480000 – POWER GENERATION

I. DESIGN

A. PV Design

1. The Architect/Engineer is responsible for evaluating and maximizing on-site renewables based on available space, targeting 100% or greater of a site's existing/anticipated electrical use.
   a. If existing utility data is not available, such as in new construction, the A/E shall estimate the building's monthly electric consumption using an approved energy modeling software.
   b. In accordance with the County's sustainability and renewable energy goals, the A/E shall consider the feasibility, system performance, and cost-effectiveness of solar PV in the following forms:
      1) Sloped/Pitched Roof
      2) Flat Roof
      3) Ground Mount
      4) Awnings or Canopies
      5) Carport

2. Detailed System Performance Estimates & Life-Cycle cost analysis to demonstrate expected payback calculation.
   a. The A/E shall include a detailed system performance estimate with the solar PV design. Helioscope, PV Syst, System Advisory Model (SAM) or other approved modeling software shall be used to estimate monthly PV output.
   b. Inputs should include geographic region, DC system size, AC system size, array azimuth, array tilt, shading, soiling and other factors.
   c. Display the following as part of an analysis summary:
      1) Energy Yield Ratio of the annual kWh produced by the PV system to the array's DC system size. This value is expressed as kWh per kW.
      2) Performance Ratio Efficiency of the PV system based on the ratio between actual and theoretical output. This value is expressed as a percentage.
      3) Life Cycle Cost Analysis to demonstrate payback calculation.
         a) A life-cycle cost analysis shall be performed by the A/E, for informational purposes only, to demonstrate the PV system's expected return on investment (ROI).
         b) System maintenance, PV module performance degradation, structural reinforcement (if necessary), and utility rate increases shall be factored into the total life-cycle cost analysis.

4) A/E is responsible for understanding building's utility rate and communicating the utility breakdown to the BDCD Project Manager.
   a) Utility Rate Analysis must show distinct $/kWh and $/kW charges in lieu of a blended $/kWh rate.

3. Meeting or exceeding applicable code requirements.
   a. NEC
      1) All Solar PV equipment and wiring shall comply with the requirements of the Fairfax County adopted version of the National Electrical Code (NEC).
   b. ASCE
      1) The structure supporting the Solar PV system shall comply with the requirements of the Fairfax County adopted version of ASCE 7.
   c. IBC
      1) The Solar PV layout shall comply with the requirements of the Fairfax County adopted version of the International Building Code (IBC).
   d. NFPA 70E
      1) Installation of the Solar PV system shall comply with the requirements of the Fairfax County adopted version of NFPS 70E.

4. Spacing, Setbacks, and Clearance Requirements
   a. Subarray roof edge setbacks and pathways shall be provided in accordance with the requirements of the Fairfax County adopted version of the International Building Code (IBC).
   b. Subarray shall be setback a distance of 6' or more from all mechanical equipment requiring regular maintenance.
      1) A setback of less than 6' shall not be approved unless approved by equipment manufacturer and BDCD project manager following consultation with management agency.
   c. PV inverters shall be placed 15' or greater from roof edge to maintain safe clearances for operations and maintenance. This allows PV inverters to be outside of the required range for a guard rail, safety net or travel restraint system. See OSHA 1910.28(b)(13)iii
      1) Exception: A solar PV design using panel-integrated micro-inverters may locate panels within 15' of a roof edge. However, the A/E shall coordinate with the BDCD project manager to ensure adequate fall protection means are available for long-term maintenance.

d. Subarray shall be setback a distance of 2’ feet from all vents, drains, and miscellaneous obstructions.
e. Pathways to all vents, drains, and miscellaneous obstructions shall be provided without stepping through subarrays.
f. All spacing, setback, and clearance requirements shall be clearly shown and dimensioned on the plans.
g. The A/E shall ensure adequate laydown area is considered for future roof replacement and roof top equipment replacement while maintaining setbacks and clear access pathways.

5. Electrical Considerations
   a. Point of Interconnection
      1) A/E shall ensure that the PV projects point of interconnection is depicted accurately based on the site conditions and sites electrical infrastructure.
      2) The outlined interconnection methods below have been listed in order of preferred priority.
         a) Back-fed Breaker
         b) Line-Side Connection
         c) Switchgear or acceptable electrical equipment
         d) Secondary of utility transformer if utility approves
   b. Solar in conjunction with an existing onsite backup generator
      1) The solar PV system must be electrically isolated from any existing or planned emergency backup generator.
      2) The A/E shall design an automatic transfer switch (ATS) or multiple transfer switches to properly isolate the solar PV system while maintaining emergency backup power.
   c. Utility power outages due to loss of voltage
      1) The PV system shall be designed to properly shut down during a utility power outage (UL1741).
      2) Consult with the BDCD Project Manager, FMD, and the OEEC Resilient Fairfax team to consider solar with battery storage as an alternative emergency backup option.
   d. Electrical Conduit and UAD
      1) The A/E shall anticipate placement of the inverters on the rooftop and how AC conductors will be routed to the main electrical room. The A/E shall design interior conduits from the rooftop to the electrical room that are large enough to support the maximum solar array size, as determined by the A/E.

2) Where possible, conduit(s) shall be located in the building interior and routed above ceiling and/or hidden from sight, with pull-boxes located appropriately to allow for installation of solar PV conductors.
3) The A/E shall anticipate and show placement of the utility accessible disconnect (UAD). Conduit shall be designed and clearly indicated for routing from the interconnection point to the UAD and from the UAD to the inverter (or combiner panel if multiple inverters).
4) The UAD shall be designed such that it disconnects power to the entire solar PV array without impacting any other circuits, devices, or equipment.

6. Shading (structures, trees, etc.) rules of thumb and general guidance
   a. A/E is responsible for evaluating potential shading for a given site.
   b. Shading shall be evaluated by considering surrounding buildings and obstructions (rooftop equipment, trees etc.).
   c. PV modules shall not be placed in areas on the roof where more than 50% of the annual production is lost due to shading when compared to the performance of non-shaded areas.
   d. The impact of shading shall be considered in the production model run by the A/E and the electrical PV designer.

7. Documentation – Expected Deliverables
   a. The A/E shall include the following pages in the construction drawings:
      1) Site Plan shall indicate the location of all equipment associated with the Solar PV system.
      2) Scaled layout of all added electrical equipment shall be provided as part of Electrical Drawings.
      3) Single line diagrams, communications diagram, and dedicated PV module stringing diagram.
      4) Single line diagrams shall indicate specifications for all equipment, wiring, and conduit.
      5) Calculations shall be done and displayed clearly on the drawings to account for AC/DC voltage drop, conduit fill, system voltage, amperage, and grounding.
      6) Systems grounding diagram/plan showing Solar PV grounding system and how it connects to or isolates from existing building, separately derived system (generator), low voltage and lightning protection grounding systems.

8. System Production Modeling

a. The A/E shall include a production estimate on the drawings, referencing values obtained using a modeling software such as Helioscope, PV Syst, System Advisory Model (SAM), or other approved modeling software.

9. Roofing and Warranties
   a. Age Limitations:
      1) Rooftop PV systems will be prioritized at facilities with roofs that have recently been replaced or coated.
      2) If the County is planning to replace the roof concurrently with a new solar PV system, the A/E shall design the roof for a minimum 20-year life expectancy.
      3) A new roof or roof replacement design shall incorporate a membrane with high reflectivity to maximize solar production from bifacial modules.
      4) Solar PV will be considered on a case-by-case-basis on roofs that are greater than 10 years old.
   b. Coatings and Compatibility:
      1) A facility with an aging roof, that is an otherwise good candidate for rooftop solar, may still be considered for rooftop solar PV. At such facilities, a roof coating shall be considered as an alternative to a full roof replacement.
      2) The A/E shall specify a roof coating which is designed for a minimum 20-year life expectancy.
      3) The A/E shall specify a roof coating that extends the existing warranty of the roof in cases where a warranty extension is offered by original roofing system manufacture.
      4) Any roof coating must be compatible as determined by both the original roofing system manufacturer and the coating manufacturer.
      5) Provide written documentation of compatibility and warranty extension to the BDCD Project Manager and FMD.
   c. Warranty Continuation:
      1) The A/E shall contact roof manufacturer prior to installation to ensure selected racking system and associated equipment are compatible with the roof manufacturer’s requirements and shall not void the warranty.
      2) The A/E shall require the contractor to obtain a statement of warranty continuation from the roofing system manufacturer after the solar PV system is installed.
      3) Any roof inspections required prior to, or after, installation of the solar PV system shall be indicated by the A/E as the responsibility of the contractor.

10. Coordination and Arc Flash Studies

a. Required Circumstances
    1) An arc flash hazard analysis shall be performed on all added or modified panels and disconnect switches, and an arc flash hazard warning label shall be posted on the equipment in accordance with the Fairfax County adopted versions of the NEC and NFPA 70E. A/E to discuss with BDCD project Manager for exemptions.
    2) A breaker coordination study shall be required for all back-fed / Line Side interconnections where applicable. A/E to discuss with BDCD project Manager for exemptions.

11. Training
    a. A/E shall require contractor to perform training for maintenance & operations BDCD staff, FMD staff and the local fire department upon request.
    b. Staff training shall include:
        1) Equipment Locations
        2) System Components
        3) Maintenance of Key Equipment
        4) Troubleshooting
        5) DC & AC Side
        6) Safety
        7) Monitoring
    c. Local fire department training shall include:
        1) Equipment Locations
        2) System Components
        3) Emergency Shutdown Process

12. Other
    a. The A/E shall provide all pertinent information to the Building Owner for interconnection application from the electrical service utility prior to construction.
    b. A/E shall provide structural approval with a wind and snow load letter prior to construction.
    c. PV drawings shall be stamped by professional engineer registered in the Commonwealth of Virginia.
    d. A/E shall require contractor to provide I-V Curve test results for every string of the PV System as part of project commissioning. I-V Curve results directly from the inverter shall be accepted.

e. The A/E shall specify that the contractor and/or its solar subcontractor must hold a Virginia's contractor's license with the Alternative Energy Systems (AES) and Electrical (ELEC) specialties.
f. A commercial solar permit shall be obtained prior to construction of the solar PV system. A/E shall specify that contractor shall submit final inspection report to the utility as part of a request for Permission to Operate (PTO) approval of the system.

13. Responsibilities of System Designers
   a. The A/E is responsible for the following items that pertain to the design of the PV system:
      1) Site Plan and Overall PV layout
         a) The A/E is responsible for creating a site plan and overall PV layout, which labels relevant equipment (PV Modules, Inverters, PV Disconnects etc.)
         b) The A/E is responsible for determining equipment and roof edge setback distances and displaying the relevant dimensions on the PV layout drawing(s).
      2) Shading issues
         a) A/E is responsible for the placement of PV modules in high irradiance areas and shall avoid shaded areas unless directed otherwise by BDCD Project Manager or FMD.
      3) Orientation of PV Modules
         a) The A/E is responsible for specifying the orientation of the PV modules and ensuring modules are placed in an orientation for maximum PV output.
         b) PV modules may sometimes be located on north-facing roof areas with reduced production in order to support Fairfax County's goals for Zero Energy or Net Zero Buildings. Modules shall only be placed in the north facing direction with the approval of BDCD Project Manager.
      4) PV Module Tilt
         a) The A/E is responsible for specifying the tilt of the PV modules.
         b) Ideal tilt angles for PV modules range from 5-30 degrees, depending on the roof slope and mounting system. PV modules tilted outside of this range must be approved by BDCD Project Manager.
         c) Ideal PV tilt angles based on mounting type:
            (i) Flat Roof: 5-10 Degrees
            (ii) Pitched Roof: 0 Degrees – Flush with existing roof pitch.
            (iii) Ground Mount: 25-30 degrees
            (iv) Carport 2-15 degrees
      5) Energy Yield

a) The A/E is responsible for specifying the PV yield on the cover page or site plan of the PV design drawing package.
b) A/E shall ensure PV system can achieve maximum yield given site conditions and overall design.

6) Equipment Selection
   a) A/E is responsible for including full specifications for PV equipment selected as part of the design.
   b) The design shall include the quantity, make, and model of key PV equipment such as PV modules, PV inverters, PV racking, PV monitoring, and associated BOS (balance of system) components.
7) Electrical Design
   a) A/E is responsible for submitting an electrical design consisting of a single line diagram, communications diagram and dedicated PV module stringing diagram.
   b) The electrical design shall be stamped by a professional engineer licensed in the Commonwealth of Virginia.
8) Occupational Safety Risks
   a) A/E shall require contractor to be aware of and list potential safety risks that the site may present including, but not limited to electrical and fall protection hazards.
9) Access to Designated PV Array Location
   a) Identify access pathways to PV equipment and access to PV array locations (roof hatch, staircase, etc.).
10) Integration with Architectural Features
   a) The A/E shall consider the need for potential solar PV attachments when designing the architectural roof assembly. Avoid designing sloped roofs that are not standing seam metal where possible to eliminate the need for roof penetrations and attachments.
   b) Avoid designing sloped roofs that require roof penetrations and racking attachments to the metal roof decking, especially when the metal decking is a specialty noise-dampening type and/or exposed to the space below.

II. PRODUCTS

A. Solar Modules

1. Type of Solar Module
   a. Monocrystalline:

1) The A/E shall specify a PV module for a given design that is monocrystalline. Mono-facial or Bi-facial monocrystalline modules are preferred.

b. Alternative Options:

1) Alternative PV modules are permitted as long as the efficiency requirement is met or a special/unique circumstance arises where the PV module is integral to the building design (Eg. Building Integrated PV)

a) Thin Film PV modules are permitted given they meet the provided specifications.

b) Poly-Crystalline PV modules shall not be used unless approved by BDCD Project Manager following consultation with OEEC.

2. Module Specifications

a. PV Module efficiency shall be 19% or greater.

b. PV Module degradation shall not exceed 20% degradation in year 25.

B. Mounting

1. Racking Compatibility:

a. Rooftop solar racking systems must be compatible with the existing or planned roofing material.

b. The A/E shall confirm with the racking manufacturer that the specified product is compatible with the roof type.

c. Slip sheets shall be specified for flat roof installations where applicable, A/E shall check with roofing manufacturer for PV system design requirements.

2. Roof Penetrations:

a. Penetrations through the roofing system shall be avoided, whenever possible.

b. If roof penetrations are unavoidable in the design of the solar PV system, the A/E shall specify a reinforced liquid flashing detail in lieu of a pitch pocket.

3. Flat Roofs:

a. Mounting systems for solar PV arrays on flat roofs shall be designed as a ballasted system.

b. The A/E shall indicate the racking type to be used, with a specified tilt of 5 to 10 degrees.

c. The A/E shall coordinate with the racking manufacturer to determine the quantity, location, and weight of CMU blocks to be used as ballast for the system.

d. Flat roof ballasted mounting systems should avoid penetrations through the roofing system.

4. Sloped/Pitched Roofs:
   a. While the installation of solar PV systems on sloped roofs is possible, particularly those that are not standing seam metal, it's crucial to assess each case individually. This approach will help minimize the need for roof penetrations and attachments to the roof decking. If a PV system is to be installed on a non-metal sloped roof with acoustical qualities, the A/E should evaluate the number of roof attachments required and how this may affect the functionality of the roof decking and the aesthetics of the space below.
      Quantify and discuss the number and type of roof attachments with BDCD Project Manager and FMD before proceeding with the proposed roof type, if solar PV is anticipated on that particular roof.
   b. Metal
      1) Solar PV systems on sloped metal roofs shall be designed to use racking systems which attach directly to the roofing system.
      2) The A/E shall specify the correct clips/clamps which attach to the particular metal roof seam type or roof channel.
      3) For racking applications that require penetrations through the metal roof, A/E shall require the use of a butyl style penetrating mount.
      4) Roof penetrations shall be avoided on metal roofs if possible (e.g. standing seam roof clamp).
   c. Asphalt
      1) Asphalt Shingle
         a) Solar PV systems mounted on pitched asphalt shingle roofs shall use a flashing style mounting system.
         b) Flashings shall either fasten to existing wooden roof trusses or directly to deck.
         c) The use of flash-less attachment systems may be approved on a case-by-case basis by the BDCD Project Manager and FMD.
      2) Rolled Asphalt
         a) Solar PV systems mounted on flat or slightly pitched rolled asphalt roof should be designed with racking systems designed specifically for rolled asphalt applications.
         b) Should a penetrating solution be used, A/E shall ensure design requires mounting system to be compatible with existing roofing manufacturer and shall not void roof warranty
      3) Membrane

a) Solar PV systems mounted on flat or slightly pitched membrane roofs should be designed with racking systems specifically for membrane roof applications.
b) Should a penetrating solution be used, A/E shall ensure design requires mounting system to be compatible with existing roofing manufacturer and shall not void roof warranty.
c) Adhered non-penetrating attachment solutions are acceptable if roof manufacturer approves of said product and does not void existing roof warranties.

5. Low Sloped Roofs
   a. On sloped membrane roofs that are pitched at an angle greater than 7 degrees, a hybrid ballasted/attached racking system shall be designed.
   b. The A/E shall coordinate with the racking manufacturer to minimize the number of roof penetrations on the solar PV system design.
   c. Sloped membrane roofs that are pitched at an angle less than 7 degrees shall be classified as a flat roof for the purposes of this guideline and shall be designed as a ballasted system.

6. Carports, Awnings, and Canopies
   a. Carports, awnings, and canopies must be designed by a professional engineer registered in the Commonwealth of Virginia.
   b. Carport, awning, and canopy designs should account for water/snow management and be accessible for routine cleaning and maintenance.

7. Ground Mounts
   a. Ground mount PV systems shall adhere to all local zoning and setback requirements.
   b. The leading edge of all PV modules in a ground mount system must maintain at least 2’ of clearance from the ground.
   c. Ground mount systems shall be surrounded by a fence with accessible gates to ensure routine cleaning and maintenance can occur.
   d. Ground mount PV systems shall not be installed in flood plains or areas where large amounts of water consistently pond.
   e. Ground mount PV systems shall be covered aggregate or vegetation.
      1) The use of vegetation (e.g. perennial garden) for ground mount systems is encouraged; however, a vegetation management plan and associated long-term costs need to be accounted for by A/E.

C. Inverters

1. Efficiency
   a. Inverters shall have a minimum efficiency of 96% unless justified by a lifecycle cost analysis.

2. Capacity (DC/AC Ratio)

a. Systems shall be designed to have a DC/AC power ratio between 1.0 and 1.5, with an ideal power ratio of 1.2. DC/AC ratios that fall outside of this range shall require BDCD approval.

3. Monitoring
   a. Inverters shall provide a minimum of string-level production and error monitoring for all Solar PV installations.

4. Rapid Shutdown
   a. Power Optimizers, Rapid Shutdown Devices, Rapid Shutdown Boxes, and Inverters shall comply with Rapid Shutdown Requirements specified in NEC 690 when applicable.

D. Balance of System Components

1. DC Combiner Panels
   a. DC Combiner Panels shall be rated NEMA3R or greater.
   b. Enclosure shall be rated for the designated PV voltage.
   c. Enclosure shall be labeled for use.

2. AC Combiner Panel
   a. AC Combiner Panel shall be rated NEMA3R or greater.
   b. Enclosure shall be rated for the designated PV voltage.
   c. Enclosure shall be labeled for use.
   d. The use of panelboards with breakers or AC fuses is acceptable.

3. Disconnects (Service, Utility Accessible, etc.)
   a. A/E shall identify disconnects on drawings.
   b. The utility accessible disconnect shall be within line of sight of the utility meter.
   c. The use of maps shall be permitted with additional utility approval for disconnects placed in locations that do not have a direct line of sight of the utility meter.
   d. Disconnects shall be rated NEMA3R or greater.
   e. Enclosure shall be rated for the designated voltage.
   f. Enclosure shall be labeled for use.
   g. Knife blade AC disconnect switches are required unless utility approves an alternative.

4. PV Transformers

a. The use of step-up transformers is permitted.
b. Units shall be rated NEMA3R or greater.
c. Enclosure shall be rated for the designated voltages.
d. Transformer shall be compatible with bi-directional current flow.

5. Back-fed Breakers
   a. The use of back-fed breakers is permitted.
   b. Breakers shall be rated for bi-directional current flow.

E. Monitoring / BAS Integration

1. PV Submeters
   a. The A/E shall consult with the BDCD Project Manager and FMD about the type of submetering required for each solar PV system design.
   b. If a solar submeter is desired, it shall be integrated into the facility's building automation system (BAS).
   c. If the facility's BAS accepts BACnet integration, BACnet MS/TP or BACnet IP protocols shall be used.
   d. The A/E shall develop a solar submeter monitoring (controls) package which includes the integration I/O points to be pulled in, displayed on the graphic, and properly trended.
   e. PV submeters shall also be integrated into the PV inverter when possible.
   f. The A/E shall require the contractor to set up trends of daily, weekly, monthly, and yearly kWh production.
   g. Additionally, they shall require trends of peak kW production.
   h. The A/E shall specify that real kW and apparent power kVA be displayed on the graphic of the BAS.

2. Revenue Grade Meter
   a. If a revenue grade electric submeter is required, the A/E shall specify a meter (e.g. Honeywell E-MON Green Class Meter) capable of satisfying the ANSI C-12 requirement (minimum accuracy of +/- 2%).
   b. The BACnet communication protocol of the submeter shall be BTL certified.
   c. A revenue grade meter is required if SREC arbitrage is a short or long-term goal for the solar PV system (See below for SREC arbitrage).
   d. SREC Arbitrage
      1) For every MWh (1,000 kWh) produced by a solar PV system, one Solar Renewable Energy Credit (SREC) is generated.

2) An SREC substantiates the sustainability benefits of solar renewable energy production.
3) SREC arbitrage consists of REC's being sold, swapped, retained or retired. SREC swapping consists of selling the PV generated SREC at a higher price to one consumer while purchasing less expensive RECs or SRECs from another party.
4) SREC arbitrage may be used as a strategy to meet the County's renewable energy portfolio goals while improving the ROI of a solar PV system.
5) Consult with the BDCD Project Manager and OEEC to determine if a financial model, incorporating SREC arbitrage, is required for the project's solar PV system.

3. PV Inverter Production Data
   a. Inverter production and error monitoring shall be accessible from a remote location via an online portal. Access to portal shall be provided to system owner post system commissioning and energization.
   b. Hardwired Inverter
      1) Connection to Inverter shall be hardwired to building main distribution frame (MDF) in all cases where access to the MDF is provided by the system owner.
   c. Cellular Communication Solutions
      1) In cases when owner cannot provide access to the MDF, the inverter shall report monitoring data via cellular communication.
   d. Wi-Fi Based Communication Solutions
      1) The use of Wi-Fi for communications purposes shall not be permitted.

F. Minimum Component Warranties

1. PV Modules
   a. Performance
      1) The PV module(s) specified shall have a minimum performance/production warranty of 20 years.
      2) Consult with the BDCD Project Manager and FMD to determine if an extended warranty is required.
   b. Material
      1) The PV module(s) specified shall have a minimum product warranty of 10 years.
      2) Consult with the BDCD Project Manager and FMD to determine if an extended warranty is required

2. Inverter(s)
   a. The inverter(s) specified shall have a minimum product/component warranty of 10 years.
   b. Consult with the BDCD Project Manager and FMD to determine if an extended warranty is required.
   c. If an inverter comes with a standard 5-year warranty, a warranty extension shall be provided to meet the 10-year requirement.

3. Rapid Shutdown Devices and Power Optimizers
   a. The rapid shutdown devices and/or power optimizers specified shall have a minimum product warranty of 25 years.
   b. Consult with the BDCD Project Manager and FMD to determine if an extended warranty is required.

4. Racking
   a. The racking system(s) specified shall have a minimum product warranty of 20 years.
   b. Consult with the BDCD Project Manager and FMD for approval if standard warranty is below 20 years.

STRUCTURAL DESIGN GUIDELINES

I. DESIGN

A. These guidelines provide structural recommendations for applying gravity, wind and seismic loads in rooftop photovoltaic (PV) array applications to new and existing building roof areas. The guidelines are separated into gravity (Dead Load (DL), Live Load (LL), Rain Load, Snow Load), Wind Load and Seismic Load considerations for Fairfax County Facilities. The scope of these guidelines apply to elevated roof areas only.

B. These guidelines apply to the Virginia Construction Code (2021) with Specific reference to Chapter 16 (Structural Design), International Building Code (IBC 2021) and International Existing Building Code (IEBC 2021). These guidelines have not been written for applications for one and two-family dwellings governed by the International Residential Code (IRC).

C. The designer is encouraged to identify (early in the design process) the type of PV system to be installed. Early identification of the type of PV system will assist the designer in determining the loading demand and load path. Examples include but are not limited to:

1. Low profile, permanently fixed (non ballasted), low slope roof
2. Rack mounted, permanently fixed (non ballasted), low slope roof
3. Rack mounted, ballasted, low slope roof
4. Low profile, permanently fixed, moderate slope roof
5. Rack mounted on steel dunnage permanently fixed, low slope roof

D. Structural drawings shall designate the roof areas that are considered **"Solar Ready"**. Solar Ready areas are locations that have been designed (for new construction), verified or reinforced (for existing roofs) to support PV array dead loads. PV dead load design loadings should be identified on the Solar Ready plan with the type of solar panel system the loadings are based on.

1. For new construction, Solar Ready plans shall include all flat (low pitch) roofs and designated moderate pitched roofs.
   a. Low pitch roofs are roofs with a slope less than 5 degrees.
   b. For the purposes of these guidelines, Moderate pitched roofs are defined with a slope greater than 5 degrees and less than 40 degrees.

2. For existing construction, Solar Ready roof areas shall be identified as part of the structural evaluation process. Solar Ready roof plans should identify the following areas:
   a. Adequate capacity – PV Panels are Permitted
   b. Strengthening Required – Due to additional PV loads
   c. Strengthening Required - Due to additional other loads such as Snow drift loads & Include PV loads
   d. PV Panels Not Allowed – Areas determined by others during the design process where PV panels are not beneficial to the project. Examples include small or not easily accessible roof areas and low roof areas shaded from high roofs.

E. Structural support systems supporting PV arrays shall be designed to satisfy life-safety performance for a design basis earthquake ground motion event and a design wind event.

II. STRUCTURAL DESIGN LOADING CONSIDERATIONS

A. Dead Load Requirements

1. PV System weights are generally well known, not movable and contribute to the mass dead load of the building. For these reasons, PV system weights should be considered **dead load.** For design purposes, a minimum of **10 pounds per square foot (psf) dead load** shall be used for **all non-ballasted PV arrays** and **most ballasted systems**. The weight of *PV modules,* supporting system, and ballast are included in the 10 psf dead load and shall be verified by the engineer of record.
   a. The dead load from the PV system shall be considered in the seismic response analysis (see lateral load requirements).

B. Live Load Requirements

1. New Construction: Roof framing of new buildings must be designed to safely support code minimum roof live load assuming no PV is present, including the 300lb concentrated load requirements and all live load applied to the underside of roof framing members, such as hung loads from truss bottom chords.

2. Considerations for Existing Roofs: Where PV panels are installed relatively close to the roof surface, the physical panels prohibit application of significant roof live loading. Roof live loads shall be taken as zero where the clearance between the PV panels and roof is less than 24in. **See Figure 1**

3. All existing roofs that have adequate area shall be evaluated for the addition of PV panels. Structural capacity of roofs shall be considered for all areas of existing roof members.
   a. PV panel systems with a clearance greater than 24in do not prohibit roof live load from being applied below the panels. As such, roofs with taller PV panel systems should be designed for all code roof live loads.
   b. Roofs with PV systems and varying heights should be designed for roof live load in areas greater than 24in clear between the roof surface and PV panel.
   c. Roof members that support open access aisles and other areas where PV panels are not installed shall be designed to support both PV dead load tributary to that member and code roof live loads over the open area. In addition, roof live load shall be considered in areas below PV panel that are taller than 24in.

4. Live Load Reduction: Individual members that receive large live loads above the threshold limits where reductions are applicable may be reduced per building code standards. Live load reduction shall be based only on the part of the tributary area

subject to live load. It should be noted that LLR is likely not practical as snow loads, rain on snow surcharge or ponding loads will likely govern the design.

C. Rain Loads and Ponding:

a. New construction: Where roof systems are adequately sloped to drains at a pitch greater than or equal than ¼ in/ft, specific ponding analysis by the code is not required and the subsequent design for rain should not be a factor.

b. Considerations for Existing Roofs: Dead load from PV arrays will increase demands and deflections of existing roof members. Rain loads on roofs shall be considered whenever water can accumulate on a roof. Consideration should be given to primary and secondary (overflow or scupper) drains where the primary drain becomes blocked resulting in static head in localized areas. Structural framing adjacent to primary and secondary drains should be checked for adequacy considering PV dead load deflections and localized ponding.

D. Snow Loads:

1. PV panels may allow for greater snow accumulation by sheltering the snow from wind that might otherwise blow the snow off the roof. PV panels may also alter drift patterns.

2. Where low profile systems are used and the panels are lower than the depth of snow corresponding to the roof snow load, the panels may have a negligible effect on roof snow loads.

3. Where rack mounted systems are used and the panels are higher than the depth of snow corresponding to the roof snow load, the panels will have a higher effect on roof snow loads, possibly resulting in localized drifting. Special attention should be paid to the thermal factor (Ct = 1.2) for unheated open frame systems.

E. Lateral Load Requirements

1. Wind Load
   a. The Building Risk Category, Building Enclosure Category, Ultimate Wind speed, and Wind Exposure Category shall be designed to and identified on the structural drawings.
   b. The PV Roof Zones, Effective wind and Normalized Wind area, External Pressure coefficients for effective wind and normalized wind (GCrn), (GCrn)nom, respectively, and associated PV wind pressures shall be determined by the Specialty Engineer designing the solar panel system.

1) Note that PV Roof Zones are calculated differently in ASCE 7-16 than roof zones for components and cladding.

c. For New Construction - The structural integrity of the building including all elements of the lateral resisting system shall be determined and verified compliant considering the additional wind load induced to the building from the PV system.

d. For Existing Construction – For PV arrays added to existing buildings, the lateral force resisting system of the building shall be checked per the requirements of the IEBC.

1) Any existing lateral load carrying structural element whose demand/capacity with the addition of PV panels considered is no more than 10% greater than its demand/capacity ratio with the PV panels ignored shall be permitted to remain unaltered.

a) For purposes of this exception, comparisons of demand/capacity ratios and calculation of design lateral loads, forces and capacities shall account for the cumulative effects of additions and alterations since original construction.

e. Solar Area ready roofs shall be designed for cases where solar arrays will be installed and cases where solar arrays could be removed.

2. Seismic Load

a. The Building Risk Category, Seismic Importance Factor, Seismic Design Category, Site Classification, Seismic Response Coefficients (Ss, S1, Sds, Sd1), Design Base Shear, Seismic-Force Resisting System, Analysis Method and Seismic Response Coefficients (R, Cd, Cs, TL) shall be determined by the engineer of record and identified on the structural drawings.
b. For New Construction - The structural integrity of the building including all elements of the lateral resisting system shall be determined and verified compliant considering the additional dead load induced from the PV system.
c. For Existing Construction – For PV arrays added to existing buildings, the seismic force resisting system of the building shall be checked per the requirements of the IEBC.

1) If the added mass of the PV array does not increase the seismic mass tributary to any lateral-force resisting structural element by more than 10%, the seismic-force resisting system of the building is permitted to remain unaltered.

a) For purposes of this exception, comparisons of demand/capacity ratios and calculation of design lateral loads, forces and capacities shall account for the cumulative effects of additions and alterations since original construction.

III. CONSIDERATIONS SPECIFIC TO EXISTING BUILDINGS

A. General

1. Any existing gravity load-carrying structural element for which an addition and its related alterations cause an increase in design gravity load of more than 5% (5% trigger) shall be evaluated for adequacy, strengthened, supplemented, replaced, or otherwise altered as needed to carry the increased gravity load required by the IBC code for new structures.

2. Existing Wood Framed Roof Considerations
   a. Consideration of the long-term dead load effects on older wood-framed roof members must be made. Older allowable stresses are not sufficiently conservative. Glue-laminated beams fabricated prior to 1970 also warrant additional consideration.
   b. If the 5% trigger intends to cover an increase of 5% in any of the load cases involving gravity, the maximum weight of an added PV system would be limited to 5% of the total dead load of the roof assembly, unless the capacity of the existing structure is evaluated.
   c. For existing buildings where the required moisture content of the wood was not specified as 19% or less, or if the original drawings are not available, or if the existing framing members lack grade stamps, the existing deflections are recommended to be estimated with the assumption that the wood had a moisture content greater than 19% at the time of installation.
   d. Deflections shall be checked for drainage and ponding issues.
   e. Deflections of supporting members (compound deflections) shall be considered.

3. Steel Framed Roofs Considerations
   a. The reduction of live load to justify the addition of PV systems is reasonable, but may not be relevant dependent on snow loads.
   b. The 5% trigger is permitted to apply only to the critical/governing load case(s).
   c. Local and compounded deflections shall be checked for drainage and ponding cases.

4. Concrete Framed Roofs Considerations
   a. The reduction of live load offset to justify the addition of PV systems is reasonable, but may not be relevant dependent on snow loads.
   b. The 5% trigger is permitted to apply only to the critical/governing load case(s).

c. Long term deflections shall be checked for drainage and ponding cases.

5. Other Roof Framing Systems
   a. Other framing systems may exist that are not identified above. The designer of record shall follow the IEBC requirements when evaluating existing framing systems for adequacy.

IV. MINIMUM STRUCTURAL SUBMITTAL REQUREMENTS

A. General

a. PV Submittal shall be submitted to Fairfax County for review and shall be signed and sealed by a Professional engineer registered in Virginia. Submittal shall include the following:

1) Racking layout with clearances and aisles
2) Ballast layout with placement details
3) Mechanical anchorage details
4) Typical installation details

b. Minimum Calculations

1) Calculations shall reflect and confirm the Basic Building Design Criteria identified on the structural drawings
2) Ballast weight calculations, if required, to satisfy the loading requirements
3) Mechanical fastening capacities, product data and connection information
4) Panel specific seismic and wind variables used in the panel submittal design

V. REFERENCES

480000 – POWER GENERATION

2021 - Virginia Uniform Statewide Building Code (Chapter 16)

2021 – International Building Code

2021 – International Existing Building Code

American Society of Civil Engineers (ASCE 7-16)

Structural Engineers Association of California (SEAOC) Solar Photovoltaic Systems Committee, Structural Seismic Requirements and Commentary for Rooftop Solar PV Arrays – PV1-2012

Structural Engineers Association of California (SEAOC) - Solar Photovoltaic Systems Committee, Wind Design for Rooftop Solar PV Arrays – PV2-2017

Structural Engineers Association of California (SEAOC) - Solar Photovoltaic Systems Committee, Gravity Design for Rooftop Solar PV Arrays - PV3-2019

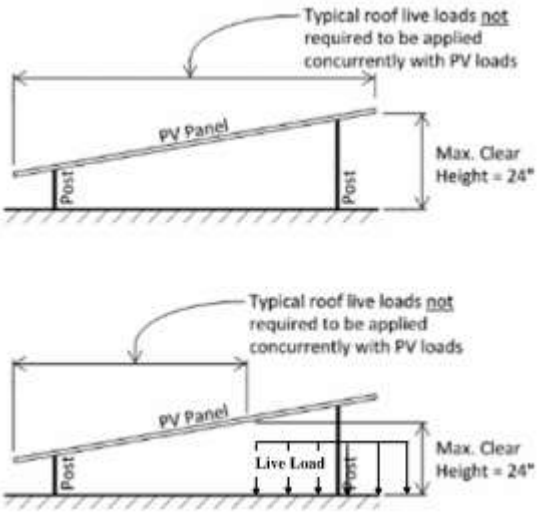

Figure 1: Examples of areas where live loads shall be considered in addition to PV loads