ECLIPSE ENGINEERING INC.

January 9, 2013

Mr. Rick Nichols
Sunlight Solar Energy, Inc.
50 SE Scott Street – Suite #13
Bend, OR 97702

City of Portland
REVIEWED FOR CODE COMPLIANCE
JAN 10 2013
(1)
Permit Number

Re: Smith Residence - Solar Panel Attachment
2441 SE Sherman Street
Portland, Oregon 97214

Rick,

As requested, we have reviewed the solar array connection to the building structure at the above noted residence. The purpose of our review is to determine the required spacing of the connection points to the existing roof structure. We have also analyzed the roof rafters to verify the adequacy of the existing framing members to support the additional load from the solar panels. The solar array consists of 12 Solarworld SW255 Mono solar panels located on the south side of the roof in two rows of six panels each. The roof ridge is a maximum of 27' above grade and is sloped at 10 degrees from the horizontal.

As provided by Sunlight Solar, the existing roof structure at the proposed solar array locations consists of a 2x10 rafters spaced at 16" o.c. supported by glu-lam beams at the ridge and mid points. The solar panels will be installed in landscape format with (2) rails along each row of panels as shown on Detail 1 of Sheet PV2.0 provided by Sunlight Solar. The rails installed at, and perpendicular to, the 2x10 rafters will be Unirac standard rails with a Sunmodo standoff base and a Unirac tilt leg located at a maximum of 48" o.c. (therefore at every third rafter) and each solar panel shall have a minimum of two supporting rails. The standoff base and tilt leg shall be fastened to the rafters with a 5/16" diameter lag screw with a minimum of 2-½" penetration into the framing member (as shown on Detail 2 of Sheet PV2.0). The rack and rail system supporting the solar panel array shall be reviewed by others down to the connection points.

We find that the solar array connections and the existing roof framing is adequate to support the required loading of the Portland area (95 mph exposure B wind, 20 psf roof snow load, and the additional 3.1 psf dead weight of the solar panels). We have reviewed the adequacy of the connection to the existing roof structure to support the required vertical and lateral loads from the solar array system as well as the adequacy of the 2x10 rafters to support the increase in load from the solar panels. We do not take responsibility for any other portion of the solar array support system, any other structural elements not contained within this letter, or the integrity of the structure as a whole.

Sincerely,
Eclipse Engineering, Inc.

Robert VanCamp

Robert VanCamp, PE
Project Engineer

Enclosed: Supporting Calculations

REGISTERED PROFESSIONAL ENGINEER
76024PE
OREGON
DEC. 13, 2012
ROBERT VANCAMP

Expires 6.30.2014

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DEDICATED SERVICE STRUCTURAL SOLUTIONS SINCE 1995

ROOF SNOW LOAD - Per 2009 IBC Section 1608 and 2010 OSSC based on ASCE 7-05

$psf := lb \cdot ft^{-2}$

ROOF DESIGN CRITERIA -

Roof Pitch - $\alpha := 10 \cdot deg$

Ground Snow Load - $P_g := 15 \cdot psf$ (Minimum Per Bldg Dept and Snow Load Maps)

EXISTING ROOF SNOW LOAD - Per ASCE 7-05, Section 7.3

Exposure Factor - $C_e := 1.0$ Per ASCE Table 7-2

Thermal Factor - $C_{t1} := 1.1$ Per ASCE Table 7-3

Importance Factor - $I := 1.0$ Per ASCE Table 7-4 CAT II

Slope Factor - $C_{s1} := 1.0$ Per ASCE Table 7-2 Non-Slippery

Flat Roof Snow Load - $P_{fr} := 0.7 \cdot C_e \cdot C_{s1} \cdot C_{t1} \cdot I \cdot P_g = 11.6 \cdot psf$

Minimum Flat Roof Load - $P_{frmin} := 20 \cdot psf \cdot I = 20 \cdot psf$ Per ASCE 7.3

Flat Roof Design Snow Load - $P_f := if(P_{frmin} > P_{fr}, P_{frmin}, P_{fr}) = 20 \cdot psf$

Sloped Roof Design Snow Load - $P_{s1} := P_f$ $\boxed{P_{s1} = 20 \cdot psf}$

NEW ROOF SNOW LOAD - Per ASCE 7-05, Section 7.4

New Thermal Factor - $C_{t2} := 1.2$ Per ASCE Table 7-3

New Slope Factor - $C_{s2} := 1.0$ Per ASCE Figure 7-2 Slippery - 7.2b

Flat Roof Design Snow Load - $P_{fr2} := 0.7 \cdot C_e \cdot C_{s2} \cdot C_{t2} \cdot I \cdot P_g = 12.6 \cdot psf$

Minimum Flat Roof Load - $P_{frmin} = 20 \cdot psf$

Flat Roof Design Snow Load - $P_{f2} := if(P_{frmin} > P_{fr2}, P_{frmin}, P_{fr2}) = 20 \cdot psf$

Sloped Roof Design Snow Load - $P_{s2} := P_{f2}$ $\boxed{P_{s2} = 20 \cdot psf}$

Estimated weight of Solar Panels $W_s := 3.1 \cdot psf$

Net Increase in Load on Roof $W_t := P_{s2} + W_s = 23.1 \cdot psf$

% Increase in Load on Roof $\%_{inc} := \dfrac{W_t - P_{s1}}{P_{s1}} \cdot 100 = 15.5\ \%$

NOTE: The original snow load is 20 psf. The increase in load on the roof from the addition of the solar panels is greater than the 5% allowed by the IEBC; therefore, verify existing framing members are adequate to support the increase in load from the solar panels

SIMPLE SPAN BEAM DESIGN - 2x10 Rafters

$plf := lb \cdot ft^{-1}$ $psf := lb \cdot ft^{-2}$ $psi := lb \cdot in^{-2}$

DESIGN CRITERIA:

Allowable Stress for DF#2 - $F_b := 900 \cdot 1.15 \cdot 1.1 \cdot 1.15 \cdot psi = 1309 \cdot psi$ $E := 1600000psi$

$F_v := 180 \cdot 1.15 \cdot psi = 207 \cdot psi$

Span - $L := 13.75 \cdot ft$ 14' Span at 10 Deg

Roof Dead Load - $w_d := 10 \cdot psf$

Roof Snow Load - $w_s := 20 \cdot psf$

Roof Tributary Width - $W_r := 4 \cdot ft$ Share Load with Adjacent Rafters

Spacing of Rafters - $W_{raft} := 16 \cdot in$

Additional Dist. Load - $w_a := 3.1 \cdot psf \cdot W_r = 12 \cdot plf$ Solar Panel DL

Roof Distributed Load - $w := \frac{1}{2} \cdot \left[W_r \cdot (w_s) + 2 \cdot W_{raft} \cdot w_d + w_a\right] = 60 \cdot plf$

Maximum Design Moment - $M := \frac{w \cdot L^2}{8}$ $M = 1407\, ft \cdot lb$

Maximum Design Shear - $V := \frac{w \cdot L}{2}$ $V = 409\, lb$

CHECK: (1) 2x10 Rafter

$b := 1.5 \cdot in$ $d := 9.25 \cdot in$

$A := b \cdot d = 13.9 \cdot in^2$ $S := \frac{b \cdot d^2}{6} = 21.4 \cdot in^3$ $I := \frac{b \cdot d^3}{12} = 98.9 \cdot in^4$

Actual Shear Stress - $f_v := \frac{3}{2} \cdot \frac{V}{A}$ $f_v = 44 \cdot psi$

Actual Bending Stress - $f_b := \frac{M}{S}$ $f_b = 789 \cdot psi$

$\boxed{\text{if}\left(F_v > f_v, \text{"Shear OK"}, \text{"NO"}\right) = \text{"Shear OK"}}$ $\boxed{\text{if}\left(F_b > f_b, \text{"Bending OK"}, \text{"NO"}\right) = \text{"Bending OK"}}$

Total Load Deflection - $\Delta := \frac{5w \cdot L^4}{384 \cdot E \cdot I} = 0.302 \cdot in$

$\boxed{\text{if}\left(\frac{L}{\Delta} > 180, \text{"Deflection OK"}, \text{"Deflection Exceeded"}\right) = \text{"Deflection OK"}}$ $\frac{L}{\Delta} = 545$

(E) 2x10 DF#2 purlins spanning between roof trusses are adequate to support the addtional load from the solar panels

CALCULATE WIND PRESSURE - Tilt Up Panels
ASCE 7-05 Fig 6-19A C&C Monoslope Free Roof

$psf := lb \cdot ft^{-2}$ $plf := lb \cdot ft^{-1}$ $psi := lb \cdot in^{-2}$ $ksi := 1000 \cdot lb \cdot in^{-2}$

Wind Loading - ASCE 7-05

Section 6.5.13 - Wind Loads on Other Structures:

3 - Second Wind Gust (Basic Wind Speed) - $V := 95$ mph

Fastest Mile Wind Speed - $V_{fm} := (V - 10.5) \cdot 1.05^{-1} = 80.$: mph

Importance Factor - $I_w := 1.0$

Wind Directionality Factor Table 6-4 - for Main Wind Force Resisting Systems $K_d := 0.85$

Velocity Pressure Exp. Coefficient Table 6-3 - For 25 ft above grade - exp B $K_z := 0.70$ Case 1

Topographic Coefficients Figure 6-4- $K_1 := 1.0$ $K_2 := 1.0$ $K_3 := 1.0$

Topographic Factor - 6.5.7.2 - $K_{zt} := (1 + K_1 \cdot K_2 \cdot K_3)^2$ $K_{zt} = 4$

Height of Hill - $H := 0 \cdot ft$

Length of 1/2 Height - $L_h := 0 \cdot ft$

Factor per section 6.5.7.1 - #4 $\frac{H}{L_h} = 0$

Note: As per ASCE - 6.5.7.1: $K_{zt} := 1.0$

6.5.7.1 - #3, the structure is not located in the upper one-half of the hill
- #4, H/Lh is less than 0.20

Velocity Pressure - 6.5.10 - $q_z := 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2 \cdot I_w \cdot psf$ $q_z = 13.7 \cdot psf$

Gust Factor 6.5.8.1 - $G := 0.85$

For Clear Wind Flow @ 10 Degree Tilt on a 10 Degree Roof

Force Coefficient, Fig 6-19A $C_{N0} := 2.55$ $C_{N180} := -3.2$ Zone 2

Pos at 10 deg Downward — Neg at 20 deg Uplift

Wind Force - 6.5.15 : $P_{wA0} := q_z \cdot G \cdot C_{N0} = 29.8 \cdot psf$ Downward — $P_{wA180} := q_z \cdot G \cdot C_{N180} = -37.4 \cdot psf$ Uplift

SOLAR ARRAY CONNECTION TO ROOF - Tilt Up Panels

$psf := lb \cdot ft^{-2}$ $plf := lb \cdot ft^{-1}$ $psi := lb \cdot in^{-2}$ $ksi := 1000 \cdot lb \cdot in^{-2}$

Wind Loading - ASCE STANDARD - ASCE 7-05

Velocity Pressure - 6.5.10 - $p_{net} := |P_{wA180}|$ $\boxed{p_{net} = 37.4 \cdot psf}$ Uplift

Length of Solar Panel - $L_p := 33 \cdot in$ (max load is half of panel)

Spacing of Base Supports - $S_b := 48 \cdot in$ (every third rafter)

Height of Solar Rack - $h_p := 3 \cdot in$ (worst Case)

Area of Solar Panel @ support - worst case for offset panel $A_p := L_p \cdot S_b$ $A_p = 11\,ft^2$

Uplift per Bracket - $T_b := p_{net} \cdot A_p$ $T_b = 411\,lb$

Shear Force per Bracket - $V_b := p_{net} \cdot h_p \cdot S_b$ $V_b = 37\,lb$

Number of Screws per bracket - $N_s := 1.0$

Tension/Shear per Screw - $T_s := \frac{T_b}{N_s} = 411.3\,lb$ $V_s := \frac{V_b}{N_s} = 37.4\,lb$

Angle of Component Loading - $\theta := atan\left(T_s \cdot V_s^{-1}\right)$ $\theta = 84.8 \cdot deg$

Component Load on Screw - $Z_c := \sqrt{T_s^2 + V_s^2}$ $\boxed{Z_c = 413\,lb}$

Shear & Withdrawl - 5/16" Lag - $Z := 1.6 \cdot 130 \cdot lb = 208\,lb$

Withdrawl Capacity per Inch - $W := 205 \cdot \frac{lb}{in}$ $p := 2.25 \cdot in$ $T := 1.6 \cdot W \cdot p = 738\,lb$

Capacity of Lag Screws - $Z_a := \frac{(T) \cdot Z}{(T) \cdot \cos(\theta)^2 + Z \cdot \sin(\theta)^2}$ $\boxed{Z_a = 722.9\,lb}$

$if\left(Z_a > Z_c, \text{"LAG SCREW OK"}, \text{"LAG SCREW OVERSTRESSED"}\right) = \text{"LAG SCREW OK"}$

USE: 5/16" DIAMETER LAG SCREWS spaced a maximum 48" on center across the slope (every third rafter) with two rails per panel down the slope

MWFRS - Wind Pressure Calculations: ASCE 7-05, Section 6.4

Definitions: $plf := \frac{lb}{ft}$ $psf := \frac{lb}{ft^2}$ $psi := \frac{lb}{in^2}$

Coefficients:

Wind Pressure: 95 mph 3-second Gust Speed
Exposure B

NOTE: By inspection, wind forces on the new solar array control the increase in lateral forces on the existing structure due to their projected area above the roof surface.

Wind Pressure on Existing Roof: Figure 6-2

Mean Roof Height/Angle: $H_r := 24.5ft$

Roof Rise: $\alpha := 10 \cdot deg$

Adjustment Factor: $\lambda := 1.0$ 20-25ft Above Grade

Topographic Factor: $K_{zt} := 1.0$

Importance Factor: $I_w := 1.0$

Base Wind Pressures: $P_w := 16.2 \cdot psf$ Wall Presssure

$P_r := 5.2 \cdot psf$ Roof Pressure

Design Wind Pressures: $P_{Ae} := P_w \cdot \lambda \cdot K_{zt} \cdot I_w$ $\boxed{P_{Ae} = 16.2 \cdot psf}$

$P_{Be} := P_r \cdot \lambda \cdot K_{zt} \cdot I_w$ $\boxed{P_{Be} = 5.2 \cdot psf}$

Wind Pressure on Existing Roof with Tilt Up Solar Panels: Figure 6-2

Mean Roof Height/Angle: $H_r := 25.5ft$

Roof Rise: $\alpha_n := 20 \cdot deg$

Adjustment Factor: $\lambda := 1.0$ 25-30ft Above Grade

Topographic Factor: $K_{zt} := 1.0$

Importance Factor: $I_w := 1.0$

Base Wind Pressures: $P_w := 16.2 \cdot psf$ Wall Presssure

$P_r := 5.2 \cdot psf$ Vertical Roof Pressure

Design Wind Pressures: $P_{An} := P_w \cdot \lambda \cdot K_{zt} \cdot I_w$ $\boxed{P_{An} = 16.2 \cdot psf}$

$P_{Bn} := P_r \cdot \lambda \cdot K_{zt} \cdot I_w$ $\boxed{P_{Bn} = 5.2 \cdot psf}$

MWFRS - Wind Pressure Calculation - Shear Walls:

Definitions: $plf := \frac{lb}{ft}$ $psf := \frac{lb}{ft^2}$ $psi := \frac{lb}{in^2}$

Coefficients:

Width of Building:	$W := 26.5ft$	Controls with Panel Direction
Width of Array:	$W_s := 20ft$	
Roof Height:	$H_r := 27ft$	
Roof Height w/ Panels:	$H_{rp} := 28.5ft$	
Height of Panels:	$H_p := H_{rp} - H_r = 1.5\,ft$	
Height of Shear Wall:	$h := 9ft$	
Roof Slope:	$\alpha = 10 \cdot deg$	
Solar Panel Slope:	$\alpha_n = 20 \cdot deg$	
Wind Pressures:	$P_{Ae} = 16.2 \cdot psf$	Existing
	$P_{An} = 16.2 \cdot psf$	New

Verify that Additional Load from Solar Panels add less than 10% Load to System:

1. Total base shear:

Existing Total Base Shear: $V_e := W \cdot h \cdot P_{Ae}$ $V_e = 3864\,lb$

New Total Base Shear: $V_n := W \cdot h \cdot P_{An} + W_s \cdot H_p \cdot P_{Bn}$ $V_n = 4020\,lb$

Check that Resultant Wall Pressure is at least 10psf, on average:

$$PSF := \frac{P_{Ae} \cdot h + P_{Bn} \cdot H_p}{H_p + h} \qquad PSF = 15 \cdot psf \qquad \text{OK}$$

Percent Increase In Load: $\%_{inc} := -100\left(1 - V_n \cdot V_e^{-1}\right)$ $\%_{inc} = 4$ % OK

THE ADDITION OF SOLAR PANELS DOES NOT RESULT IN AN INCREASE OF GREATER THAN 10% LATERAL LOAD ON THE EXISTING STRUCTURE DUE TO WIND OR SEISMIC FORCES AS ALLOWED BY THE IBC/CBC, Chapter 34.