prone areas, additional structural considerations are necessary to account for earthquake forces. The seismic design loads are determined based on the seismic zone and building characteristics.

1. The installation method of the PV system will affect what load considerations will be required during construction.
   a. Pitched roofs will require PV to be flush mounted at the pitch of the roof as shown below, and to be mechanically fastened to underlying roof framing.


[2]

   b. Flat roof[3] ballasted systems rely on weights – fashioned from concrete or another suitably dense material – to withstand wind loads after installation. The system is typically installed at a fixed tilt, with fixed spacing and module orientation as shown below.

      i. Roofs exceeding 50 feet (15.24m) and especially as the building approaches or exceeds 100’ (30.48m), the loading values rise quickly and will potentially

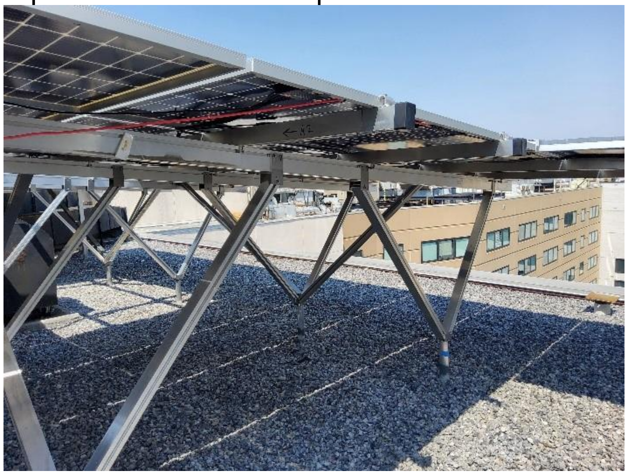
[2] Photos procured from the internal database of REV Energy Ventures
[3] According to the IBC a roof is considered "flat" when it has a slope of 2:12 (9.8 degrees) or less.

require some combination of weights and mechanical attachment to install the equipment on a flat space.

- Using mechanical attachment in addition to ballasts is often referred to as a hybrid system and arises from the lack of space for additional weights to meet the requirements to resist high wind loads when more than 12 psf is required.

c. *Stanchion* designs can be used to build over rooftop equipment or overcome wind loads because of the mechanical attachments. PSF values for point load attachments vary based on the racking table size, building height, wind speed, snow load, parapet height etc; and require a project specific analysis to be performed for structural preparedness coordination.

- The option to use raised stanchions should be pursued when other rooftop equipment cannot be consolidated to provide adequate space for PV. An example is below.



ii. Include any additional structural provisions required by the PV system in the structural drawing sets during the process of construction coordination.

- International Context - These considerations can vary by location. Reliance on local codes and professionals will be required to ensure that construction is completed in a manner that will pass inspection and ensure lasting safety and reliability.
  a. US & Canada (USCA) typically rely on the International Building Code (IBC) for guidelines on rooftop loading for PV. Roof structures that provide support for photovoltaic panel systems are referenced in Sections 1607.13.5.1 through 1607.13.5.4.
  b. Caribbean and Latin America (CALA) have modeled their building codes from internationally recognized code standards including the IBC and Uniform Building Code (UBC). Countries have further developed individual standards to meet regional variances in wind speed and seismic events.

c. Middle East and Africa (MEA) base guidelines on International Electrotechnical Commission (IEC) for the basis of loading requirements in some locals, as they do in some parts of APEC, but will invariably require investigation of local governing bodies to ensure full compliance. For example, the Saudi Building Code (SBC) in Saudi Arabia sets many of these standards for that nation, while the South African Bureau of Standards (SABS) and South African National Standards (SANS) may need to be consulted if new construction is happening in South Africa.
d. In the Asia Pacific excluding China (APEC) region, Australia will generally use the National Construction Code (NCC), while India has the National Building Code (NBC). Earthquake-prone Japan follows their *Building Standard Law* which requires strict measures for seismic compliance and volume to land ratios. Indonesia has attempted to unify all regions with a system of building codes, the most recent edition being SNI 1726:2019, which is principally modeled from ASCE 7-16, though many principalities follow local regulations for building construction.
e. In Greater China, the local branch of the State Administration of Market Regulation (SAMR), specifically the division responsible for building standards generally sets the requirements for developments in that country. Other entities such as the National Energy Administration and China Photovoltaic Industry Association (CPIA) may have influence over the construction requirements for PV systems in China.
f. In Europe, Eurocode 1-3 offers information on the various loads that need to be considered when designing the supporting structures for photovoltaic systems in Europe. It includes guidance on dead loads, live loads, wind loads, snow loads, and other factors that may impact the structural design.

c. Documentation and Certification:
   i. As PV planning continues into the design and engineering phases of construction, the following requirements should also be considered:
      1. Document the structural assessment, load calculations, and any modifications made to the rooftop structure.
      2. Obtain necessary certifications, inspections, or approvals from relevant authorities, as required by local regulations, to ensure compliance with safety and building standards.

4.2 Rooftop Design Considerations

This section includes rooftop area guidelines for solar PV installations on commercial use structures, considering factors such as available space, shading, orientation, and obstructions.

a. Available Space:
   i. Assess the total available rooftop area for solar PV installation. This includes considering parameters such as the dimensions, shape, and configuration of the rooftop.
      1. This will involve using preliminary building drawing sets to reproduce a roof outline in a computer-aided drafting or similar program to establish the building parameters outlined above.
      2. Exclude areas that are occupied by rooftop equipment, ventilation systems, walkways or other obstructions that may hinder the

installation of solar panels and are shown on the existing drawings of the roof level.

a. Consolidate and strategically locate rooftop equipment.
    - These adjustments can significantly benefit the effectiveness of the solar PV system from both a cost and energy production standpoint.
b. If unable to improve equipment locations such as may be required to meet the desired PV system size, the use of a stanchion based solar racking system as discussed in section 4.1 could be utilized to elevate it above obstructions such as plumbing vents and mechanical equipment.
    - *Note: Multiple iterations of the layout are often required as more detailed levels of mechanical, plumbing and electrical equipment locations are included in the drawings.*

b. Orientation and Slope
    i. Evaluate the orientation and slope to determine the optimal layout and arrangement of the solar PV modules.
        1. In the northern hemisphere, modules should be directed within 90 degrees of true south whenever possible. In the southern hemisphere it is the opposite, and solar panels should be directed north to the greatest extent possible.
            a. The angle of the module tilt will be determined by the tradeoff between space optimization and yield[4]. Tilt the array 5 degrees near the equator and 10 degrees at higher latitudes (increasing as latitude increases) for the best yields when considering a ballast system on flat roofs.
                i. Standard pitches for ballast racking equipment may limit the ability to optimize tilt.
        2. Flush mount PV systems on pitched roofs will match the pitch of the roof.
        3. Maximize the PV arrays on optimal or near-optimal azimuths before expanding to other roof sections.
        4. Regarding flat roof scenarios, match the orientation of any building lines at optimal or near optimal azimuths to allow for maximum roof space utilization and produce the most effective balance of yield and system size.
            a. Tilted systems on flat or low slope[1] roofs can have azimuth optimized (ie directing the system to the south in the northern hemisphere) when using a ballasted system which does not include mechanical attachments, because there is no correlation between the ballast weights and underlying roof framing. This will result in a more efficient system but may limit the system size more than matching building line orientation.
    ii. Consider potential shading impacts from nearby structures, trees, or tall obstructions that may impact the performance of the solar PV system.

[4] Kilowatt-hour per kilowatt system size-this serves as a metric for system efficiency describing energy output given the total system size.

1. While tree shading can be a concern on multi-story buildings, the shade produced by adjacent structures, parapets and equipment on the roof are the principle focus of rooftop PV shading considerations in the hospitality industry.
    a. Include pedestals installed under HVAC systems in their total height.
    b. Model all stairways and elevator shafts that reach roof level at their appropriate height as indicated on the building drawing set.
    c. Model any parapets, particularly those 3’ (1 meter) or higher to account for shade impacts at building edges.
2. Use shading analysis tools or consult with the solar contractor to assess the impact of shading throughout the day and different seasons. Minimize shading to maximize solar energy production.

iii. Determine clearances and access paths for equipment maintenance, ensuring safe and convenient access to the rooftop area.

1. Access paths are required for the installation and maintenance of rooftop equipment. It is common for these to be 4’ (1219 mm) wide and include access from applicable rooftop entry points (stairs, ladders) to the equipment, as well as to the exterior edges of the building.
2. Regional regulation may force arrays to be split up by introducing walkways after exceeding a certain solar PV array size, and to provide walkways to rooftop equipment.
    a. NFPA 70 which guides standards in North America for PV layouts requires specific criteria that allow for movement on the roof.[5]
        i. Straight line access to ventilation hatches and/or roof standpipes must be provided. Wherever ventilation hatches and standpipes are located, a pathway of at least 48” (1219 mm) must be provided.
        ii. A 48” (1219 mm) pathway around all roof access hatches must also be provided. In addition, at least one 48” pathway must be provided from the roof access hatch to the roof edge or parapet.
        iii. A pathway every 150 ft (46 m) is required. The 150 ft (46 m) distance cannot be exceeded in either the length or the width of the building. This essentially limits the PV array to a maximum size of 150 ft by 150 ft (46 m by 46 m).
        iv. Any building with a length or width greater than 250 ft (76.2 m), requires a minimum 6 ft (1829 mm) pathway around the perimeter. If both length and width are 250 ft (76.2 m) or less, then the pathway is only required to be 4 ft (1219 mm)[2].
    b. Section 1205 of the International Fire Code (IFC), adopted in the majority of US states and territories, lays out access pathways and roof edge setbacks for pitched roofs.

[5] https://www.nfpa.org\

c. Regional variances may increase or decrease the requirements of access pathways on the roof, but beginning the process of solar layout with some consideration of walkway and setback requirements is essential.

c. Solar Panel Size and Configuration:
   i. Select the appropriate solar panel size and configuration based on the available rooftop area and desired energy output. This includes considering the dimensions and wattage of the solar panels.
      1. The considerations in this guide are examined well in advance of building construction, so selection of modules must reflect an effort to predict module characteristics available at the time of solar construction. In general terms this means selecting from among the top producing products on the market, with the knowledge that within the time frame considered here (1-3 years of design before construction) these might only be in the top half of products on offer with respect to efficiency.
         a. Choose high output modules at the beginning so production estimates hold up against the progression of technology
   ii. Determine the spacing between panels to account for factors such as maintenance access, fire safety requirements, and shading impacts.
   iii. It is recommended to design with equipment from established and trusted manufacturers, with excellent workmanship records and product warranties. One outlet for such a list is The Solar Analytica Assessment Criteria analyses with available data offering scores within the following primary categories.[6]
      1. Design
      2. Durability
      3. Efficiency
      4. Performance
      5. Guarantee

d. Energy Production and System Sizing:
   i. Conduct a solar energy production analysis to estimate the expected energy output based on the available rooftop area, shading, and orientation.
   ii. Size the solar PV system to meet the building's energy demand, considering factors such as service size, energy consumption patterns, and sustainability goals.
      1. These figures are often estimated via energy use analyses based on preliminary construction materials and methods, as well as area - or can be derived by proxy comparison to other similar buildings in similar locales when such information can be obtained.
      2. The utility agreement will also influence how a system is sized.
         a. Net Metering (NEM) results in ownership offsetting electricity costs by exporting excess solar energy to the grid. If the utility policy is such that the credits offered to exporting facilities are high, and if local governance allows, then sizing the system to produce more energy than can be consumed onsite may benefit ownership from a revenue standpoint. More commonly, the value of credits received from exporting

[6] https://solaranalytica.com/tier-1-solar-panels/

excess solar energy to the grid in the commercial context is not high, and so limiting the system size to what is required to offset anticipated building demand is recommended.

- The value of credit for exported energy is considered high if it approaches or matches the retail rate at which electricity is purchased from the provider.

b. Other utility agreements, including participation in an established microgrid or feed-in tariff scenario could also incentivize designing the PV and/or BESS systems to exceed onsite demand.

3. It is typical to attempt to offset 90% of the building's energy demand, to allow for energy efficiency upgrades and changes to energy use profiles to bring the offset close to 100% in the future.
   a. In most cases on hospitality projects, all electrical demand metered onsite is the responsibility of the hotel.
      - The exception is any retail space (shops, restaurants) onsite that will be individually metered to the operator. It may be possible to establish a lease agreement with these operators such that provisions for solar should be included which allow for some amount of PV energy to be distributed to retail load centers for a monthly fee, but details for such an agreement are not standard and are not discussed at length within this guide.
4. Sizing of a BESS will be determined by factors including desired duration, or time that the batteries can supply the building with power; tariff model (i.e., what the storage energy will be used for if not purely emergency backup) and sustainability targets.
   a. Tariff models to consider in order to maximize the benefit of BESS onsite include the following:
      - Time of Use (TOU): This describes an environment in which the price of electricity is higher during peak demand hours to incentivize lower usage, which supports grid maintenance and balancing. If the batteries can be charged with excess PV power during the day when usage is lower, then they can be discharged to meet demand onsite in the evening in lieu of paying higher prices to the utility at those times, creating significant savings.
      - Scheduled Discharge: This describes an agreement with the utility to discharge all or most of the stored energy in the batteries during high demand to assist in grid balancing. The utility customer then receives a monthly or annual rebate for the energy sent to the grid.
      - Micro-grid support: This describes the use of batteries to support small sections of the grid – or completely isolated "micro-grids" – by allowing any amount of energy stored in batteries onsite to balance demand spikes in the proximity. A separate meter is required to measure the amount of energy exported from the batteries in this

support capacity and ownership may be paid per unit of this energy.

- Demand Shaving: In environments where the utility charges differently depending on the *Peak Demand* (in kW) pulled from the utility in a given billing period, the BESS can be scheduled to discharge before that figure is reached, supplementing utility supply and therefore avoiding additional costs by reducing peak power drawn through the utility meter.

e. Local Regulations and Building Codes:
   i. Consult local regulations and building codes to ensure compliance with any specific requirements related to rooftop area, setback requirements, or other relevant factors.
   ii. Confirm any limitations or restrictions on solar PV installations on building rooftops in the specific jurisdiction.
   iii. Review available tariff/utility rate landscapes to determine what combination of onsite consumption and export will provide the greatest return for the property.

4.3 Electrical Design

Listed here are considerations for integrating solar PV systems and BESS systems with the building's electrical infrastructure. Interconnection requirements, transmission of power, metering, and grid compliance.

a. Building Preparation
   i. It is imperative that provisions for equipment space and transmission of PV power via rough-in conduits is coordinated on building drawings for the development to ensure that these notes and any notes required for additional auxiliary equipment is put in place during the construction phase.
      - While in most cases the PV system will be installed on the rooftop, electrical equipment for the building and BESS components will typically be installed on lower floors due to the nature and size of this equipment. Interconnection will typically occur at the main distribution switchgear or electrically fed switchboards, and provisions for routing conduit between the rooftop and these locations is paramount.
      1. Conduit: Identify vertical pathways within the building that remain consistent in relative function and location between PV location and main electrical rooms. These locations should be shown to include solar conduit and equipment in future iterations.
         - *Note: Conduit will be routed to electrical rooms containing the equipment for interconnection but will not stub up directly at that equipment since it will be necessary to pass through combiners, disconnects and possibly additional metering equipment before interconnection.*
         a. These opportunities are typically identified as stacked electrical, mechanical, trash, or communication rooms, through which conduit can be run vertically through the building during construction.
         b. Furring on the exterior side of stairway walls to provide space for electrical or ventilation ducting may also be an option.
         c. Conduit should be shown against a wall to limit the support structures required for installation.

d. Consider whether any firewalls exist which create boundaries that cannot be crossed or penetrated.
e. Consider using existing electrical pathways which are shown on the building plans and can act as a route for future solar conduit as well.
f. When practical, conduit should be routed underground between areas of the building during construction. This is often vital to bringing power to a main electrical room for interconnection after routing down from the roof. These details should be included in iterative versions of the building design drawings to ensure they are implemented during construction.
    i. Sizing
        1. Individual conduit is typically limited to 4” under the conditions described here, after which additional conduits should be shown to accommodate additional conductors.
            a. At a minimum it is recommended to call for (2) 4” conduits and (1) 1” conduit to be stubbed up at the roof with their origins at the solar equipment (typically in or near the main electrical room) and the main telecommunications roof (for access to the MDF) respectively.
                - It is highly recommended that a hardline connection is made between telecom equipment in the building and the solar communication equipment. This will require including provisions for solar at the MPOE or MDF.
            b. If any of the following scenarios apply, include a minimum of (1) 1” and (1) 4” conduits between potential solar locations and applicable switchgear:
                i. If there are multiple buildings within a planned development, each should be prepared with conduits to allow for future solar options.
                ii. If there are ancillary buildings with electrical equipment fed from a service within the main building, solar conduits should be installed from the main building electrical room to the electrical room in these buildings as well.
                iii. If an onsite parking structure has been identified as suitable

for solar in the form of one or several carports, solar conduits should be routed to the top floor of the structure.

iv. If ground level parking lots are suitable for solar, solar conduits should be routed out to the proposed solar locations, generally by means of handholes in parking islands near the carport locations.

v. If there is a conference center roof separated from other roof sections by parapets, conduits should be stubbed up at the roof.

- It is by far the simplest option to account for these potential future needs and install larger or multiple conduits during construction.

2. Conductors: For cost efficiency, it is typical to use aluminum conductors for power transmission from the PV system to the point of interconnection, though local code may call for copper.
    a. While Adjustment Factors may differ marginally between specific code sets as shown in Figure 1.0 at end of this chapter, the general principle of using large conductors to consolidate inverter output circuits and oversizing conduit to allow for future solar potential are central principles to including solar PV requirements as part of building construction.
3. PV Equipment in the electrical rooms.
    a. To reduce the number of conductors, minimize voltage drop and other power characteristics changes, and simplify interconnection, inverters associated with the PV arrays are typically combined in *Solar Panelboards* – electrical panels serving to consolidate inverter output circuits with overcurrent protection. When possible, these can be placed on the roof or in attic space to produce fewer sets of conductors for transmission from the upper levels of the building to the point of interconnection.
    b. Other times these solar panelboards will be in the same room as the equipment being used for interconnection.
        i. Indicate on the building drawings the location and relative size of any panelboards projected to be in the electrical room, along with any conduits being routed to them.
        ii. As drawing sets are finalized with building electrical equipment locations, additional revisions may be required to ensure that locations marked out for solar

remain available and sensible with respect to interconnection and conduit routing.

c. Include locations for inverter and solar panelboard (where applicable) installation on vertical walls, stairwells or elevator structures which stand at roof level.
    i. Whenever possible, to limit the amount of solar conduit running across the roof surface, equipment should be arranged as to be near the point where conduit will descend through the structure to the point of interconnection.
    ii. Where gaps in structure require separated arrays to be combined after reaching ground level using underground trenches (i.e., combining solar from a central garage structure to rooftop solar), combination at the solar panelboard may take place in the main electrical room.
d. Disconnecting means
    i. The jurisdiction may require the disconnect to be either inside or outside and is typically the last piece of equipment that the PV power passes through before interconnection.
    ii. Conduit should be shown routing from solar panelboard equipment, where circuits are combined, to the disconnect means, then to the switchgear or other point of interconnection. This may require routing to the exterior if that is a requirement of the regulating body.
        - Note: If all equipment can be installed in the electrical room, rough-in conduits between solar equipment and switchgear are not required as these can be installed by the solar contractor if the solar project is realized.

4. BESS Equipment
    a. In addition to consideration of conductor and conduit sizing provisions, energy storage systems will have unique requirements as it relates to fire safety, building construction and interconnection. Outdoor installations or installing BESS in a dedicated structure is highly encouraged to alleviate some of the more stringent requirements associated with indoor installations, and it should be determined if either is an option to streamline the permitting process.
        i. Interior locations may require additional mechanical and plumbing coordination to meet any existing requirements for fire suppression and ventilation. As a BESS product is selected, the drawing sets should be updated to include provisions for these building additions after confirming relevant regulations from local code enforcement agencies.
            1. These regulations may include the following: automatic smoke/fire detection and sprinkler

units; fire resistant building wall coatings or the use of fire-resistant construction materials; minimum ventilation requirements requiring additional air handling units; dedicated battery rooms; limits to the size of BESS within a building or room.

ii. If space is provided on the exterior of the building for BESS, provisions will commonly include a concrete mounting pad for this equipment.
iii. If a dedicated structure is included in the plans for the project, routing of conduit from the battery structure to the main building electrical switchgear room will be most easily accomplished using underground conduit, installed during building construction.
iv. Additional consideration for *Means of Egress* is common among electrical code sets and describes a suitable means of exiting the BESS space during an emergency.

b. Centralized and Distributed BESS Configurations
   i. The location of interconnection, sizing requirements and local regulations may all contribute to deciding between a single location for the BESS unit(s) or if the total battery capacity may be divided between several or many groupings. Small groupings may reduce overall weight loading considerations and reduce additional structural contingencies to accommodate the BESS, allowing batteries to be placed on the roof if space is unavailable elsewhere onsite. However, breaking up the total capacity into segregated units will require consideration of multiple conduit runs and/or consolidation of individual groupings before interconnection.
   ii. Because of the size and weight of commercial scale BESS options today, a centralized configuration almost always requires installation on grade. The alternative is coordination of reinforced or additional column supports such that the batteries may be installed on upper levels which is typically cost prohibitive. However, centralized units allow for a single set of conductors and more limited conduit coordination from battery spaces to interconnection, generally at the same location, but separate from PV interconnection.
   iii. Conduit provisions for BESS equipment will be required in addition to the PV system. The size of conduit and conductors will be contingent on the sizing of the equipment, but the principle of preparing the building for projected and optional future installation of batteries is important and consistent with preparing the building for solar.

c. Means of Disconnect:
   i. Invariably, the utility company associated with the project will require a means of disconnecting the PV system and any associated battery equipment separate from the overcurrent protection used for interconnection. Location requirements will vary by locale, but disconnecting means will be the final piece of equipment before interconnection.
   ii. Conduit routing to disconnects on the exterior of the building (when required) should be indicated on the building drawings as being placed underground

during construction. This avoids many of the complications involved with traversing interior and exterior walls after construction.

iii. Provisions for BESS disconnecting means will also be required during construction coordination when they are included in the plans and may be required within the battery room(s) (when applicable) or may be required on the exterior of the building regardless of BESS location. Similar conduit routing considerations to that of PV coordination should be included in drawing set provisions. This may include underground routing, vertical routing between building levels and ensuring sufficient space and access within electrical rooms for all relevant equipment.

5. Interconnection
    a. Connecting the PV system and BESS to the building's electrical equipment requires selecting equipment suitable for producing electricity in-line with the parameters of the grid (including voltage, frequency and phase); as well as preparing the electrical equipment in ways that will lead to a streamlined interconnection during installation.
        i. In most parts of the world – excluding most of North America, Japan and South Korea – the grid operates at 50 hz and will typically operate under 3-phase conditions for commercial applications. Operating voltage will vary between 208 – 480V depending on the region.
        ii. To prepare electrical equipment for load side connections, typically accomplished by installing a circuit breaker for interconnection, provisions should be included in the design drawings indicating the frame rating needed at the bottom of the busbar (or opposite the service entrance in cases where that is required by code) to accommodate the PV power.
            1. The limit for this type of interconnection in the NEC (705.12) is determined by multiplying the bus rating of the panelboard by a factor of 1.2 and subtracting the rating the main OCPD. Provisions from the IEC and IEEE (Institute of Electrical and Electronics Engineers) offering a basis for PV connections for the global community are listed in section 'iv' below.
                a. It is advantageous to increase the rating of the busbar (while maintaining MCB size) of switchgear or switchboard to allow for additional solar to be connected on the load side.
                    - It is not recommended to request panels below 1600A be upsized since this would move them into a category of "switchgear" instead of "switchboards", which require significantly more space, are more expensive and can be

difficult to source. Increasing busbar rating within the category of "switchgear" may be acceptable.

b. A bus or conductor tap may also be an option for a Load side interconnection depending on panel space constraints and local regulations.

iii. To prepare electrical equipment for a Line side or utility side connection, switchgear can be specified to have lug provisions installed during manufacturing which allows for connection between the utility meter and the main overcurrent protection device (OCPD), or main circuit breaker (MCB) for multiple parallel conductors carrying the PV system output after combining**.**

1. Smaller panelboards will need to be supplemented with a junction box on the line side of the panel that will serve as a tap point for solar in which a connection can be made on the service conductors.

iv. The limit for this type of interconnection in the NEC (705.11, 230.82) is determined by the ampacity rating of the service conductors and associated terminals. The sum of all the ratings of all overcurrent devices connected to power production sources shall not exceed the rating of the service.

- Regional governance will dictate which interconnections are viable from a range of standpoints including system monitoring, tariff type and historic norms. Electrical code enforcement bodies in the region will have input on the capacity of the electrical equipment to accommodate each type of interconnection.
  a. IEC 60364-7-712 describes rules for Solar photovoltaic (PV) power supply systems.
  b. IEC 61727 describes Photovoltaic (PV) systems - Characteristics of the utility interface.
  c. IEEE 1547 addresses the interconnection and interoperability of distributed energy resources (DERs), including solar PV systems, with the electric power system.

b. Interconnecting BESS

i. In a limited set of cases, where the inverter equipment is appropriately configured to accommodate substantial amounts of battery energy, it may make sense to attach the BESS to the inverter for a single interconnection. This *DC-coupled* configuration is more commonly seen in residential contexts but may be relevant to certain new build projects depending on storage needs.

ii. In most cases, provisions for interconnection of the BESS will have to be detailed separate from the PV system. After selecting appropriate *Power Control System (PCS)* equipment (alternatively described as *Battery Management System* or *Energy Management System)* – if not included by the manufacturer – interconnection considerations will be based on the amp load produced during operation including any current multipliers required by relevant code sections. NFPA 70 requires a multiplying factor of 1.25 to nameplate operating amps.

6. Communication and Monitoring
    a. To ensure the system is functioning and to respond to malfunctioning, monitoring and communication equipment will be installed, and cabling will be provided for it.
        i. (1) 1" conduit will be required between rooftop equipment and the main telecommunications room. This is for the low voltage cabling required for solar communication equipment.
        ii. The drawings may refer to an MDF (Main Distribution Frame), or MPOE (Minimum Point of Entry). (see Glossary for definitions)
            1. It is common for this conduit to be run alongside other PV conduit for all or part of the route from roof to interconnection, however if the main telecommunication room is not in the main electrical room, conduit paths will deviate at some point.
        iii. The equipment monitoring the solar system will also need access to single phase power for operation typically 110-120V, or 220-230V depending on location. Include provisions for access to this power in the building electrical design. The location of this circuit needs to be adjacent to the 1" conduit(s) at roof level that are roughed in for transmission of solar comms cabling.

Figure 1 Adjustment Factor differences between the NEC and IEC as it relates to raceway fill calculations

NEC Adjustment Factors For More Than Three Current-Carrying Conductors In A Raceway Or Cable	
Number of Current-Carrying Conductors	**Percent of Values in Tables 310.15.2011 Edition**
4-6	80
7-9	70
10-20	50
21-30	45
31-40	40
41 +	35

IEC Adjustment Factors For Groups Of More Than One Circuit Or Multicore Cable		
Number of Circuits	**Number of Loaded Single-Core Conductors In a Group**	**Adjustment Factors**
1	3	1.00
2	6	0.80
3	9	0.70
4	12	0.65
5	15	0.60
6	18	0.55
7	21	0.55
8,9,10	24-30	0.50
12,14	36-42	0.45
16,19,20	48-60	0.40

5.0 ENERGY STORAGE SOLUTIONS

There are several battery options on the market today, with varying availability, cost and function. The most popular chemistry composition for most contexts is Lithium ion due to high energy density, extensive testing, and scalability. Other energy storage technologies, such as flow batteries, sodium-ion batteries, and solid-state batteries, are also being researched, developed and deployed for solar energy storage. While these technologies offer certain advantages, such as lower environmental impact and cost-effectiveness, they are in earlier stages of commercialization and face certain technical and economic challenges. The list below describes each technology and offers some insight into advantages and disadvantages.

a. Li-ion: In addition to high energy density and availability, Lithium-ion batteries also boast a long cycle life, leading to many potential recharges. They offer rapid response times when deploying energy during emergencies and can be combined to produce large power outputs.
b. Lead-Acid Batteries: Lead-acid batteries have been in use for decades and are well established for commercial applications. They are reliable and cost-effective, but present a lower power density, meaning that size and weight considerations come into play when deploying lead acid. They also have a shorter cycle life when compared to Li-ion batteries. However, they remain a popular choice for certain commercial energy storage applications.
c. Flow Batteries: Flow batteries store energy in liquid electrolytes contained in separated reservoirs. They offer the advantage of decoupling power and energy capacity by storing the electrolyte used to generate energy in a separate container from the reaction chamber. This allows for a more scalable battery – increasing reservoir size increases the capacity of the battery – which is suitable for long-duration energy storage applications. Vanadium redox flow batteries (VRFBs) are the most common type of flow battery commercially available. Other types include zinc-bromine flow batteries and iron-chromium flow batteries. Size and weight considerations impact deployment as energy capacity increases.
d. Sodium-Sulfur (NaS) Batteries: Sodium-sulfur batteries use a high-temperature operating system and liquid electrodes of sulfur and sodium. The energy density is similar to that of lithium-ion batteries, but materials are less expensive and non-toxic. NaS batteries are known for their high energy density, long cycle life, and ability to handle high-power applications. They have been deployed in various grid-scale energy storage projects.
e. Lithium Iron Phosphate (LiFePO4) Batteries: LiFePO4 batteries are also a lithium-ion technology, but they utilize iron phosphate as the cathode material. They have excellent thermal stability, long cycle life, and an even better safety record when compared to other Li-ion chemistries. LiFePO4 batteries are commonly used in commercial applications where safety and long lifespan are primary considerations.

6.0 CONSTRUCTION DESIGN SET PROVISIONS

Below is a series of sample diagrams illustrating typical language and requirements for including solar provisions in the building development drawing set during the process of construction coordination.

Figure 2 Structural Title Page - Provision requests for the structural loading requirements of a standard flat roof ballasted system. 10-12 psf (48.8 – 58.6kg/m^2) additions typically correspond to a building around 50' tall in an average wind speed zone. Lower loading requirements are required for the lower roofs in this case which is at a height of 30 feet (9.1 meters).

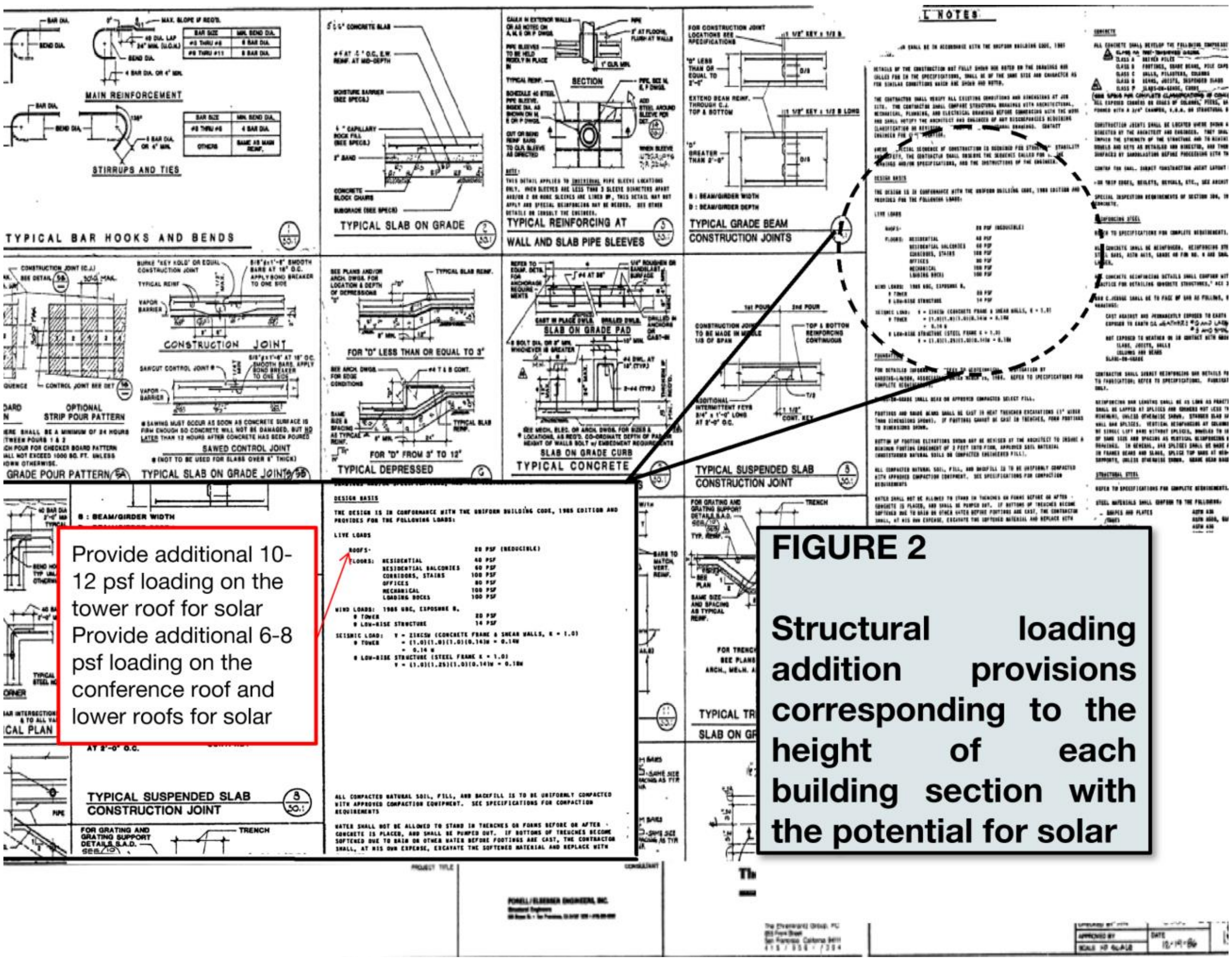


Figure 3A Transmission Conduit Provisions at roof level - Provision requests for 4” and 1” rough-in conduits to be stubbed up at roof level, including pull string labeling and specifying from where the conduits should originate including the name of the room in which the solar panelboard will be installed. Also includes requests for Low voltage power to support communications equipment.

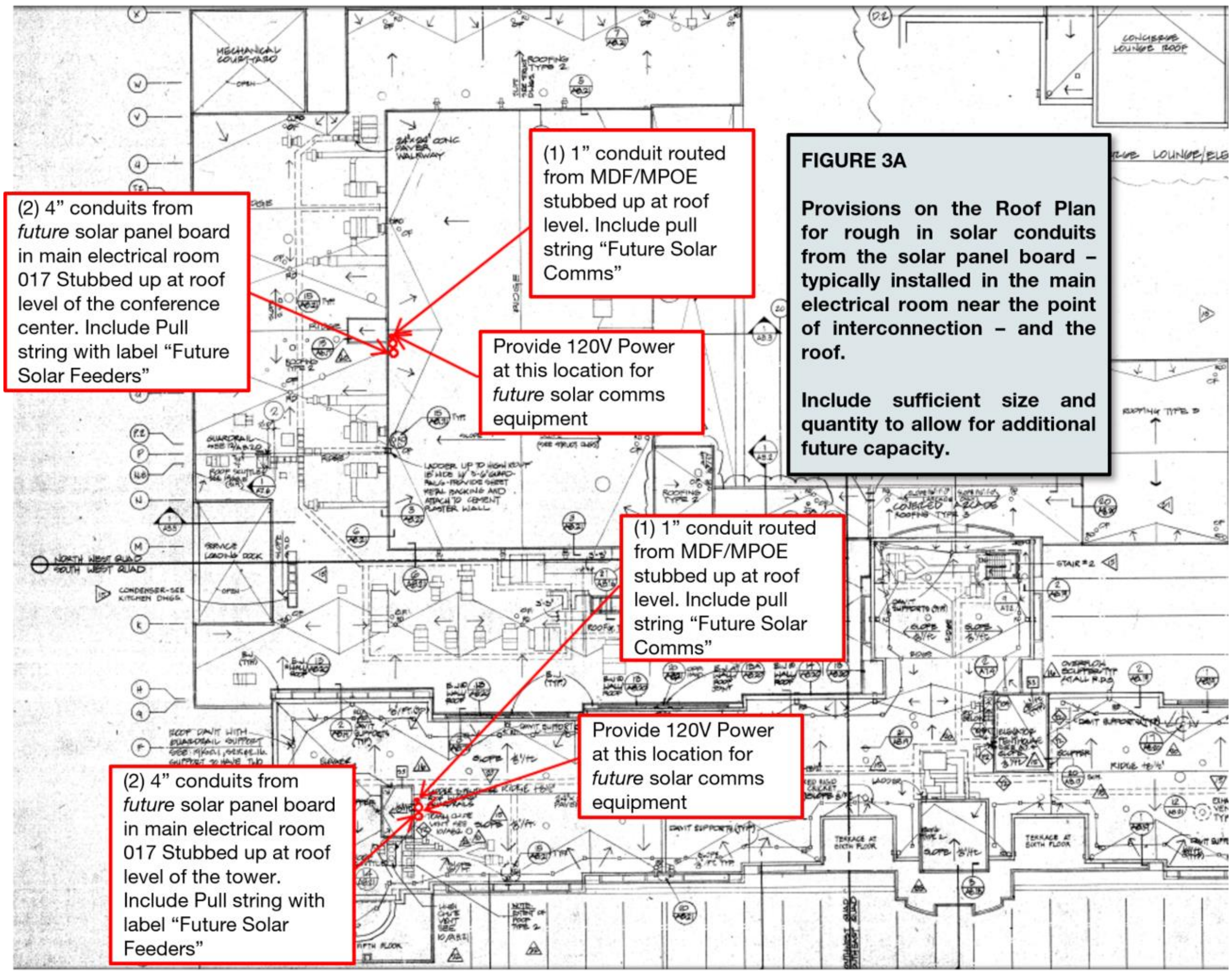


Figure 3B A visual reference of the example property to accompany Figure 3a, illustrating building topography and supporting the need for separate callouts for conduit provisions by roof section.

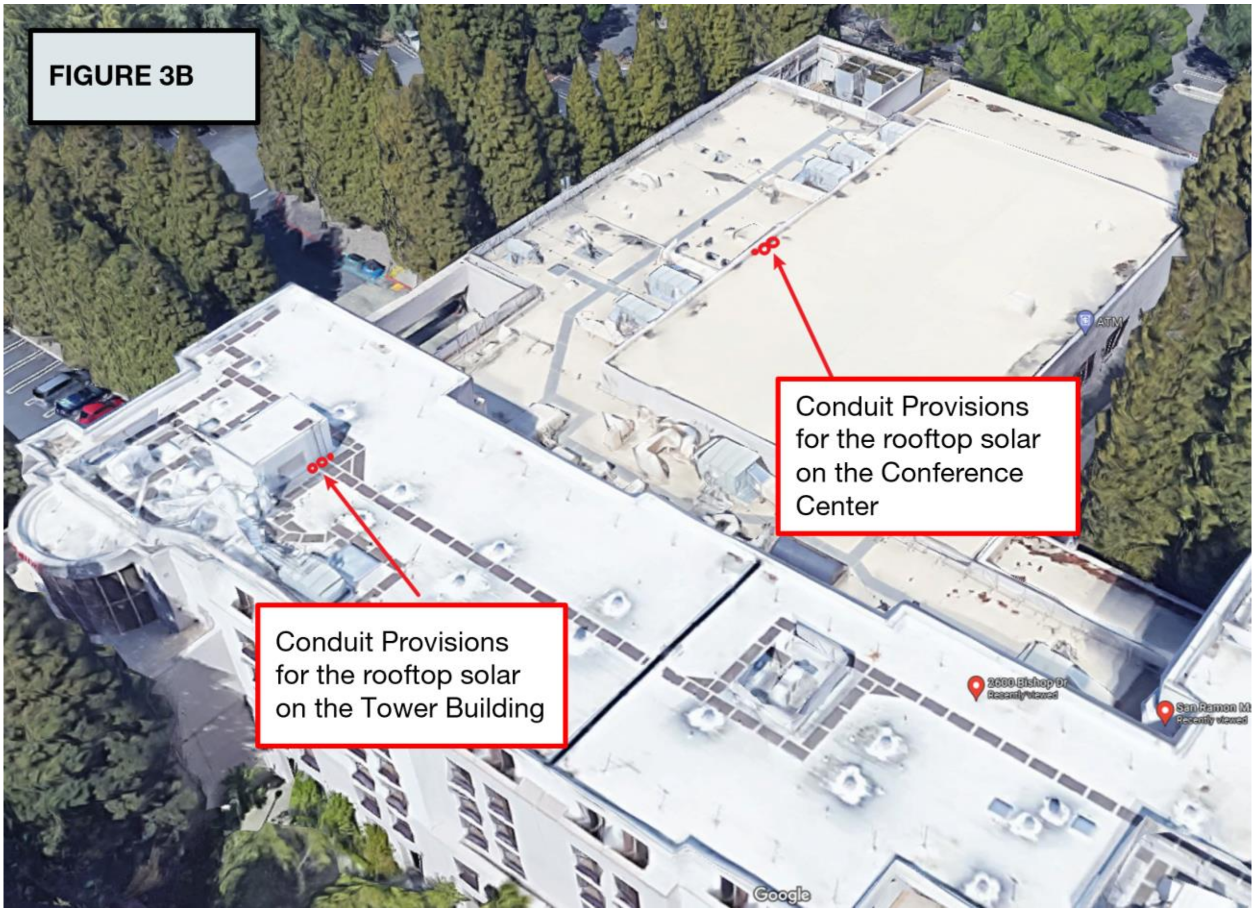


Figure 4A Electrical Room – Solar provisions for conduits, equipment, routing, and space considerations in the electric room and for bringing PV energy from the rooftop to the main electric room [typically] for interconnection.

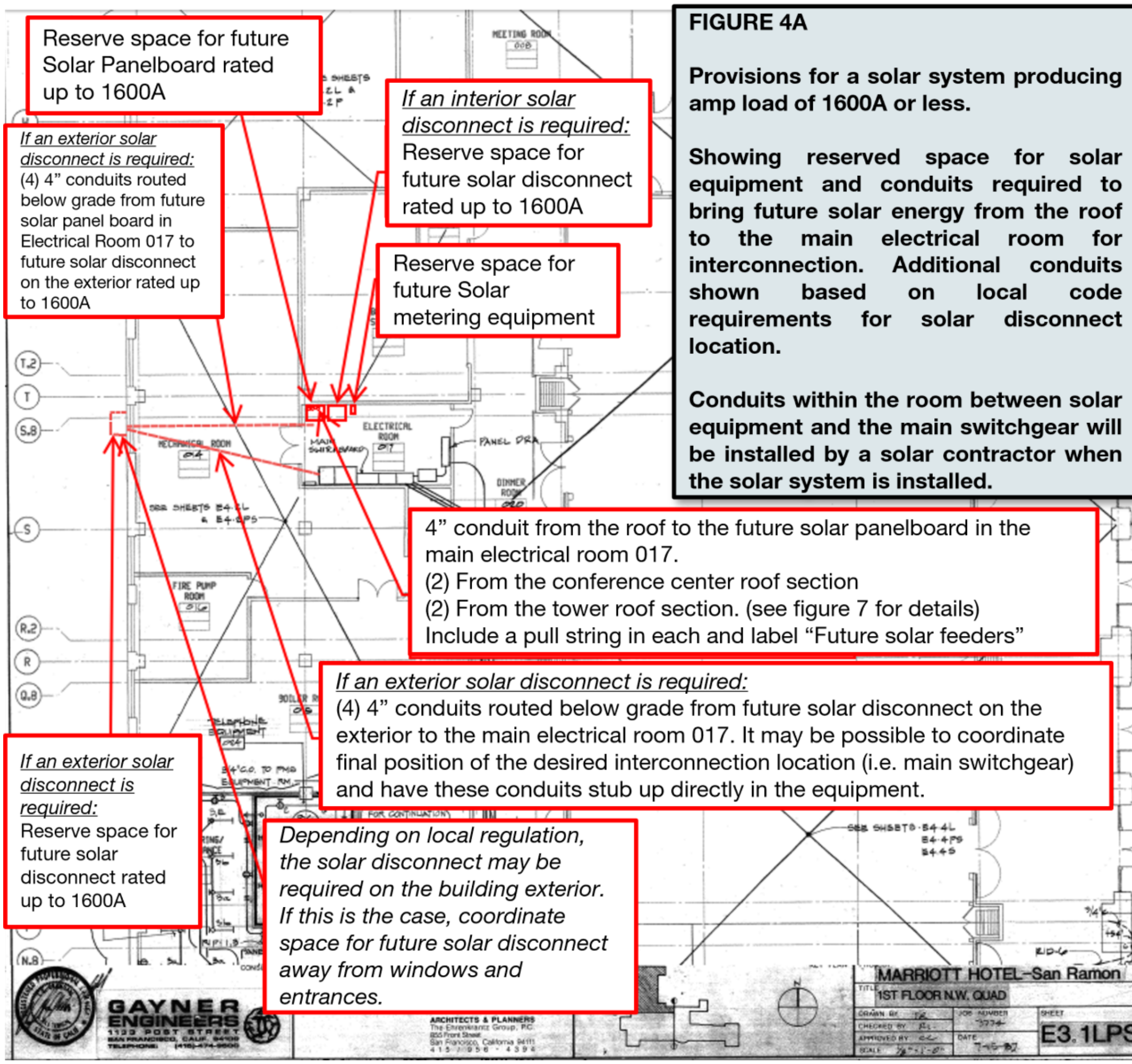


Figure 4B Electrical Room – Solar provisions for conduits, equipment, routing, and space considerations. If space cannot be made for solar equipment in the electrical room, consider nearby locations to minimize additional conduit. Local requirements will dictate where the solar disconnect must go.

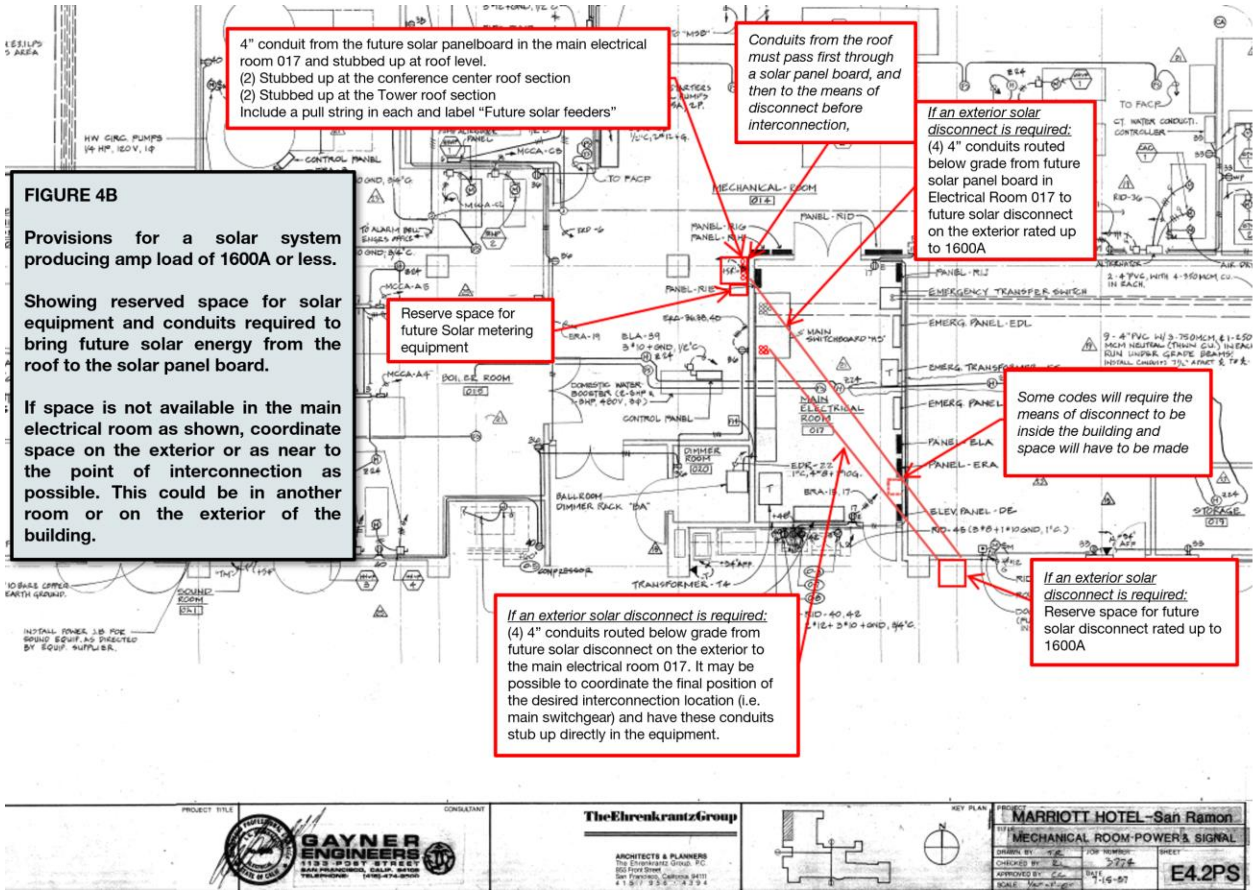


Figure 5 Single Line Diagram – Solar provisions for interconnection, including busbar rating increases and line side tap provisions.

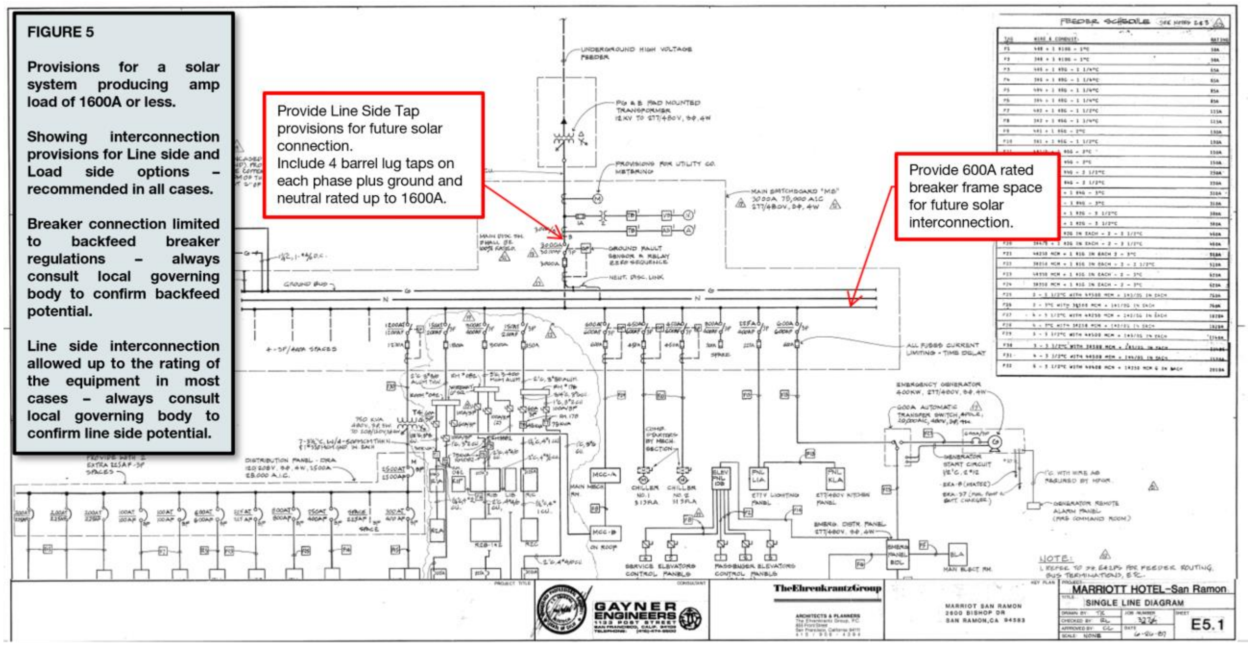
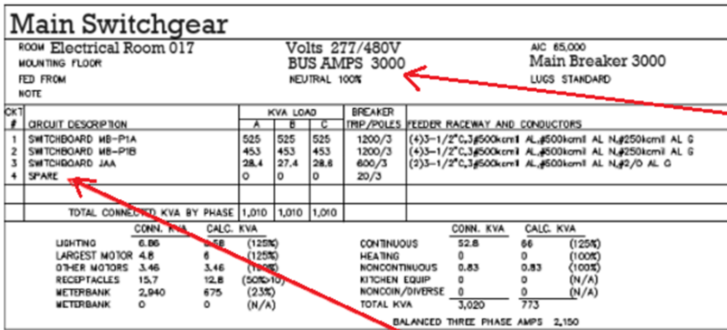


Figure 6 Panel Schedules – Whenever possible, panel schedules should also include provisions for Solar Breakers and line side tap provisions.



Main Switchgear

ROOM Electrical Room 017 | Volts 277/480V | AIC 65,000
MOUNTING FLOOR | BUS AMPS 3000 | Main Breaker 3000
FED FROM | NEUTRAL 100% | LUGS STANDARD
NOTE

CKT #	CIRCUIT DESCRIPTION	KVA LOAD A	KVA LOAD B	KVA LOAD C	BREAKER TRIP/POLES	FEEDER RACEWAY AND CONDUCTORS
1	SWITCHBOARD MB-P1A	525	525	525	1200/3	(4)3-1/2"C,3#500kcmil AL,#500kcmil AL N,#250kcmil AL G
2	SWITCHBOARD MB-P1B	453	453	453	1200/3	(4)3-1/2"C,3#500kcmil AL,#500kcmil AL N,#250kcmil AL G
3	SWITCHBOARD JAA	28.4	27.4	28.6	600/3	(2)3-1/2"C,3#500kcmil AL,#500kcmil AL N,#2/0 AL G
4	SPARE	0	0	0	20/3	
	TOTAL CONNECTED KVA BY PHASE	1,010	1,010	1,010		

	CONN. KVA	CALC. KVA	
LIGHTING	6.86	[illegible]	(125%)
LARGEST MOTOR	4.8	6	(125%)
OTHER MOTORS	3.46	3.46	[illegible]
RECEPTACLES	15.7	12.8	(50%>10)
METERBANK	2,940	675	(23%)
METERBANK	0	0	(N/A)

	CONN. KVA	CALC. KVA	
CONTINUOUS	52.8	66	(125%)
HEATING	0	0	(100%)
NONCONTINUOUS	0.83	0.83	(100%)
KITCHEN EQUIP	0	0	(N/A)
NONCOIN/DIVERSE	0	0	(N/A)
TOTAL KVA	3,020	773	

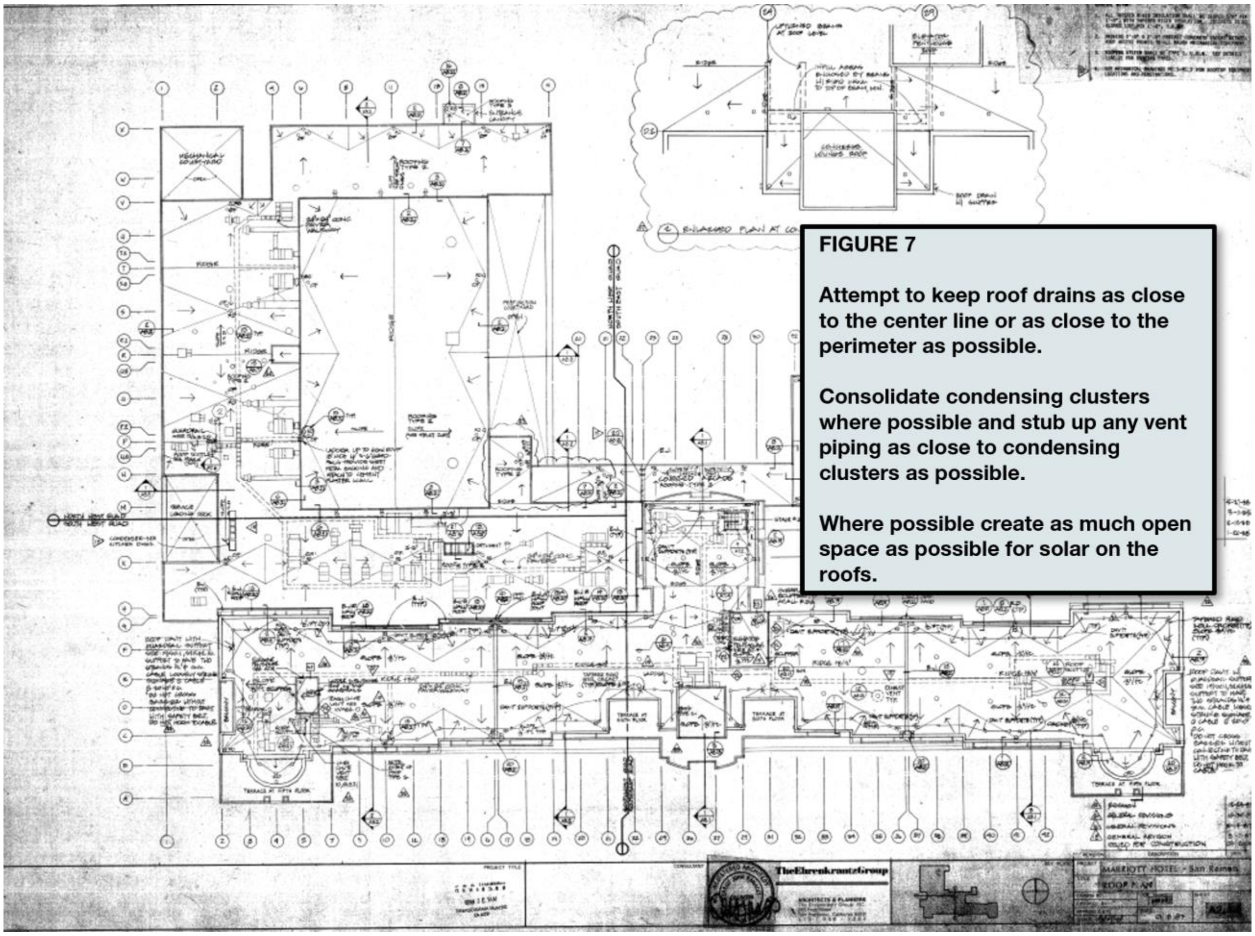
BALANCED THREE PHASE AMPS 2,150

Provide Line Side Tap provisions for future solar connection.
Include 4 barrel lug taps on each phase plus ground and neutral rated up to 1600A.

FIGURE 6

600A Frame Space for future Solar PV. Must be the last breaker at the end of the bus opposite the service entry.

Figure 7 Rooftop Equipment Statements – An example of the language to use when coordinating with other contractors on the location of rooftop equipment.



7.0 GLOSSARY

BESS – Battery Energy Storage System. Any of several possible chemistry-based batteries to store energy from the grid or produced from a solar generation plant.

HVAC – "Heating, ventilation, air conditioning". Describes the equipment used for air movement and climate control. In the context of this document it refers to rooftop air conditioning units and affiliated equipment.

Irradiance – The amount of solar energy available to convert to electricity in a given location, typically averaged over a one year period.

Kilo-Watt hour (kWhr or kWh) – Unit of energy commonly used to describe the movement (generation or consumption) of electricity globally.

Photovoltaic (PV) System – The total components, circuits, and equipment up to and including the PV system disconnecting means that, in combination, convert solar energy into electric energy. (Definition provided by the National Electric Code 2020 - Article 100).

Power Purchase Agreement (PPA) – A contract between the owner of an energy producing facility and energy consumer for the latter to buy energy produced at the generation facility for a set rate and set period of time.

MPOE – 'Minimum Point of Entry' refers to the point at which a telecommunication provider's wiring crosses or enters the hotel. This will be the main telecommunications room for the hotel.

MDF – 'Main Distribution Frame' is a rack or set of shelving used to manage telecommunications wiring and equipment between the primary cabling brought in by the telecommunications provider and any number of "intermediate distribution frames" (IDF) providing internet to other parts of the building.