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Instant Roof Framing Analysis

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STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: Zachary Kennedy; Location: 5671 Elliott Bridge Road Linden Nc 28356, Linden, NC 28356

Prepared for:

FREEDOM SOLAR POWER

Freedom Solar, LLC

4801 Freidrich Ln, Ste 100 - Austin, TX 78744

Calculation Report Index

Project Number: 36.110584, Rev. 0

Report Date: 06/07/2023

Report Prepared by:

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Digitally signed by Richard Pantel
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Date: 2023.06.07 15:35:00 -04'00'

Loading Summary

Exposure and Occupancy Categories		
B		*Exposure Category (ASCE 7-16 Table 26.7.3, Page 266)*
II		*Building Use Occupancy / Risk Category (ASCE 7-16 Table 1.5-1, Page 4)*

Wind Loading:			
v	119	*mph*	*ASCE 7-16, Figure 26.5-1 A, B or C, pp 249-251. [(119 mph, 50 year wind MRI)]*
qz	21.53	*psf*	*Velocity qz, calculated at height z [ASD]*

Snow Loading			
pg	10	*psf*	*Ground Snow Load pg (ASCE 7-16 Table 7.2-1, Page 52-53)*
Total Snow Load			
ps	10.00	*psf*	*Effective snow load on roof and modules*

Module Data			
WAAREE ENERGIES LIMITED: WSMD-400			
Dimensions	*mm*	*ft*	*in*
Length	1,923	6.31	75.70
Width	1,039	3.41	40.90
Area (m^2, ft^2)	2.0	21.50	
Weight	kg	lb	
Module	22.00	48.50	

Roof Panel (Cladding) Loading Summary		Module Loading Summary			
Support Point Loads		*Upward*	*Upward*	*Upward*	*Downward*
Roof Zone		1,2e,2r	2n,3r	3e	All
Net total load / support point	*lb*	-71	-108	-162	186

Positive values indicate net downward force

Lag Bolt Data	Size	5/16x2.10	Pre-drill	0.16" dia	Material	Stainless

Rack Support Lag Bolt Pull-out Calculations in US Spruce Roof Framing				
Roof Zone		1,2e,2r	2n,3r	3e
Bolt Pullout Per Module Connection	*lb*	71	108	162
Number of Pullout Loads / Support		2	2	2
Safety Factor		1.50	1.50	1.50
Pull-out for 5/16 dia bolts	*lb/in*	206	206	206
Min threaded inches embedment required	*in*	0.26	0.39	0.59
Min threaded Inches embedment provided	*in*	1.10	1.10	1.10
Min Lag Bolt length to use	*in*	2.10	2.10	2.10

Conclusions

Princeton Engineering was asked to review the roof of Zachary Kennedy, located at 5671 Elliott Bridge Road Linden Nc 28356, Linden, NC by Freedom Solar, LLC, to determine its suitability to support a PV solar system installation.

The referenced building's roof structure has been field measured by Freedom Solar, LLC on 06/01/2023. The framing calculations we prepared reflect the results of those field measurements combined with the PV solar module locations shown on the construction PV solar roof layout design prepared by Freedom Solar, LLC. Loads are calculated to combine the existing building and environmental loads with the proposed new PV array loads.

Freedom Solar, LLC has selected the SunPower InvisiMount 6000 series racking system. The racking and support stanchions shall be placed as shown on the plans prepared by Freedom Solar, LLC, dated 06/05/2023, and shall be fastened to the roof deck using lag bolt sizes as indicated in this report. Rack support spacing shall be no more than shown on each calculation. Note that support points for alternating rows shall share the same rafter. Intermediate rows shall move the support points to laterally the next rafter.

Google Location Map

Framing Summary

Based upon the attached calculations, the roofs are capable of supporting the additional loading for the proposed Freedom Solar, LLC PV system along with the existing building and environmental loads. No supplemental roof framing structural supports are required.

Bracket to Roof Framing Lag Bolts

US Spruce rafters have a bolt pullout strength of 207 lb / inch of thread using the 5/16" dia. fasteners. In order to maintain at least a 1.5X Safety Factor for pullout, 1.1 inches of THREAD embedment are required. Use a 2.10" x 5/16" stainless lag bolt, or larger, in order to achieve the above specified embedment into each joist at each rail support point. Predrill with a 0.16" dia pilot hole.

Notes: (1) Bolt threads must be embedded in the side grain of a rafter or other structural member integral with the building structure. (2) Lag bolts must be located in the middle third of the structural member. (3) Install lag bolts with head and washer flush to surface (no gap). Do not over-torque.

References and Codes:

1) *ASCE 7-16 Minimum Design Loads for Buildings and Other Structures*
2) *IBC 2018*

3) *2018 International Residential Code, NC Edition*
4) *American Wood Council, NDS 2005,Table 11.2A, 11.3.2A.*
5) *American Wood Council, Wood Structural Design, 1992, Figure 6.*

Location: MP 1

Member: Rafter - Total Length 15.29 ft, Unsupported 15.29 ft

Roof Data			
Θ	*deg.*	43.99	*Angle of plane of roof from horizontal, in degrees*
L	*ft.*	72.00	*Length of Building, in feet (meters).*
W	*ft.*	11.00	*Width of Building, in feet (meters).*
h	*ft.*	15.00	*Height of Building, in feet (meters).*

Roof Wind Zone Width			
	use, a =	3.00	*ft*

Wind Velocity Pressure, q_z evaluated at the height z						
q_z=	21.53	*psf*	*Vasd* q_z=	13.17	*psf*	Basic wind pressure
V=	119	mph				

Framing Data		
Wood type	US Spruce	
Wood source, moisture content	White 0.12%	
# Framing Members / Support		1
Rafter / Truss OC	*in*	16.00
Member Total Length	*ft*	15.29

3	# Rafters / Rack Support Width
4.00	Rack Support Spacing (ft)
48	Max. Rack Support Spacing (in)
2	Max # of mod's / Rafter

Member Properties		**Member**
Name		(1)1.5x7.5
Repetitive Member Factor (Cr)		1.15
Max Shear perp. to grain	*psi*	530
Max Shear parallel to grain	*psi*	1,100

** Mem properties based upon field measurements*

Rafter

16.00	Collar tie OC spacing, in.

Module Data			
WAAREE ENERGIES LIMITED: WSMD-400			
Weight	kg	lb	psf load
Module	22.00	48.50	2.26
4 Stanchions	1.36	3.0	0.14
Total Module and Support load	23.36	51.5	2.40

Existing Dead Loads	*Units*	*Value*	*Description*
Framing Member	*psf*	1.43	
Roof Deck & Surface	*psf*	4.40	*0.50 in. Plywood w/ Standard Asphalt Shingles*

Rack Support Spacing and Loading				
Across rafters	*ft*	4.0		
Along rafter slope	*ft*	6.3		
Area / support point	*sf*	12.6		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	15.29	
Maximum member free span	*ft*	15.29	Rafter span
Rafter segment to calc	*ft*	15.29	Free span
Deflection Ratio		180	Use max delta 1/x for deflection

Eave Overhang Length past Rafter Plate	0.83	*ft*
Uphill Distance from Eave to Lowest Support	2.67	*ft*

ASCE 7-16 Method for Calculating Uplift on PV Modules

Notation
Lp = Panel chord length.
p = uplift wind pressure
γa = Solar panel pressure equalization factor, defined in Fig. 29.4-8.
γE = Array edge factor as defined in Section 29.4.4.
θ = Angle of plane of roof from horizontal, in degrees.

29.4.4 Rooftop Solar Panels Parallel to the Roof Surface on Buildings of All Heights and Roof Slopes.

Θ >= 7 deg TRUE

	Exposed	**FALSE**
	1.5(Lp) =	5.11
γE =	1	
γa =	0.67	

$p = qh(GCp)\ (\gamma_E)\ (\gamma_a)$ (lb⁄ft2) (29.4-7)

Zones	1,2e,2r	2n,3r	3e
p, Windload (psf)	-12.90	-15.33	-18.93

ASCE 7-16 Chapter 2 Combinations of Loads, Table 2.4, Page 8 (in psf)				
Zones	1,2e,2r	2n,3r	3e	All Zones
2.2 SYMBOLS AND NOTATION	*Module Upward*	*Module Upward*	*Module Upward*	*Downward*
D = dead load of PV Module + Stanchion	2.40	2.40	2.40	2.40
S = snow load	10.00	10.00	10.00	10.00
W = wind load	-12.90	-15.33	-18.93	10.10

2.4 Combining Nominal Loads Using Allowable Stress Design (in psf)				
2.4.1 Basic Combinations. Loads listed herein shall be considered to act in the following combinations; whichever produces the most unfavorable effect in the building, foundation, or structural member being considered. Effects of one or more loads not acting shall be considered.				
Combination Formulae	*Upward*	*Upward*	*Upward*	*Downward*
Use this loading combination for DOWNWARD for Proposed PV Dead Load				
6. D + 0.75L - 0.75(0.60W) + 0.75(Lr or S or R)	12.40	12.40	12.40	16.94
Module Support point load (lb)	156	156	156	214
Cr Factored Module Support point load (lb)	136	136	136	186

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.6D + 0.6W	-2.80	-4.26	-6.43	8.22
Module Support point load (lb)	-35	-54	-81	104

DOWNWARD

Presume loading directly over member.

Combined Dead and Wind Pressure Downward Loading					
	Rafter span				
PV Module Row	Point load loc's from Left support		Module Support Point Load	Comment	Module Orientation
	ft from left		*lb*		
1	1.84			Support placed on adjoining rafter	Portrait
1	8.15		186		Portrait

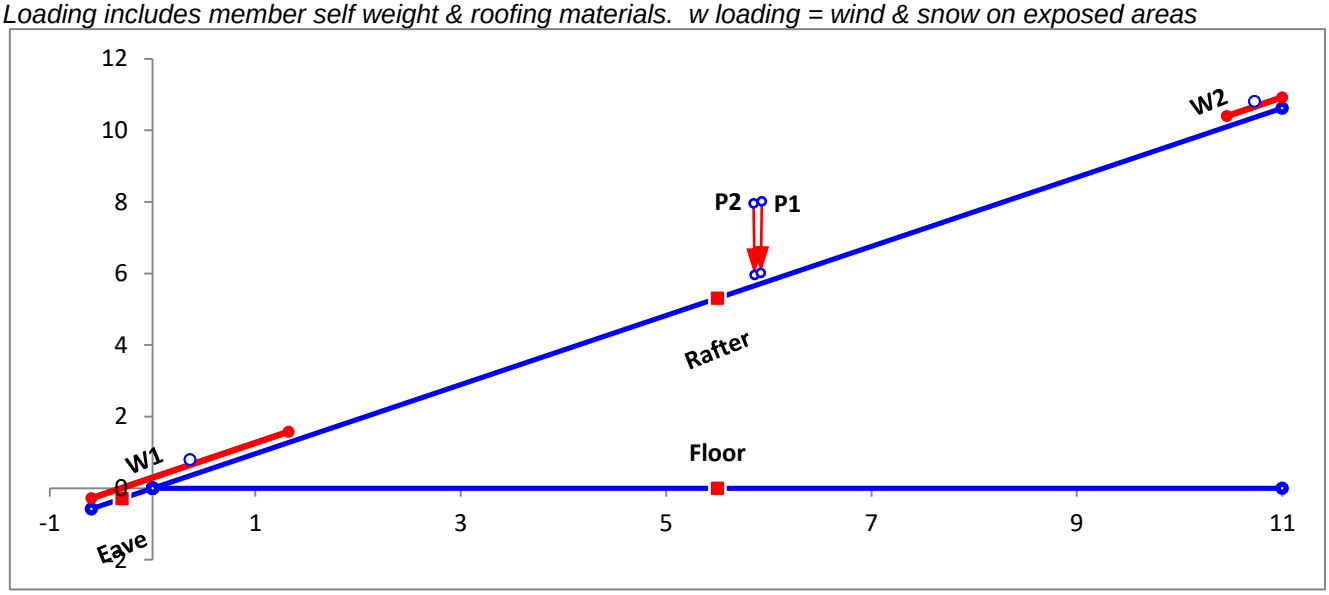
2	8.23		186		Portrait
2	14.54			Support placed on adjoining rafter	Portrait

Analysis for PV impacted areas

5. Simple Beam - Exposed Roof Snow Load - Above and Below PV				
Parameter	*Units*	*Total*	*Allowed*	*Check*
Delta @ mid span	*in*	0.01	1.02	***OK***
M at mid span	*lb-ft*	13	7,656	***OK***

Sum Downward Loading Conditions: PV; Beam DL; Exposed Roof Environmental Load				
Parameter	*Units*	*Total*	*Allowed*	*Check*
Delta	*in*	0.70	1.02	***OK***
Percent Max Delta	*%*	69%	100%	***OK***
Moment	*lb-ft*	1,503	7,656	***OK***
fs	*psi*	1,283	6,533	***OK***

** Loading includes member self weight & roofing materials. w loading = wind & snow on exposed areas*



Framing section with max stress: Rafter span

Location: MP 2

Member: Rafter - Total Length 16.68 ft, Unsupported 16.68 ft

Roof Data			
Θ	*deg.*	44.01	*Angle of plane of roof from horizontal, in degrees*
L	*ft.*	72.00	*Length of Building, in feet (meters).*
W	*ft.*	12.00	*Width of Building, in feet (meters).*
h	*ft.*	15.00	*Height of Building, in feet (meters).*

Roof Wind Zone Width			
	use, a =	3.00	*ft*

Wind Velocity Pressure, q_z evaluated at the height z						
q_z=	21.53	*psf*	*Vasd* q_z=	13.17	*psf*	Basic wind pressure
V=	119	mph				

Framing Data		
Wood type	US Spruce	
Wood source, moisture content	White 0.12%	
# Framing Members / Support		1
Rafter / Truss OC	*in*	16.00
Member Total Length	*ft*	16.68

3	# Rafters / Rack Support Width
4.00	Rack Support Spacing (ft)
48	Max. Rack Support Spacing (in)
3	Max # of mod's / Rafter

Member Properties		**Member**
Name		(1)1.5x7.5
Repetitive Member Factor (Cr)		1.15
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* *Mem properties based upon field measurements*

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Existing Dead Loads	*Units*	*Value*	*Description*
Framing Member	*psf*	1.43	
Roof Deck & Surface	*psf*	4.40	*0.50 in. Plywood w/ Standard Asphalt Shingles*

Rack Support Spacing and Loading				
Across rafters	*ft*	4.0		
Along rafter slope	*ft*	6.3		
Area / support point	*sf*	12.6		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	16.68	
Maximum member free span	*ft*	16.68	Rafter span
Rafter segment to calc	*ft*	16.68	Free span
Deflection Ratio		180	Use max delta 1/x for deflection

Eave Overhang Length past Rafter Plate	0.83	*ft*
Uphill Distance from Eave to Lowest Support	0.58	*ft*

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Zones	1,2e,2r	2n,3r	3e
p, Windload (psf)	-12.90	-15.33	-18.93

ASCE 7-16 Chapter 2 Combinations of Loads, Table 2.4, Page 8 (in psf)				
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7. 0.6D + 0.6W	-2.80	-4.26	-6.43	8.22
Module Support point load (lb)	-35	-54	-81	104

DOWNWARD

Presume loading directly over member.

Combined Dead and Wind Pressure Downward Loading					
	Rafter span				
PV Module Row	Point load loc's from Left support		Module Support Point Load	Comment	Module Orientation
	ft from left		*lb*		
1	-0.25			Support outside of max stressed section	Portrait
1	6.06		186		Portrait

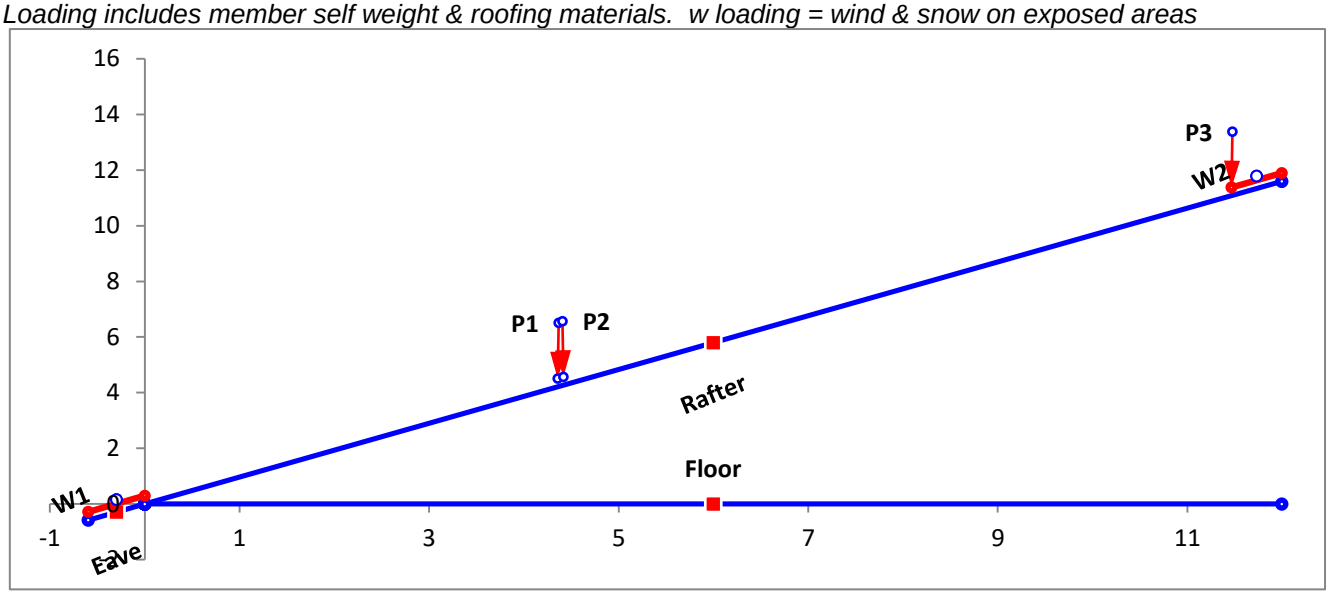
2	6.14		186		Portrait
2	12.45			Support placed on adjoining rafter	Portrait
3	12.53			Support placed on adjoining rafter	Landscape
3	15.94		186		Landscape

Analysis for PV impacted areas

5. Simple Beam - Exposed Roof Snow Load - Above and Below PV				
Parameter	*Units*	*Total*	*Allowed*	*Check*
Delta @ mid span	*in*	0.00	1.11	***OK***
M at mid span	*lb-ft*	2	7,656	***OK***

Sum Downward Loading Conditions: PV; Beam DL; Exposed Roof Environmental Load				
Parameter	*Units*	*Total*	*Allowed*	*Check*
Delta	*in*	0.89	1.11	***OK***
Percent Max Delta	*%*	80%	100%	***OK***
Moment	*lb-ft*	1,407	7,656	***OK***
fs	*psi*	1,201	6,533	***OK***

** Loading includes member self weight & roofing materials. w loading = wind & snow on exposed areas*



Framing section with max stress: Rafter span

Snow Loading Analysis

where:

		Fully Exposed	Exposure category
Ce	=	0.9	Exposure Factor, Ce (ASCE 7-16 Table 7.3-1, Page 58)
Ct	=	1.0	Thermal Factor, Ct (ASCE 7-16 Table 7.3-2, Page 58)
Is	=	1.0	Snow Importance Factor, Is (ASCE 7-16 Table 1.5-2, Page 5)
p_g	=	10	Ground Snow Load pg (ASCE 7-16 Table 7.2-1, Page 52-53)

p_f	=	**0.7CeCtIsPg**	Flat Roof Snow Load, pf (ASCE 7-16 Table 7.3-1, Page 58)
p_f	=	**6.3**	psf

but where Pf is not less than the following:

Minimum Snow Load pm (ASCE 7-16 Table 7.3.4, Page 53)

p_m	=	**10**	When Pg <=20 psf, then use Pf = Pg x Is

p_f	=	**10**	psf. Resultant Snow pressure to be used with Roof slope factor below
p_s	=	$C_s p_f$	Sloped Roof Snow Load ps (ASCE 7-16 Table 7.4, Page 54)

Roof Type Warm Roofs

Roof slope factor Cs for Warm Roofs, where Ct = 1.0

Roof surface condition = Slippery Roof

C_s	=	1.00	Roof Slope Factor, Cs (ASCE 7-16 Table 7-2a, Page 36)

Total Snow Load

p_s	=	**10.00**	**psf**	Roof snow load