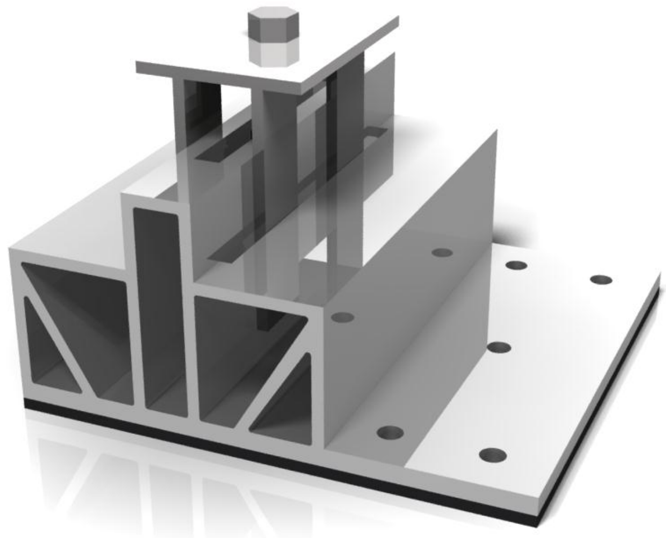


# DynoRaxx® EVOLUTION PR

## Guide to Code Compliant Installation

# Table of Contents

## I. Installer Responsibilities:

Thank you for choosing Evolution PR, a revolutionary technology for Pitched-Roof Racking for PV Mounting.

Evolution PR pitched-roof solar racking system is designed and engineered for commercial and residential solar racking applications. The proprietary and patent-pending design allows the solar racking to be installed on all pitched roof systems for a long lasting product life and economical solution.

Designed by installers in the field and engineered for optimal performance, Evolution PR will save on installation costs due to its universal design for all PV solar modules. No more cutting various length rails to mount on the roof or having numerous assemblies. Evolution PR offers a clean aesthetic look on the roof and decreased installation time.

To insure that the Evolution PR system is installed properly and is functional, it is important to adhere to the following guidelines. A failure to follow the guidelines may void the limited manufacturer warranty on the Evolution PR system. These include:

1. Determining whether the Evolution PR system is appropriate for a particular application or location
2. Ensuring that the building structure, which consists of the roof, its rafters, connections and other components can support the photovoltaic array under all code level loading conditions
3. Using a qualified professional to design the photovoltaic system, and applying all appropriate design parameters in order to insure that all loading requirements are met. These loading requirements include and are not limited to: snow loading, wind speed, exposure, and topographic factors
4. Complying with both local and national building codes, including those that are not listed in this manual
5. Obtaining all required building permits and approvals
6. Insuring that the site of installation is in good condition; that the roof in consideration has a sound water barrier, preventing any leaks
7. Insuring that only approved Evolution PR parts are used, and that all such parts are not visibly damaged at the time of installation
8. Insuring that the electrical systems of the PV system are installed properly in accordance to all local and national code requirements

It is important that the correct design parameters are utilized in determining the specific loading design. Please consult a licensed professional engineer to insure that all the loading design parameters comply with local codes.

## II. Simplified Procedure for Calculating Design Wind Loads

Several methods exist to determine the design wind load on a particular fixed structure. For the purpose of this manual, the methodology used as well as any relevant values and equations will be drawn from the ASCE 7-05 manual. Please refer to this manual if you have any questions about the procedure. In determining the design wind load, we will make use of method 1, as discussed in ASCE 7-05 section 6.4.

In calculating the design wind loads, we assume that the solar modules are placed parallel to the racking surface.

The application of method 1 is subject to the following restrictions:

1. The mean roof height *h* must be less than or equal to 60 ft ($h \geq 60ft$)
2. The building must be enclosed. Method 1 does not allow for partially enclosed structures.
3. The building is regularly shaped; that is it does not have any unusual geometrical patterns in its spatial form
4. The building is not placed at an extreme geographic location where the environment may greatly affect wind load
5. The building has either a flat roof, a gable roof with a pitch less than 45 degrees or a hip roof with a pitch of less than 27 degrees.

If the installation site does not conform to the restrictions above, please consult a professional engineer. For further clarification, please refer to ASCE 7-05 for more information on method 1, as outlined in section 6.4.

In order to determine the design wind load for components and cladding, the following equation will be utilized:

$$p_{net} = \lambda K_{zt} I p_{net30} \text{ (psf)}$$

Where
$\lambda$= adjustment factor for building height and exposure classifications
$K_{zt}$ = Topographic factor evaluated at the mean roof height *h*
*I* = Importance factor
$p_{net30}$ = Simplified design wind pressure for Exposure B, at *h*=30 ft, I= 1.0

The reference used in this manual is:

ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures*

# III. Calculating the Total Design Wind Load

## A. Wind Design Load Worksheet:

The following worksheet provided below will allow you to record the relevant values required in computing the total design wind load. Work through the tasks listed in the remainder of the section, and record the appropriate value in the given space.

| Quantity | Value | Task/Page |
|---|---|---|
| **Basic Wind Speed (mph)** | | Task 1, Page 5 |
| **Mean Roof Height (ft)** | | Task 2, Page 5 |
| **Exposure Category** | | Task 3, Pages 5-6 |
| **Adjustment Factor, $\lambda$** | | Task 3, Page 6 |
| **Topographic factor $K_{zt}$** | 1 | Task 4, Page 6 |
| **Occupancy Category** | | Task 5, Page 7 |
| **Importance Factor *I*** | | Task 5, Page 6 |
| **Effective Wind Area A (sf)** | | Task 6, Page 8 |
| **Least Horizontal Dimension** | | Task 7, Page 8 |
| **Roof Zone** | | Task 7, Page 9 |
| **Net design Pressure $p_{net30}$(psf)** | Down-Force: | Task 8, Page 10-11 |
| | Uplift-Force: | |

With the values recorded above, it is now possible to compute the total design wind load. This may be done by multiplying the adjustment factor, the topographic factor, the importance factor, and the net design wind pressure. Use the equation as stated below:

$$p_{net} = \lambda K_{zt} I p_{net30}$$

Total Design Wind Load (psf): ______________________________ (Down-Force)

Total Design Wind Load (psf): ______________________________ (Uplift Force)

Task 1: Calculate the Basic Wind Speed V. This value is defined to be: the largest three second gust of wind at 33ft above the ground in exposure category C. It will be assumed that the wind will come from any horizontal direction. In order to determine this value, please consult the following map and look up the value of V in the installation site:

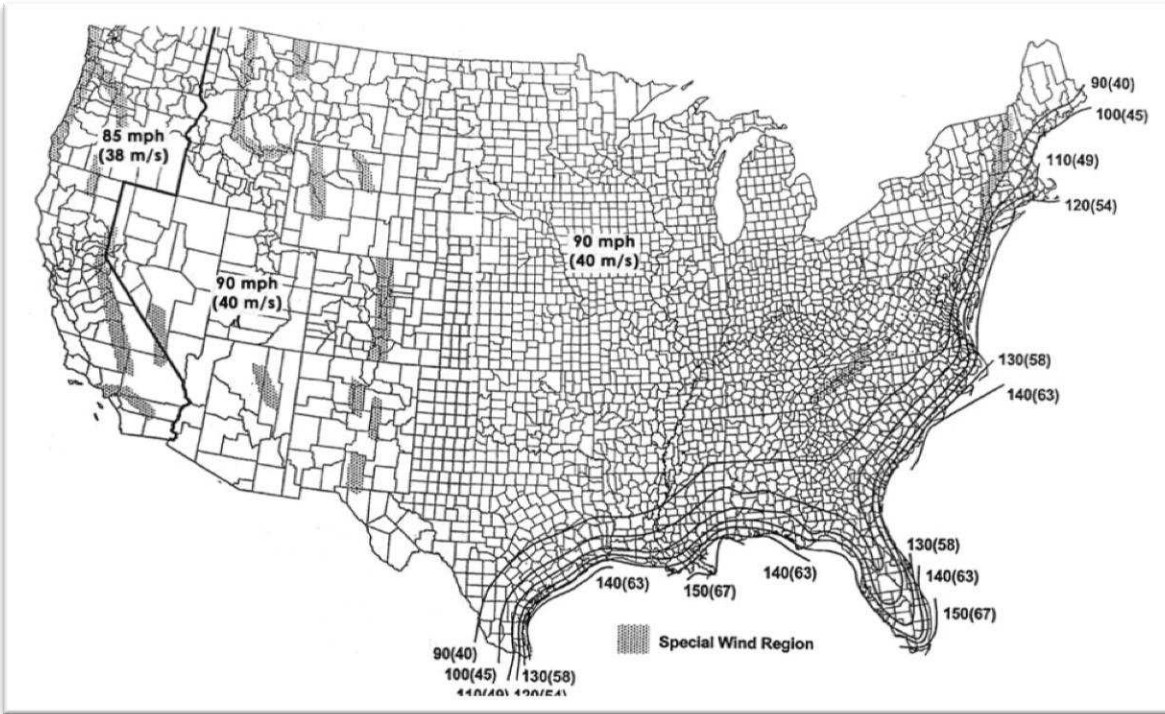



Figure 1: Basic Wind Speed, V (ASCE 7-05 figure 6-1 p.33)

Task 2: Determine the mean roof height of the building in feet.

Task 3: Determine $\lambda$, the adjustment factor for building height and exposure category. There are three exposure categories:

- Exposure B:
  - Suburban and residential areas with mostly single-family dwellings
  - Low-rise structures, less than 30 feet high
  - Urban areas with numerous closely spaced obstructions having size of single family dwellings or larger

- Exposure C:
  - Flat open grasslands with scattered obstructions having heights generally less than 30 feet
  - Open terrain with scattered obstructions having heights generally less than 30 feet for most wind directions
  - Structures are all less than 1500 feet or 10 times their height, whichever, from an open field that prevents the use of Exposure B

- Exposure D:
  - A building at the shoreline (excluding shorelines in hurricane-prone regions) with wind flowing over open water for a distance of at least 1 mile
  - Shorelines in exposure D include inland waterways, the Great Lakes, and coastal areas of California, Oregon, Washington, and Alaska

For further details on exposure categories, please consult 6.5.6.3 in the ASCE 7-05. With these exposure categories, look up the values of $\lambda$, as specified from the following table:

| Adjustment Factor for Building Height and Exposure, $\lambda$ | | | |
|---|---|---|---|
| **Mean roof height (ft)** | Exposure Category | | |
| | B | C | D |
| **15** | 1.00 | 1.21 | 1.47 |
| **20** | 1.00 | 1.29 | 1.55 |
| **25** | 1.00 | 1.35 | 1.61 |
| **30** | 1.00 | 1.40 | 1.66 |
| **35** | 1.05 | 1.45 | 1.70 |
| **40** | 1.09 | 1.49 | 1.74 |
| **45** | 1.12 | 1.53 | 1.78 |
| **50** | 1.16 | 1.56 | 1.81 |
| **55** | 1.19 | 1.59 | 1.84 |
| **60** | 1.22 | 1.62 | 1.87 |

Taken from ASCE 7-05, Figure 6.3, p. 44

Task 4: Determine $K_{zt}$, the topographic factor. For the purpose of this installation manual, this value will be taken to be 1. This signifies that the installation site is surrounded by ground level with no abrupt changes in general topography. If this is not the case, consult section 6.5.7 in the ASCE 7-05.

Task 5: Determine *I*, the importance factor. The importance factor accounts for the degree of hazard to human life and damage to property. Using the structure classification description provided on the next page, determine the value of *I* from the table below:

| Category | Importance Factor |
|---|---|
| **I** | .87 |
| **II** | 1.00 |
| **III** | 1.15 |
| **IV** | 1.15 |

Adapted from ASCE 7-05 Table 6-1, p.77

| Occupancy Category | **Nature of Occupancy** |
|---|---|
| I | Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to:<br>• Agricultural Facilities<br>• Certain temporary facilities<br>• Minor storage facilities |
| II | Buildings and other structures except those listed in Categories I, III, and IV |
| III | Structures that represent a substantial hazard to human life in the event of failure including, but no limited to:<br>• Buildings where more than 300 people congregate in one area<br>• Buildings with day-care facilities with capacity greater than 150<br>• Buildings with elementary or secondary schools with capacity greater than 250<br>• Buildings with an occupant load greater than 500 for colleges or adult education facilities<br>• Health care facilities with an occupant load of 50 or more resident patients, but not having surgery or emergency treatment facilities<br>• Jails and detention facilities<br>• Any other building with an occupant load greater than 5,000<br>• Power-generating stations, water treatment for potable water, waste water treatment facilities and other public utility facilities not included in Occupancy Category IV |
| IV | Building and other structures designated as essential facilities, including but not limited to:<br>• Hospitals and other health care facilities having surgery or emergency treatment facilities<br>• Fire, rescue, and police stations and emergency vehicle garages<br>• Designated earthquake, hurricane or other emergency shelters<br>• Designated emergency preparedness, communitcation, and operation centers and other facilities required for emergency response.<br>• Power-generating stations and other public utility facilities required as emergency backup facilities for Occupancy Category IV Structures<br>• Ancillary structures (including, but not limited to, communication towers, fuel storage tanks, cooling towers, electrical substation structures, fire water storage tanks, or other structures housing or supporting water, or emergency<br>• Aviation control towers, air traffic control centers, and emergency aircraft hangars<br>• Water storage facilities and pump structures required to maintain water pressure for fire suppression<br>• Buildings and other structures having critical national defense functions |

Adapted from ASCE 7-05 Table 1-1, p 3

Task 6: Calculate the Effective Wind Area, A. As defined in section 6.2 of the ASCE, this area is taken to be the "span length multiplied by an effective width that need not be less than one-third the span length." In other words, the Effective Wind Area is the area of the smallest continuous configuration of modules that will be installed. If this area is greater than 100 square feet, then 100 will be used.

Task 7: Determine the Roof & Wall Zone. The total design wind load is dependent upon where the installation is located on the roof. To determine the specific zones, follow these steps:

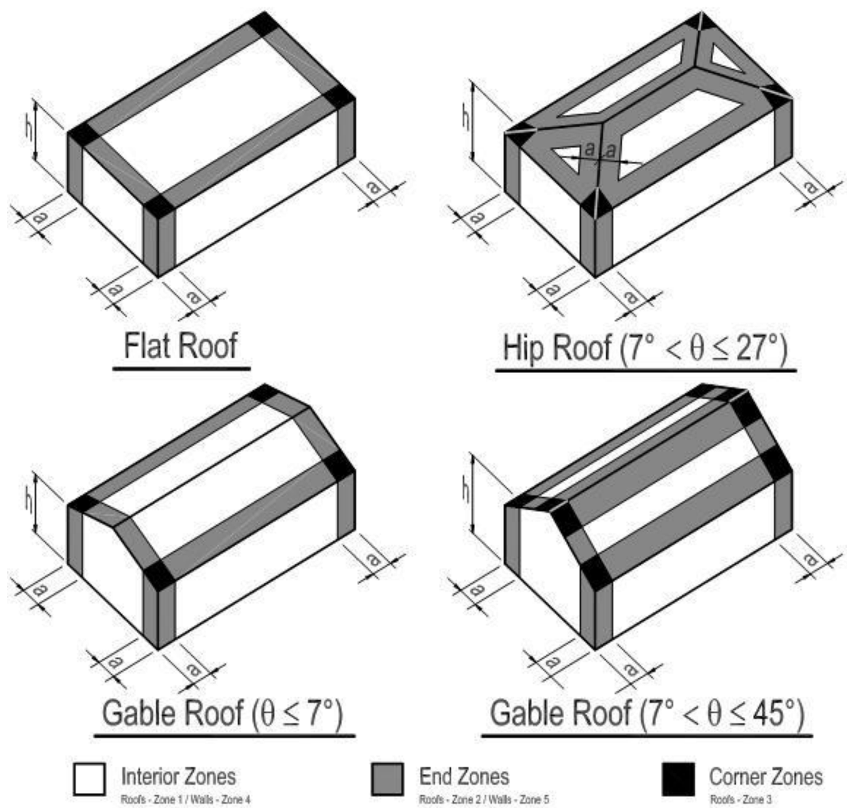
1. Calculate the length of the least horizontal dimension. The corresponding value *a* will be 10% of this dimension. Furthermore, take 40% of the mean roof height, *h*.
2. Compare *a* and *.4h,* and take the smaller value of the two. This value should not be less than 3 feet or 4% of the least horizontal dimension. Please see the chart below.
3. Finally, calculate the roof zone in accordance to the installation site. Determine $\theta$, the angle of the roof from the horizontal. See the figure on the next page.

For more information please refer to figure 6-3 of the ASCE 7-05.

| **Roof Height (ft)** | **Least Horizontal Dimension (ft)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 150 | 200 |
| **10** | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 6 | 8 |
| **20** | 3 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 8 | 8 | 8 |
| **30** | 3 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 12 |
| **40** | 3 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 16 |
| **50** | 3 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 20 |
| **60** | 3 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 20 |

Task 7: (Continued) In the figure shown below, identify the location of the installation site, and determine the angle of the roof. Then choose the appropriate zone as per the specifications. The zoning is determined as follows:

- Interior Zones are Zone 1/Walls are Zone 4
- End Zones are Zone 2/Walls are Zone 5
- Corner Zones are Zone 3




Taken from ASCE 7-05, figure 6-3 p. 41

Task 8: Determine $p_{net30}$. From Tasks 6, 7 we have determined both the Effective Wind Area A, and the Roof/Wall Zoning. With this information in hand, look up the value of the Net Design Wind Pressure, $p_{net30}$, as specified in the tables shown below. The two sets of values underneath the Basic Wind Speed represent the down/uplift forces. The positive values are the down-forces, and corresponds to the force acting towards the surface. On the other hand the negative values correspond to the uplift force, and acts away from the surface. Both of these values are crucial to the loading analysis of a particular structure, and both must be considered. Refer to figure 6-3 in the ASCE 7-05 for more information.

**Components and Cladding – Method 1** | **h ≤ 60 ft.**

**Figure 6-3 (cont'd)** | **Net Design Wind Pressures** | **Walls & Roofs**

**Enclosed Buildings**

**Net Design Wind Pressure, $p_{net30}$ (psf)** *(Exposure B at h = 30 ft. with I = 1.0 and $K_{zt}$ = 1.0)*

| | Zone | Effective wind area (sf) | Basic Wind Speed V (mph) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 85 | | 90 | | 100 | | 105 | | 110 | | 120 | |
| Roof 0 to 7 degrees | 1 | 10 | 5.3 | -13.0 | 5.9 | -14.6 | 7.3 | -18.0 | 8.1 | -19.8 | 8.9 | -21.8 | 10.5 | -25.9 |
| | 1 | 20 | 5.0 | -12.7 | 5.6 | -14.2 | 6.9 | -17.5 | 7.6 | -19.3 | 8.3 | -21.2 | 9.9 | -25.2 |
| | 1 | 50 | 4.5 | -12.2 | 5.1 | -13.7 | 6.3 | -16.9 | 6.9 | -18.7 | 7.6 | -20.5 | 9.0 | -24.4 |
| | 1 | 100 | 4.2 | -11.9 | 4.7 | -13.3 | 5.8 | -16.5 | 6.4 | -18.2 | 7.0 | -19.9 | 8.3 | -23.7 |
| | 2 | 10 | 5.3 | -21.8 | 5.9 | -24.4 | 7.3 | -30.2 | 8.1 | -33.3 | 8.9 | -36.5 | 10.5 | -43.5 |
| | 2 | 20 | 5.0 | -19.5 | 5.6 | -21.8 | 6.9 | -27.0 | 7.6 | -29.7 | 8.3 | -32.6 | 9.9 | -38.8 |
| | 2 | 50 | 4.5 | -16.4 | 5.1 | -18.4 | 6.3 | -22.7 | 6.9 | -25.1 | 7.6 | -27.5 | 9.0 | -32.7 |
| | 2 | 100 | 4.2 | -14.1 | 4.7 | -15.8 | 5.8 | -19.5 | 6.4 | -21.5 | 7.0 | -23.6 | 8.3 | -28.1 |
| | 3 | 10 | 5.3 | -32.8 | 5.9 | -36.8 | 7.3 | -45.4 | 8.1 | -50.1 | 8.9 | -55.0 | 10.5 | -65.4 |
| | 3 | 20 | 5.0 | -27.2 | 5.6 | -30.5 | 6.9 | -37.6 | 7.6 | -41.5 | 8.3 | -45.5 | 9.9 | -54.2 |
| | 3 | 50 | 4.5 | -19.7 | 5.1 | -22.1 | 6.3 | -27.3 | 6.9 | -30.1 | 7.6 | -33.1 | 9.0 | -39.3 |
| | 3 | 100 | 4.2 | -14.1 | 4.7 | -15.8 | 5.8 | -19.5 | 6.4 | -21.5 | 7.0 | -23.6 | 8.3 | -28.1 |
| Roof > 7 to 27 degrees | 1 | 10 | 7.5 | -11.9 | 8.4 | -13.3 | 10.4 | -16.5 | 11.4 | -18.2 | 12.5 | -19.9 | 14.9 | -23.7 |
| | 1 | 20 | 6.8 | -11.6 | 7.7 | -13.0 | 9.4 | -16.0 | 10.4 | -17.6 | 11.4 | -19.4 | 13.6 | -23.0 |
| | 1 | 50 | 6.0 | -11.1 | 6.7 | -12.5 | 8.2 | -15.4 | 9.1 | -17.0 | 10.0 | -18.6 | 11.9 | -22.2 |
| | 1 | 100 | 5.3 | -10.8 | 5.9 | -12.1 | 7.3 | -14.9 | 8.1 | -16.5 | 8.9 | -18.1 | 10.5 | -21.5 |
| | 2 | 10 | 7.5 | -20.7 | 8.4 | -23.2 | 10.4 | -28.7 | 11.4 | -31.6 | 12.5 | -34.7 | 14.9 | -41.3 |
| | 2 | 20 | 6.8 | -19.0 | 7.7 | -21.4 | 9.4 | -26.4 | 10.4 | -29.1 | 11.4 | -31.9 | 13.6 | -38.0 |
| | 2 | 50 | 6.0 | -16.9 | 6.7 | -18.9 | 8.2 | -23.3 | 9.1 | -25.7 | 10.0 | -28.2 | 11.9 | -33.6 |
| | 2 | 100 | 5.3 | -15.2 | 5.9 | -17.0 | 7.3 | -21.0 | 8.1 | -23.2 | 8.9 | -25.5 | 10.5 | -30.3 |
| | 3 | 10 | 7.5 | -30.6 | 8.4 | -34.3 | 10.4 | -42.4 | 11.4 | -46.7 | 12.5 | -51.3 | 14.9 | -61.0 |
| | 3 | 20 | 6.8 | -28.6 | 7.7 | -32.1 | 9.4 | -39.6 | 10.4 | -43.7 | 11.4 | -47.9 | 13.6 | -57.1 |
| | 3 | 50 | 6.0 | -26.0 | 6.7 | -29.1 | 8.2 | -36.0 | 9.1 | -39.7 | 10.0 | -43.5 | 11.9 | -51.8 |
| | 3 | 100 | 5.3 | -24.0 | 5.9 | -26.9 | 7.3 | -33.2 | 8.1 | -36.6 | 8.9 | -40.2 | 10.5 | -47.9 |
| Roof > 27 to 45 degrees | 1 | 10 | 11.9 | -13.0 | 13.3 | -14.6 | 16.5 | -18.0 | 18.2 | -19.8 | 19.9 | -21.8 | 23.7 | -25.9 |
| | 1 | 20 | 11.6 | -12.3 | 13.0 | -13.8 | 16.0 | -17.1 | 17.6 | -18.8 | 19.4 | -20.7 | 23.0 | -24.6 |
| | 1 | 50 | 11.1 | -11.5 | 12.5 | -12.8 | 15.4 | -15.9 | 17.0 | -17.5 | 18.6 | -19.2 | 22.2 | -22.8 |
| | 1 | 100 | 10.8 | -10.8 | 12.1 | -12.1 | 14.9 | -14.9 | 16.5 | -16.5 | 18.1 | -18.1 | 21.5 | -21.5 |
| | 2 | 10 | 11.9 | -15.2 | 13.3 | -17.0 | 16.5 | -21.0 | 18.2 | -23.2 | 19.9 | -25.5 | 23.7 | -30.3 |
| | 2 | 20 | 11.6 | -14.5 | 13.0 | -16.3 | 16.0 | -20.1 | 17.6 | -22.2 | 19.4 | -24.3 | 23.0 | -29.0 |
| | 2 | 50 | 11.1 | -13.7 | 12.5 | -15.3 | 15.4 | -18.9 | 17.0 | -20.8 | 18.6 | -22.9 | 22.2 | -27.2 |
| | 2 | 100 | 10.8 | -13.0 | 12.1 | -14.6 | 14.9 | -18.0 | 16.5 | -19.8 | 18.1 | -21.8 | 21.5 | -25.9 |
| | 3 | 10 | 11.9 | -15.2 | 13.3 | -17.0 | 16.5 | -21.0 | 18.2 | -23.2 | 19.9 | -25.5 | 23.7 | -30.3 |
| | 3 | 20 | 11.6 | -14.5 | 13.0 | -16.3 | 16.0 | -20.1 | 17.6 | -22.2 | 19.4 | -24.3 | 23.0 | -29.0 |
| | 3 | 50 | 11.1 | -13.7 | 12.5 | -15.3 | 15.4 | -18.9 | 17.0 | -20.8 | 18.6 | -22.9 | 22.2 | -27.2 |
| | 3 | 100 | 10.8 | -13.0 | 12.1 | -14.6 | 14.9 | -18.0 | 16.5 | -19.8 | 18.1 | -21.8 | 21.5 | -25.9 |
| Wall | 4 | 10 | 13.0 | -14.1 | 14.6 | -15.8 | 18.0 | -19.5 | 19.8 | -21.5 | 21.8 | -23.6 | 25.9 | -28.1 |
| | 4 | 20 | 12.4 | -13.5 | 13.9 | -15.1 | 17.2 | -18.7 | 18.9 | -20.6 | 20.8 | -22.6 | 24.7 | -26.9 |
| | 4 | 50 | 11.6 | -12.7 | 13.0 | -14.3 | 16.1 | -17.6 | 17.8 | -19.4 | 19.5 | -21.3 | 23.2 | -25.4 |
| | 4 | 100 | 11.1 | -12.2 | 12.4 | -13.6 | 15.3 | -16.8 | 16.9 | -18.5 | 18.5 | -20.4 | 22.0 | -24.2 |
| | 4 | 500 | 9.7 | -10.8 | 10.9 | -12.1 | 13.4 | -14.9 | 14.8 | -16.5 | 16.2 | -18.1 | 19.3 | -21.5 |
| | 5 | 10 | 13.0 | -17.4 | 14.6 | -19.5 | 18.0 | -24.1 | 19.8 | -26.6 | 21.8 | -29.1 | 25.9 | -34.7 |
| | 5 | 20 | 12.4 | -16.2 | 13.9 | -18.2 | 17.2 | -22.5 | 18.9 | -24.8 | 20.8 | -27.2 | 24.7 | -32.4 |
| | 5 | 50 | 11.6 | -14.7 | 13.0 | -16.5 | 16.1 | -20.3 | 17.8 | -22.4 | 19.5 | -24.6 | 23.2 | -29.3 |
| | 5 | 100 | 11.1 | -13.5 | 12.4 | -15.1 | 15.3 | -18.7 | 16.9 | -20.6 | 18.5 | -22.6 | 22.0 | -26.9 |
| | 5 | 500 | 9.7 | -10.8 | 10.9 | -12.1 | 13.4 | -14.9 | 14.8 | -16.5 | 16.2 | -18.1 | 19.3 | -21.5 |

**Unit Conversions – 1.0 ft = 0.3048 m; 1.0 psf = 0.0479 kN/m²**

| Components and Cladding – Method 1 | | h ≤ 60 ft. |
|---|---|---|
| Figure 6-3 (cont'd) | Net Design Wind Pressures | Walls & Roofs |
| Enclosed Buildings | | |

**Net Design Wind Pressure, $p_{net30}$ (psf)** *(Exposure B at h = 30 ft. with I = 1.0 and $K_{zt}$ = 1.0)*

| | Zone | Effective wind area (sf) | Basic Wind Speed V (mph) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 125 | | 130 | | 140 | | 145 | | 150 | | 170 | |
| Roof 0 to 7 degrees | 1 | 10 | 11.4 | -28.1 | 12.4 | -30.4 | 14.3 | -35.3 | 15.4 | -37.8 | 16.5 | -40.5 | 21.1 | -52.0 |
| | 1 | 20 | 10.7 | -27.4 | 11.6 | -29.6 | 13.4 | -34.4 | 14.4 | -36.9 | 15.4 | -39.4 | 19.8 | -50.7 |
| | 1 | 50 | 9.8 | -26.4 | 10.6 | -28.6 | 12.3 | -33.2 | 13.1 | -35.6 | 14.1 | -38.1 | 18.1 | -48.9 |
| | 1 | 100 | 9.1 | -25.7 | 9.8 | -27.8 | 11.4 | -32.3 | 12.2 | -34.6 | 13.0 | -37.0 | 16.7 | -47.6 |
| | 2 | 10 | 11.4 | -47.2 | 12.4 | -51.0 | 14.3 | -59.2 | 15.4 | -63.5 | 16.5 | -67.9 | 21.1 | -87.2 |
| | 2 | 20 | 10.7 | -42.1 | 11.6 | -45.6 | 13.4 | -52.9 | 14.4 | -56.7 | 15.4 | -60.7 | 19.8 | -78.0 |
| | 2 | 50 | 9.8 | -35.5 | 10.6 | -38.4 | 12.3 | -44.5 | 13.1 | -47.8 | 14.1 | -51.1 | 18.1 | -65.7 |
| | 2 | 100 | 9.1 | -30.5 | 9.8 | -33.0 | 11.4 | -38.2 | 12.2 | -41.0 | 13.0 | -43.9 | 16.7 | -56.4 |
| | 3 | 10 | 11.4 | -71.0 | 12.4 | -76.8 | 14.3 | -89.0 | 15.4 | -95.5 | 16.5 | -102.2 | 21.1 | -131.3 |
| | 3 | 20 | 10.7 | -58.5 | 11.6 | -63.6 | 13.4 | -73.8 | 14.4 | -79.1 | 15.4 | -84.7 | 19.8 | -108.7 |
| | 3 | 50 | 9.8 | -42.7 | 10.6 | -46.2 | 12.3 | -53.5 | 13.1 | -57.4 | 14.1 | -61.5 | 18.1 | -78.9 |
| | 3 | 100 | 9.1 | -30.5 | 9.8 | -33.0 | 11.4 | -38.2 | 12.2 | -41.0 | 13.0 | -43.9 | 16.7 | -56.4 |
| Roof > 7 to 27 degrees | 1 | 10 | 16.2 | -25.7 | 17.5 | -27.8 | 20.3 | -32.3 | 21.8 | -34.6 | 23.3 | -37.0 | 30.0 | -47.6 |
| | 1 | 20 | 14.8 | -25.0 | 16.0 | -27.0 | 18.5 | -31.4 | 19.9 | -33.7 | 21.3 | -36.0 | 27.3 | -46.3 |
| | 1 | 50 | 12.9 | -24.1 | 13.9 | -26.0 | 16.1 | -30.2 | 17.3 | -32.4 | 18.5 | -34.6 | 23.8 | -44.5 |
| | 1 | 100 | 11.4 | -23.2 | 12.4 | -25.2 | 14.3 | -29.3 | 15.4 | -31.4 | 16.5 | -33.6 | 21.1 | -43.2 |
| | 2 | 10 | 16.2 | -44.8 | 17.5 | -48.4 | 20.3 | -56.2 | 21.8 | -60.3 | 23.3 | -64.5 | 30.0 | -82.8 |
| | 2 | 20 | 14.8 | -41.2 | 16.0 | -44.6 | 18.5 | -51.7 | 19.9 | -55.4 | 21.3 | -59.3 | 27.3 | -76.2 |
| | 2 | 50 | 12.9 | -36.5 | 13.9 | -39.4 | 16.1 | -45.7 | 17.3 | -49.1 | 18.5 | -52.5 | 23.8 | -67.4 |
| | 2 | 100 | 11.4 | -32.9 | 12.4 | -35.6 | 14.3 | -41.2 | 15.4 | -44.2 | 16.5 | -47.3 | 21.1 | -60.8 |
| | 3 | 10 | 16.2 | -66.2 | 17.5 | -71.6 | 20.3 | -83.1 | 21.8 | -89.1 | 23.3 | -95.4 | 30.0 | -122.5 |
| | 3 | 20 | 14.8 | -61.9 | 16.0 | -67.0 | 18.5 | -77.7 | 19.9 | -83.3 | 21.3 | -89.2 | 27.3 | -114.5 |
| | 3 | 50 | 12.9 | -56.2 | 13.9 | -60.8 | 16.1 | -70.5 | 17.3 | -75.7 | 18.5 | -81.0 | 23.8 | -104.0 |
| | 3 | 100 | 11.4 | -51.9 | 12.4 | -56.2 | 14.3 | -65.1 | 15.4 | -69.9 | 16.5 | -74.8 | 21.1 | -96.0 |
| Roof > 27 to 45 degrees | 1 | 10 | 25.7 | -28.1 | 27.8 | -30.4 | 32.3 | -35.3 | 34.6 | -37.8 | 37.0 | -40.5 | 47.6 | -52.0 |
| | 1 | 20 | 25.0 | -26.7 | 27.0 | -28.9 | 31.4 | -33.5 | 33.7 | -35.9 | 36.0 | -38.4 | 46.3 | -49.3 |
| | 1 | 50 | 24.1 | -24.8 | 26.0 | -26.8 | 30.2 | -31.1 | 32.4 | -33.3 | 34.6 | -35.7 | 44.5 | -45.8 |
| | 1 | 100 | 23.3 | -23.3 | 25.2 | -25.2 | 29.3 | -29.3 | 31.4 | -31.4 | 33.6 | -33.6 | 43.2 | -43.2 |
| | 2 | 10 | 25.7 | -32.9 | 27.8 | -35.6 | 32.3 | -41.2 | 34.6 | -44.2 | 37.0 | -47.3 | 47.6 | -60.8 |
| | 2 | 20 | 25.0 | -31.4 | 27.0 | -34.0 | 31.4 | -39.4 | 33.7 | -42.3 | 36.0 | -45.3 | 46.3 | -58.1 |
| | 2 | 50 | 24.1 | -29.5 | 26.0 | -32.0 | 30.2 | -37.1 | 32.4 | -39.8 | 34.6 | -42.5 | 44.5 | -54.6 |
| | 2 | 100 | 23.2 | -28.1 | 25.2 | -30.4 | 29.3 | -35.3 | 31.4 | -37.8 | 33.6 | -40.5 | 43.2 | -52.0 |
| | 3 | 10 | 25.7 | -32.9 | 27.8 | -35.6 | 32.3 | -41.2 | 34.6 | -44.2 | 37.0 | -47.3 | 47.6 | -60.8 |
| | 3 | 20 | 25.0 | -31.4 | 27.0 | -34.0 | 31.4 | -39.4 | 33.7 | -42.3 | 36.0 | -45.3 | 46.3 | -58.1 |
| | 3 | 50 | 24.1 | -29.5 | 26.0 | -32.0 | 30.2 | -37.1 | 32.4 | -39.8 | 34.6 | -42.5 | 44.5 | -54.6 |
| | 3 | 100 | 23.3 | -28.1 | 25.2 | -30.4 | 29.3 | -35.3 | 31.4 | -37.8 | 33.6 | -40.5 | 43.2 | -52.0 |
| Wall | 4 | 10 | 28.1 | -30.5 | 30.4 | -33.0 | 35.3 | -38.2 | 37.8 | -41.0 | 40.5 | -43.9 | 52.0 | -56.4 |
| | 4 | 20 | 26.8 | -29.2 | 29.0 | -31.6 | 33.7 | -36.7 | 36.1 | -39.3 | 38.7 | -42.1 | 49.6 | -54.1 |
| | 4 | 50 | 25.2 | -27.5 | 27.2 | -29.8 | 31.6 | -34.6 | 33.9 | -37.1 | 36.2 | -39.7 | 46.6 | -51.0 |
| | 4 | 100 | 23.9 | -26.3 | 25.9 | -28.4 | 30.0 | -33.0 | 32.2 | -35.4 | 34.4 | -37.8 | 44.2 | -48.6 |
| | 4 | 500 | 21.0 | -23.3 | 22.7 | -25.2 | 26.3 | -29.3 | 28.2 | -31.4 | 30.2 | -33.6 | 38.8 | -43.2 |
| | 5 | 10 | 28.1 | -37.6 | 30.4 | -40.7 | 35.3 | -47.2 | 37.8 | -50.6 | 40.5 | -54.2 | 52.0 | -69.6 |
| | 5 | 20 | 26.8 | -35.1 | 29.0 | -38.0 | 33.7 | -44.0 | 36.1 | -47.2 | 38.7 | -50.5 | 49.6 | -64.9 |
| | 5 | 50 | 25.2 | -31.8 | 27.2 | -34.3 | 31.6 | -39.8 | 33.9 | -42.7 | 36.2 | -45.7 | 46.6 | -58.7 |
| | 5 | 100 | 23.9 | -29.2 | 25.9 | -31.6 | 30.0 | -36.7 | 32.2 | -39.3 | 34.4 | -42.1 | 44.2 | -54.1 |
| | 5 | 500 | 21.0 | -23.2 | 22.7 | -25.2 | 26.3 | -29.3 | 28.2 | -31.1 | 30.2 | -33.6 | 38.8 | -43.2 |

**Unit Conversions – 1.0 ft = 0.3048 m; 1.0 psf = 0.0479 kN/m²**

From ASCE 7-05, figure 6-3 p. 42-43

# IV. Calculating the Snow Load:

## A. Snow Loading Worksheet

Included below is a worksheet of the values needed to compute the snow load.

| Quantity | Value | Task/Page |
| --- | --- | --- |
| **Ground Snow Load $p_g$** (psf) | | Task 1, Page 13 |
| **Exposure Factor $C_e$** | | Task 2, Page 13 |
| **Thermal Factor $C_t$** | | Task 3, Page 13 |
| **Occupancy Category** | | Page 7 |
| **Importance Factor *I*** | | Task 4, Page 14 |
| **Flat Roof Snow Load $p_f$** (psf) | | Task 5, Page 14 |
| **Roof Slope Factor $C_s$** | | Task 6, Page 17 |

$$p_f = 0.7 C_e C_t I p_g$$

$$p_s = C_s p_f$$

Sloped Roof Snow Load $p_s$(psf) ___________________________________________

For an online calculator that computes the snow load, please follow this online link:

http://courses.cit.cornell.edu/arch264/calculators/example2.3/index.html

http://www.buildingsguide.com/calculators/structural/ASCE705S/

## B. Snow Loading Calculation Procedure

This section is concerned with the effects of snow loading on a particular fixed structure. On sloped roofs, the snow load is:

$$p_s = C_s p_f$$

Where:
$p_s$ represents the sloped roof snow load
$C_s$ is the roof slope factor
$p_f$ is the flat roof snow load

Hence, in order to calculate the sloped roof snow load, one must find the corresponding flat roof snow load, and multiply that value with the appropriate coefficients. The methodology that will be used is outlined in chapter 7 of the ASCE 7-05. Please refer to this book for further information.

Task 1: Calculate the ground snow load, $p_g$. The ground snow load should be based upon the extreme values in the vicinity of the installation site. These values are shown on the map in pages 15-16. Select the value that corresponds to the installation site. If the site is located in an area that is represented by a "CS," it means that the snow fall is highly variable. In this scenario, consult a local professional for the ground snow load.

Task 2: Determine the Exposure Factor, $C_e$. These values may be determined from the table below, which lists the values for a fully and partially exposed roof. A fully exposed roof is defined to be a roof that is exposed on all sides with no shelter provided by terrain, trees, or other higher structures. Partially exposed roofs are roofs that have some form of shelter as afforded by the environment. For information on the Exposure Category, please refer back to pages 4-5 for specific descriptions.

| Exposure Category | Fully Exposed | Partially Exposed |
|---|---|---|
| **B** | 0.9 | 1.0 |
| **C** | 0.9 | 1.0 |
| **D** | 0.8 | 0.9 |

Adapted from table 7-2, p. 92 of the ASCE 7-05

Task 3: Determine the Thermal Factor, $C_t$. This variable describes the thermal condition of the structure, and in most cases is 1. However in special cases the value of this coefficient may change, and is described in the table below:

| Thermal Condition | $C_t$ |
|---|---|
| **All structures except those below** | 1.0 |
| **Structures kept just above freezing** | 1.1 |
| **Unheated structures kept below freezing** | 1.2 |
| **Continuously heated greenhouses** | 0.85 |

Adapted from Table 7-3, p. 93 of the ASCE 7-05

Task 4: Determine the Importance Factor *I*. See page 7 for the structure classification descriptions. After selecting the appropriate category for the installation site, look up the corresponding value in the following table:

| Category | *I* |
|---|---|
| I | 0.8 |
| II | 1.0 |
| III | 1.1 |
| IV | 1.2 |

Taken from table 7-4, p. 93 of the ASCE 7-05

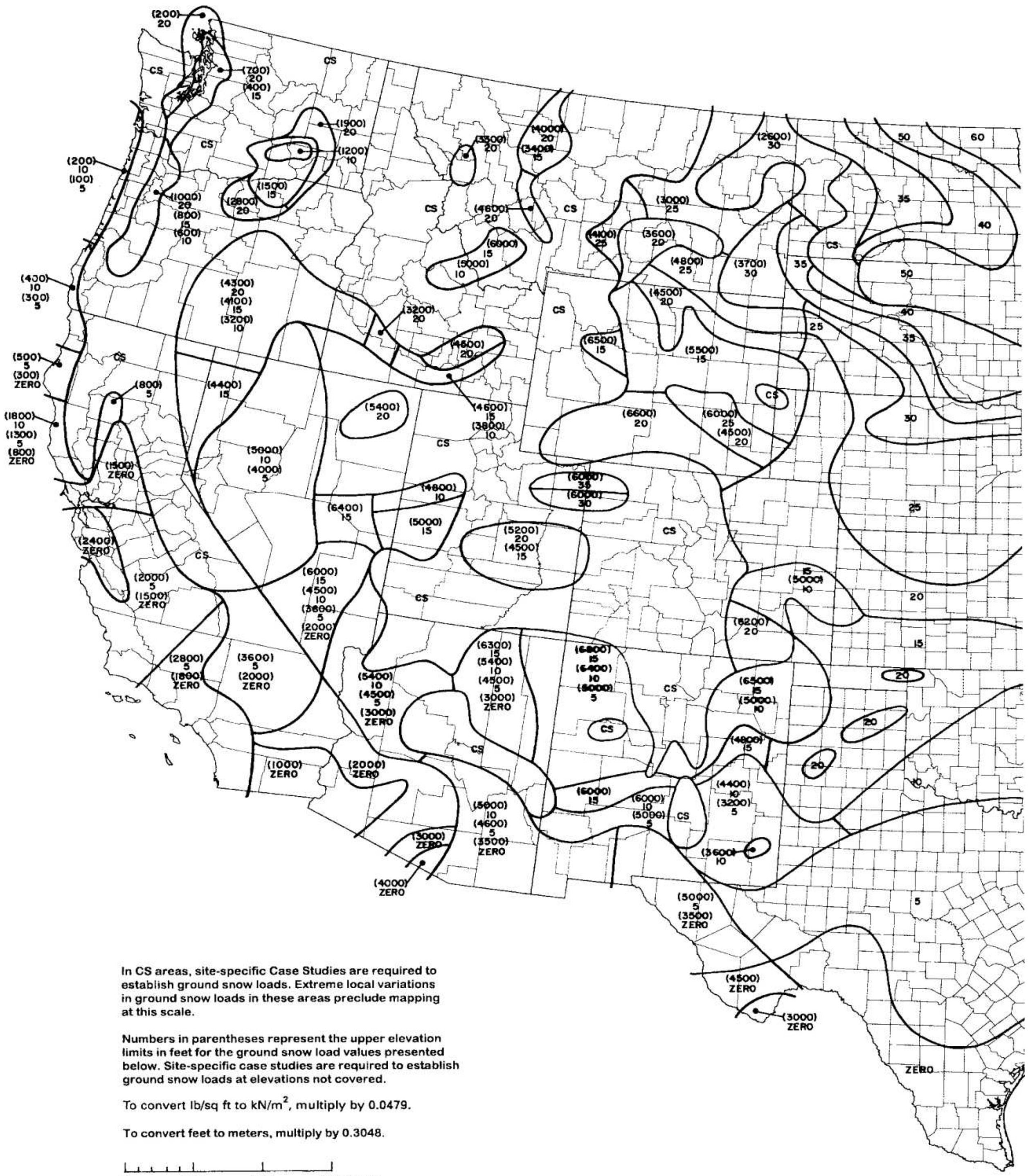
Task 5: From the values recorded from the previous steps, calculate the flat roof snow load, $p_f$. This snow load is applicable only to a roof with a slope equal to or less than 5 degrees. The equation used to determine this value is:

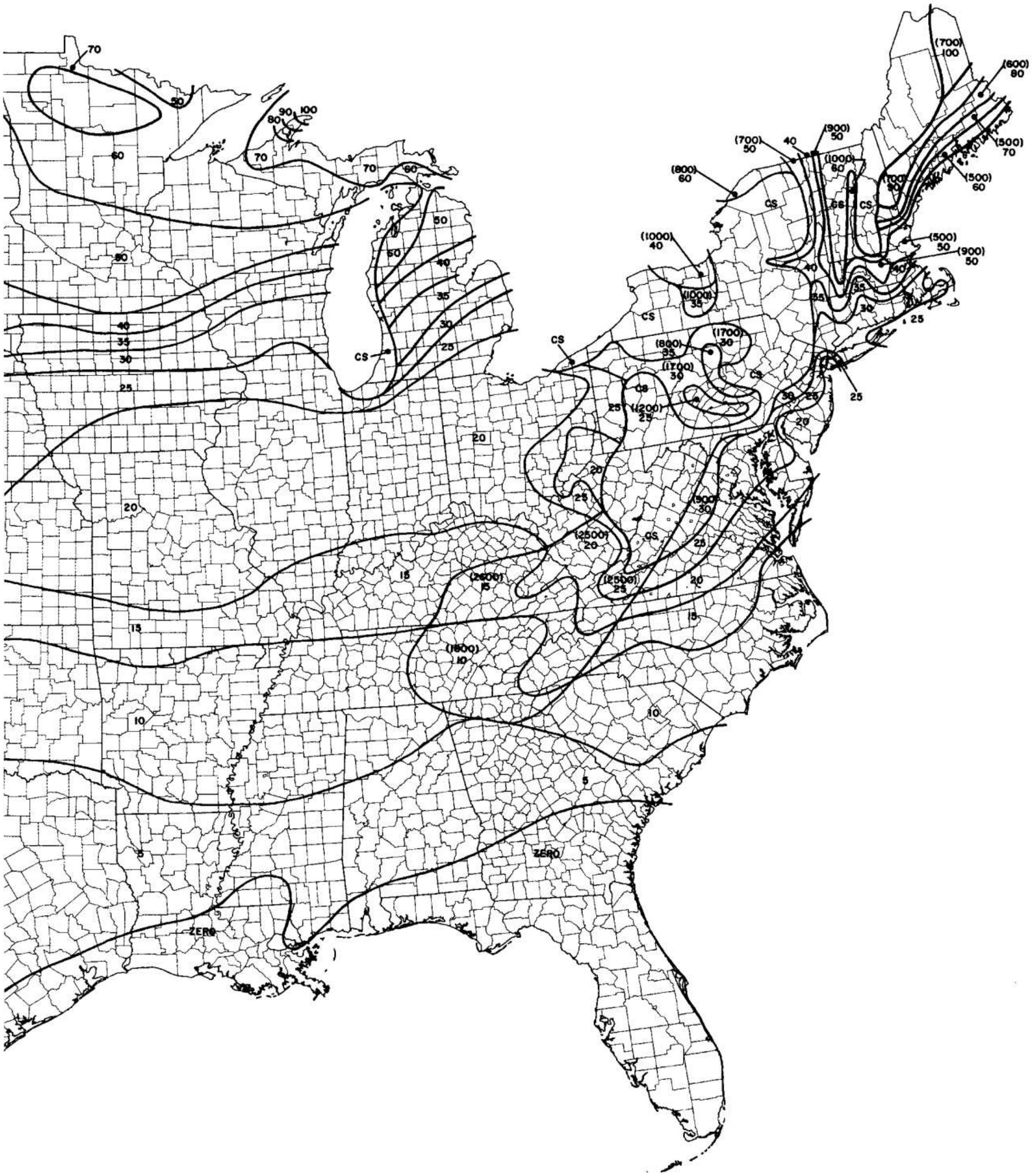
$$p_f = 0.7 C_e C_t I p_g$$

Flat roof snow load have minimum values, and are dependent on the value of the ground snow load. That is if:

1. $p_g$ is 20 pounds per feet squared or less, then $p_f = I p_g$
2. $p_g$ is greater than 20 pounds per feet squared then: $p_f = 20I$

The next two pages include the values of the various ground snow loads in the United States. If your location is not included, please consult a local engineer.




70
60
50
90
100
80
70
CS
40
35
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20
15
10
5
ZERO
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35
(1700)
30
(800)
35
(1700)
30
(1200)
25
(900)
30
(2500)
20
(2600)
15
(2500)
25
(1800)
10

Task 6: Calculate the sloped roof snow load $p_s$, using the formula from above: $p_s = C_s p_f$ . The values of $C_s$ are determined based upon the thermal factor, and the state of the roof. After installing the solar panels upon the roof, the area in consideration becomes a "slippery surface." As for such, when looking up values in the table shown below, please refer to the dashed lines.
For more information, please refer to section 7.4 of the ASCE 7-05.

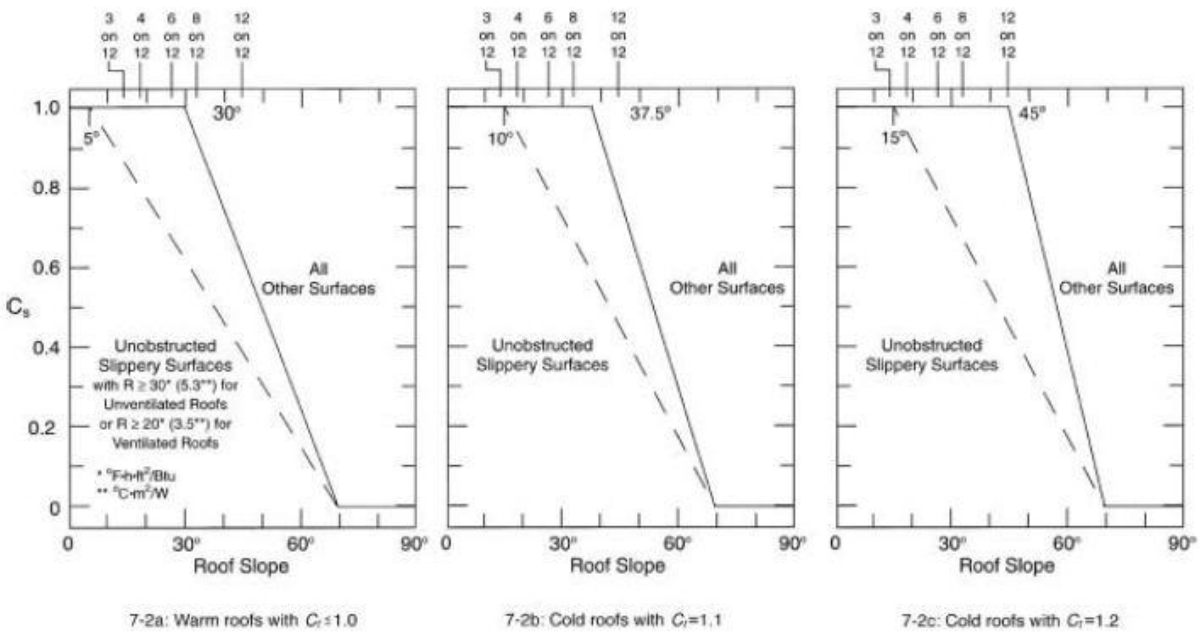



FIGURE 7-2 GRAPHS FOR DETERMINING ROOF SLOPE FACTOR $C_S$ FOR WARM AND COLD ROOFS (SEE TABLE 7-3 FOR $C_t$ DEFINITIONS)

Figure 7-2 from ASCE 7-05 p. 86

## V. Load Combinations

Often times, there is a good chance that various types of system loads are acting on a system simultaneously. Because these various loads provide different cumulative loads, the combination that produces the highest total system load must be taken into consideration. Hence, this value shall govern the system design. Shown below are the different cumulative loads as taken from Section 2.4 of the ASCE 7-05. Not all of the combinations have been shown, only the ones that are relevant to the solar racking system.

Down-Force Loading Combinations:

$$Sum_1 = D + p_s$$

$$Sum_2 = D + p_{net}$$

$$Sum_3 = D + 0.75(p_s + p_{net})$$

Uplift Force Combination:

$$Sum_4 = .6D + p_{net}$$

Here D is referred to as the dead load, or the total net weight of the system, while $p_s, p_{net}$ refer to the sloped snow load and the wind design load respectively. The use of each of these equations is dependent on the environmental conditions that are present. For example, $Sum_1$ would be applicable when there is a combination of both the snow and the dead load of the system. However, if there was also a wind pressure present in addition to these two loads, one would then use $Sum_3$. Similarly $Sum_2$ is reserved for cases when there is only wind loading present in addition to the weight of the system.

Please note that for the "Uplift Force Combination," the negative value for the wind design load needs to be used. The negative value signifies the fact that the force is acting away from the surface, not towards.

## VI. Roof Mounting:

The Evolution PR system is designed to be attached directly to the roof deck of the customer's house. With the preliminary analysis of the systems loading completed, it is necessary to work out the details for the roof mounting, in order to insure a proper and secure installation of the racking system.

The main concern of the roof mounting analysis is the withdrawal load. The withdrawal load is the force required to remove a screw by withdrawing in line with the screw. This force is directly proportional to the diameter of the screw as well as its length. Furthermore, the withdrawal load is also dependent on the type of wood used in the roofing. Hence, a safety factor of 4 is recommended to account for the many different types of materials used.

Evolution PR utilizes the TEKS self tapping screw. This screw is threaded throughout its length and has a water-resistant seal. These fasteners are drilled through the provided holes on the Evolution PR directly into the roof decking. In the table shown below, the specific values of the pull out strengths are given against different roof decks.

| Pull-Out Test Results, Average Ultimate Failure Values | |
|---|---|
| **Material Used** | Pull out Strength (lbs) |
| **SPF #2** | 1080 |
| **CDX ½"** | 520 |
| **CDX 5/8"** | 430 |
| **CDX ¾"** | 718 |
| **OSB 7/16"** | 213 |
| **OSB 15/32"** | 223 |
| **OSB 19/32"** | 301 |

Source: http://www.atlasfasteners.com/woodmetal.htm

SPF is framing lumber, CDX is plywood, and OSB is strands of wood hot pressed together.

The Evolution PR has a 1/8" layer of butyl mastic sealing tape on its bottom and five predrilled holes for deck screws. Because pull out strength is a linear function of the screws, the Evolution PR system has enough holes to account for the safety factor of 4.

## VII. Calculation of Critical Test Load

The purpose of this section is to go through the calculations described in the manual, by applying it to a critical test load. Here the critical test load signifies the highest stress loads a system may theoretically come to experience. As for such, we will make the following assumptions in our calculations:

1. The Basic Wind Speed is 130 mph
2. The mean roof height is 60 ft
3. Exposure Category D, hence a value of $\lambda$ of 1.87
4. Topographic value of $K_{zt}$=1
5. Importance Factor *I*= 1.0
6. Effective Wind Area A=20 square feet
7. Net Design Wind Pressure $p_{net30}$, 12.4 (Down-Force), -76.8 (Uplift)
8. Roofing material 5/8" CDX plywood

With these numbers, the net design pressure $p_{net}$ is:

$$p_{net} = \lambda K_{zt} I p_{net30}$$

$$p_{net} = (1.87)(1)(1)(12.4) = 23.19$$

$$p_{net} = (1.87)(1)(1)(-76.8) = -143.6\,psf$$

If the area of the solar module A is 20 square feet, we must multiply the net design pressure by 20:

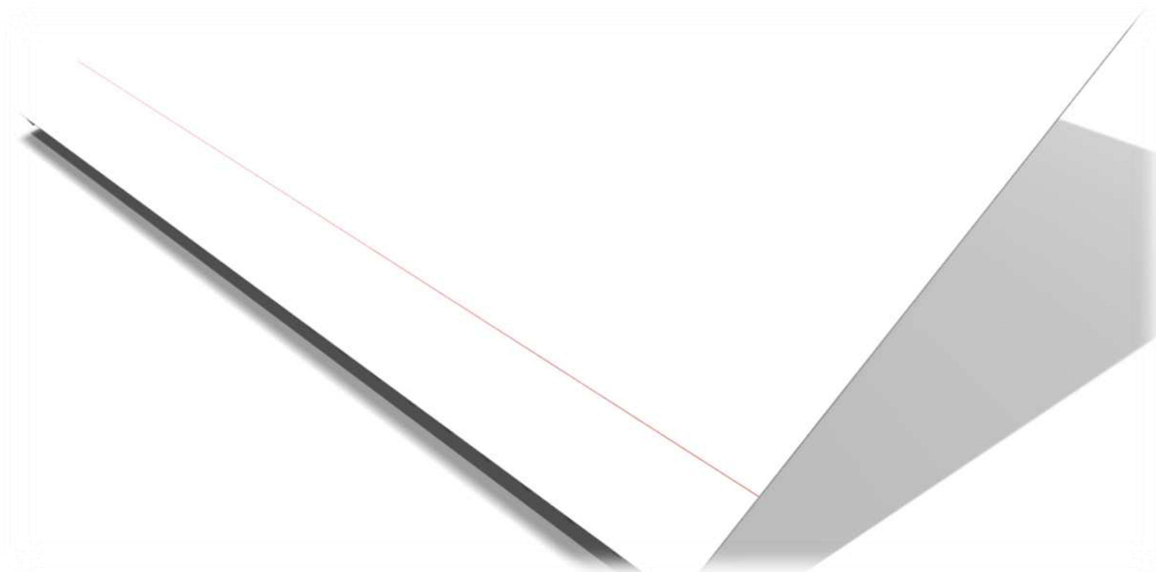
$$(-143.6)(20) = -2872\,lb$$

There is a total of 2872 pounds of uplift at the installation site. However, this wind load is distributed to 2 Evolution PRs, each having 5 screws. Hence, this force is effectively distributed between 10 screws at (2872)/(10) pounds each, or 287.2 pounds/screw. However, because the pullout strength for the CDX roofing material is 430 pounds (see the previous page), the system will not fail.

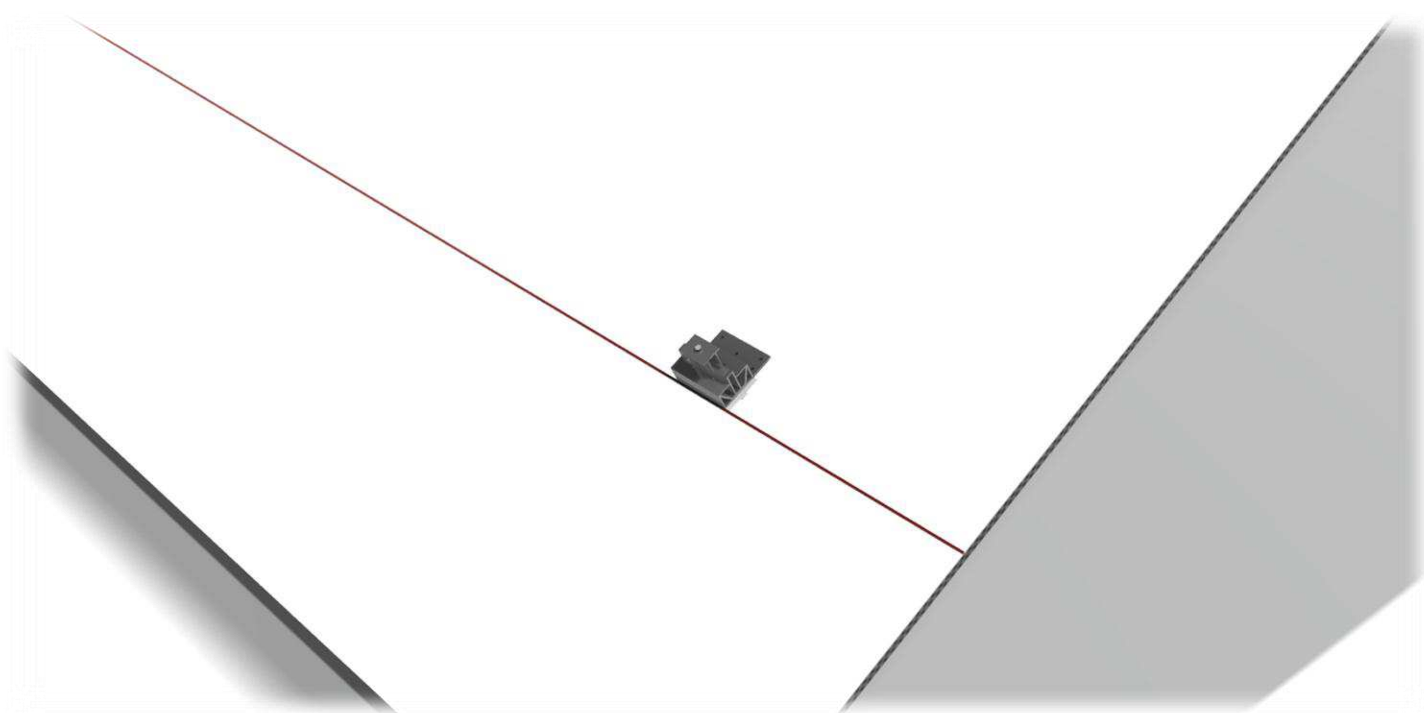
## VIII. Evolution PR Installation Instructions:

Evolution PR is easily adaptable to a variety of site plans, allowing flexibility to work around mild obstacles and gives leeway to human error in array alignment. In order to insure as efficient installation as possible, installers should follow these guidelines as close as possible:

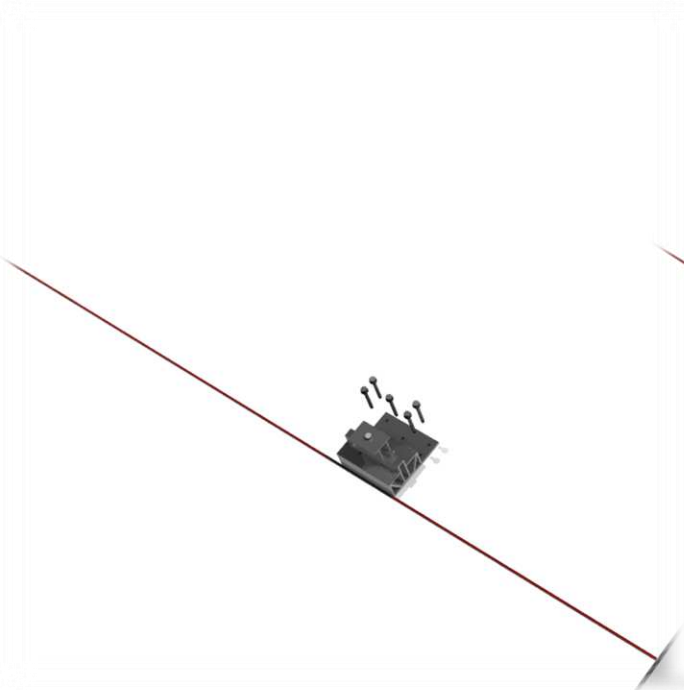
Step 1: Start by using a chalk line to make a square for your solar array. Be sure to properly align this square within the building zones your project has been approved.



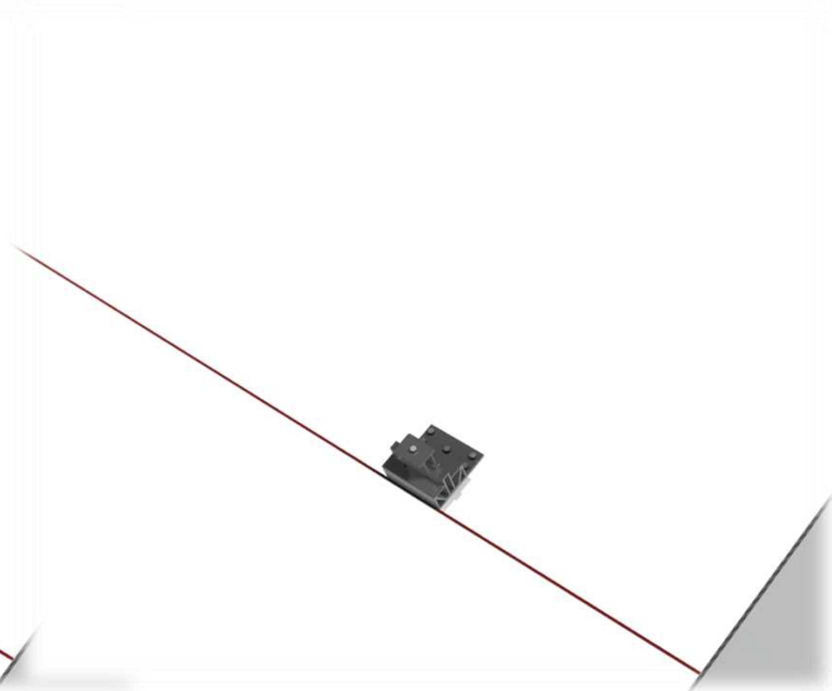
Step 2: Starting at one of the bottom corners of the roof, place the Evolution PR within a couple of feet from the edge. Make sure that the fastener holes are pointing north, in order to give the installation a pleasant aesthetic look.



Step 3: After positioning the Evolution PR, take off the butyl mastic tape and secure its position onto the roof. Taking the TEK self-tapping screws, attach them to the roof through the designated holes.

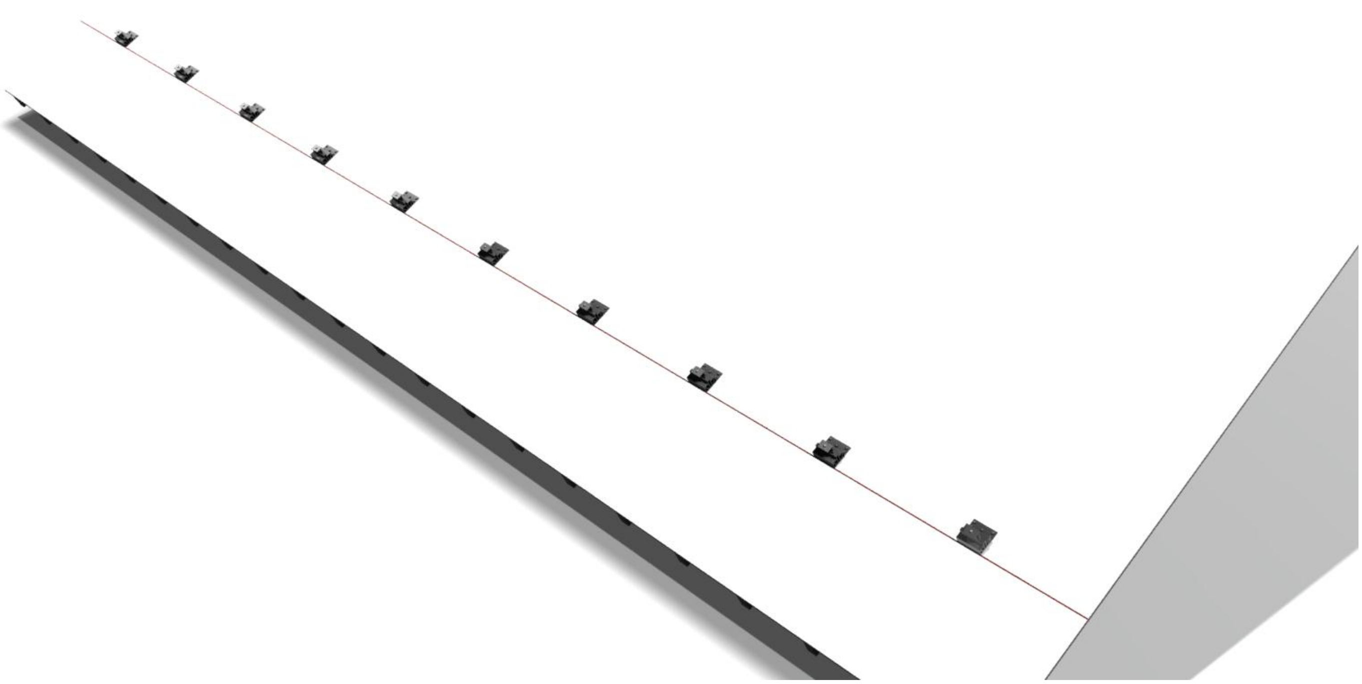


Step 1

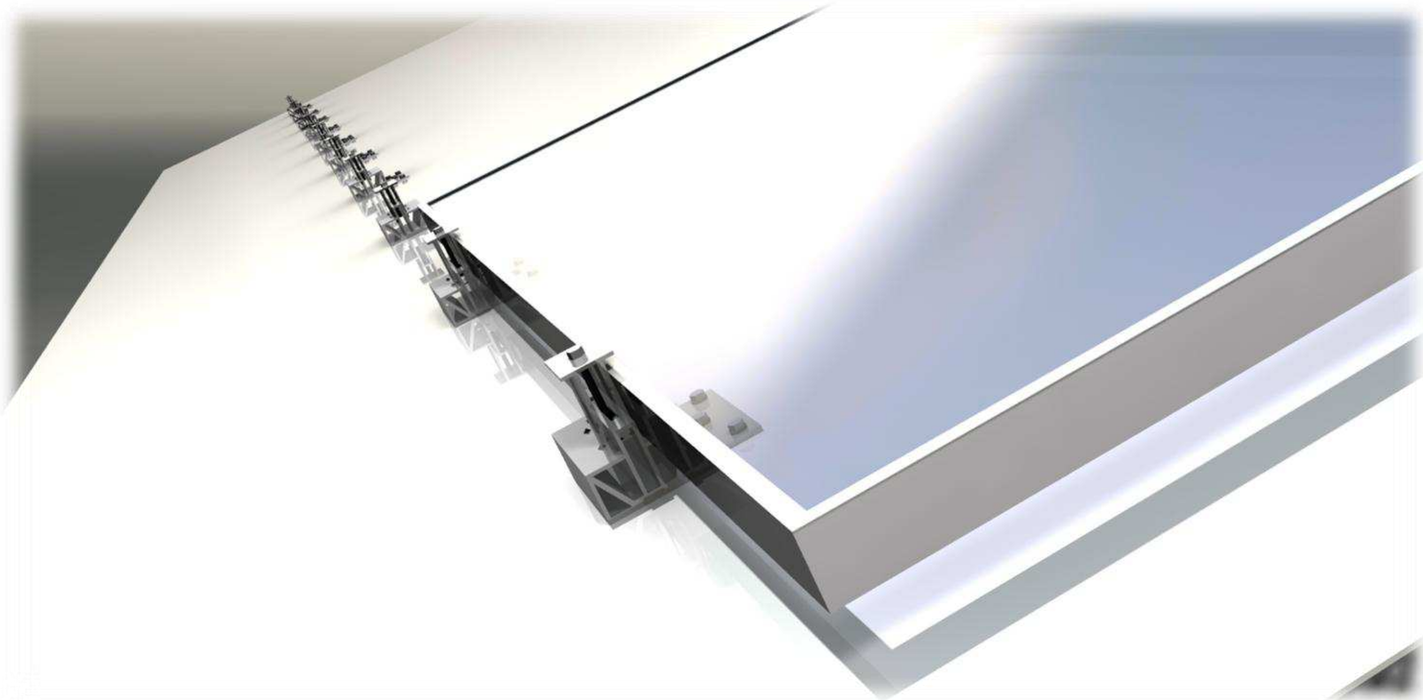


Step 2

Step 4: Continuing down the chalk line, attach the next Evolution PR a few feet apart from the first, and secure it to the roof. Repeat this step all the way to the other corner.



Step 5: Position the first solar module so a ¼ of its length extends beyond the first two bottom bases. After positioning it, place it under the clamps of the Evolution PR.



Step 6: Add a new row of Evolution PR bases, approximately in line with the first set. The Evolution PR has channels, allowing for flexibility in positioning. Attach the solar panel under the clamps of these new set of mounts.

Step 7: Secure the solar panel in place by screwing down the clamps on the base row.

Step 8: Repeat steps 5-7 until first column has all modules placed. Make sure to screw down the clamps of the previous row, to properly secure module in place.

Step 9: When the end of the column has been reached, attach the last set of Evolution PR bases by positioning the deck screw holes under the last module. Attaching the butyl mastic tape to the roof, fasten the last row of Evolution PRs in position, and secure the solar panel under the clamps. Screw down any remaining clamps, insuring that the modules are properly installed. Reversing the position of the deck screws will give a more aesthetically pleasing installation.

Step 10: Repeat steps 5-9 for the consequent columns, by attaching new sets of Evolution PRs, solar panels and securing them in place.