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Instant Roof Framing Analysis

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STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: Tavita Ponce, 2915 Sw Arbor Tree Drive, Lee'S Summit, MO 64082

Prepared for:

Sunergy

7625 Little Rd Ste 200a - New Port Richey, FL 34654

Calculation Report Index

Pages	*Description*		
1	Cover	2-4	Loading Summary
	Roof Structural Calculations for PV Solar Installation		
5-9	Location: MP 1		
10-10	Snow Loading Calculations		
13-14	Truss FEA Calculations		

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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	115	*mph*	*ASCE 7-16, Figure 26.5-1 A, B or C, pp 249-251. [(115 mph, 50 year wind MRI)]*
qz	20.14	*psf*	*Velocity qz, calculated at height z [ASD]*

Snow Loading			
pg	20	*psf*	*Ground Snow Load pg (ASCE 7-16 Table 7.2-1, Page 52-53)*
Total Snow Load			
ps	20.00	*psf*	*Effective snow load on roof and modules*

Module Data			
Trina Solar: TSM-390DE09C.07			
Dimensions	*mm*	*ft*	*in*
Length	1,754	5.75	69.06
Width	1,096	3.60	43.15
Area (m^2, ft^2)	1.9	20.69	
Weight	kg	lb	
Module	21.00	46.30	

Roof Panel (Cladding) Loading Summary		Module Loading Summary			
Support Point Loads		*Upward*	*Upward*	*Upward*	*Downward*
Roof Zones		1,2e	2n,2r,3e	3r	All
Net load per module	*lb*	-152	-266	-313	249

Positive values indicate net downward force

Stanchion Fastener Pull-out and Spacing Calculations				
Framing spacing			*ft*	2.00
Rails / Module			*ea*	2
Max proposed stanchion span			*ft*	4.00
# fasteners per stanchion				2
Screw thread embedment depth			*in*	2
Safety Factor				1.25
Pull-out for M5 threaded fasteners			*lb/in*	719
Factored max uplift capacity			*lb*	2299
Fastener details	*Material*	Stainless	*Size*	M5

Roof Zones			*1,2e*	*2n,2r,3e*	*3r*
Net lift per module		*lb*	152	266	313
Min tot screw thread embedment depth rq'd		*in*	0.13	0.23	0.27
Net uplift pressure	7. 0.60D - 0.6W	*psf*	-6.62	-11.58	-13.61
Allowable lift area / support point		*sf*	347.39	198.64	168.92
Max rail span per framing spacing		*ft*	4.00	4.00	4.00
Landscape Modules					
Length along rafter		*ft*	3.60		
Lift calc'ed max stanchion EW spacing		*ft*	> 6	> 6	> 6
Max stanchion EW spacing		*ft*	4.00	4.00	4.00
Maximum module area / support point		*sf*	7.19	7.19	7.19
Factored lift per support point		*lb*	-48	-83	-98
Portrait Modules					
Length along rafter		*ft*	5.75		
Lift calc'ed max stanchion EW spacing		*ft*	> 6	> 6	> 6
Max stanchion EW spacing		*ft*	4.00	4.00	4.00
Maximum module area / support point		*sf*	11.51	11.51	11.51
Factored lift per support point		*lb*	-76	-133	-157

Stanchion support threaded fastener sizes are indicated in the Module Loading Summary table above. Lift forces were determined from GCp and other coefficients contained in the ASCE nomographs

Conclusions

Princeton Engineering was asked to review the roof of Tavita Ponce, located at 2915 Sw Arbor Tree Drive, Lee'S Summit, MO, by Sunergy, to determine its suitability to support a PV solar system installation.

The referenced building's roof structure was field measured by Sunergy. The attached framing analyses reflect the results of those field measurements combined with the PV solar module locations shown on the PV solar roof layout design prepared by Sunergy. Loads are calculated to combine the existing building and environmental loads with the proposed new PV array loads.

Sunergy selected the K2-Systems CrossRail 44-X racking with K2-Systems Splice Foot XL w/2 bolts stanchions for this project. The racking and support stanchions shall be placed as shown on their plans, dated 11/01/2023, and shall be fastened to the roof framing using fastener sizes indicated in this report. Rack support spacing shall be no more than that shown above. Note that support points for alternating rows shall share the same truss. Intermediate rows shall move the support points laterally to the next truss.

Google Location Map

Framing Summary

Based upon the attached calculations, the existing roof's framing system is capable of supporting the additional loading for the proposed PV solar system along with the existing building and environmental loads. No supplemental roof framing structural supports are required. Minimum required anchorage fastening is described above.

Wood fastener notes: 1) Fastener threads must be embedded in the side grain of a roof support structural member or other structural member integrated into the building's structure. 2) Fastener must be located in the middle third of the structural member. 3) Install fasteners with head and where required, washer, flush to material 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, MO Edition*
4) *American Wood Council, NDS 2018,Table 12.2A, 12.3.3A.*
5) *American Wood Council, Wood Structural Design, 1992, Figure 6.*

Location: MP 1

Member: Truss - Total Length 24 ft, Unsupported 24 ft

Geometric Data			
Θ	*deg.*	27.00	*Angle of roof plane from horizontal, in degrees*
L	*ft.*	42.00	*Length of roof plane, in feet (meters)*
W	*ft.*	24.00	*Plan view width of roof plane, in feet (meters)*
h	*ft.*	25.00	*Average height of roof above grade, in feet (meters)*

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

Wind Velocity Pressure, q_z evaluated at the height z						
q_z=	20.14	*psf*	*Vasd* q_z=	12.34	*psf*	Basic wind pressure
V=	115	mph				

Framing Data		
Wood type	US Spruce	
Wood source, moisture content	White 0.12%	
# Framing Members / Support		1
Rafter / Truss OC	*in*	24.00
Member Total Length	*ft*	24.00

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

Member Properties		**Member**
Name		(1) 2x4
Repetitive Member Factor (Cr)		1.15

* *Mem properties based upon field measurements*

Top truss chord

Module Physical Data			
Weight	kg	lb	psf load
Module	21.00	46.30	2.24
4 Stanchions	1.27	2.8	0.14

Existing Dead Loads	*Units*	*Value*	*Description*
Roof Deck & Surface	*psf*	4.40	*Truss members' self weight added to FEA analysis*

Rack Support Spacing and Loading				
Across rafters	*ft*	4.0		
Along rafter slope	*ft*	5.8		
Area / support point	*sf*	11.5		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	24.00	
Maximum member free span	*ft*	24.00	Top truss chord span

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

Min.d1: Exposed	**FALSE**
Max.d1: Exposed	**TRUE**
1.5(Lp) =	5.39
γE =	1.5
γa =	0.67

Use EXPOSED for uplift calculations

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

Zones	1,2e	2n,2r,3e	3r
p, Windload (psf)	-18.59	-26.85	-30.24

ASCE 7-16 Chapter 2 Combinations of Loads, Table 2.4, Page 8 (in psf)				
Zones	1,2e	2n,2r,3e	3r	All Zones
2.2 SYMBOLS AND NOTATION	*Module Upward*	*Module Upward*	*Module Upward*	*Downward*
D = dead load of PV Module + Stanchion	2.37	2.37	2.37	2.37
S = snow load	20.00	20.00	20.00	20.00
W = wind load	-18.59	-26.85	-30.24	5.63

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)	22.37	22.37	22.37	24.91
Module Support point load (lb)	257	257	257	287
Cr Factored Module Support point load (lb)	224	224	224	249

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.60D - 0.6W	-6.62	-11.58	-13.61	7.56
Module Support point load (lb)	-76	-133	-157	87

DOWNWARD

Presume loading directly over member.

Combined Dead and Wind Pressure Downward Loading					
	Top truss chord span				
PV Module Row	Point load loc's from Left support	Point Load #'s	Module Support Point Load	Comment	Module Orientation
	ft from left		*lb*		
1	4.67		249		Portrait
1	10.42			Support placed on adjoining truss	Portrait
2	10.51			Support placed on adjoining truss	Portrait
2	16.26		249		Portrait
3	16.35		249		Portrait
3	22.10			Support placed on adjoining truss	Portrait

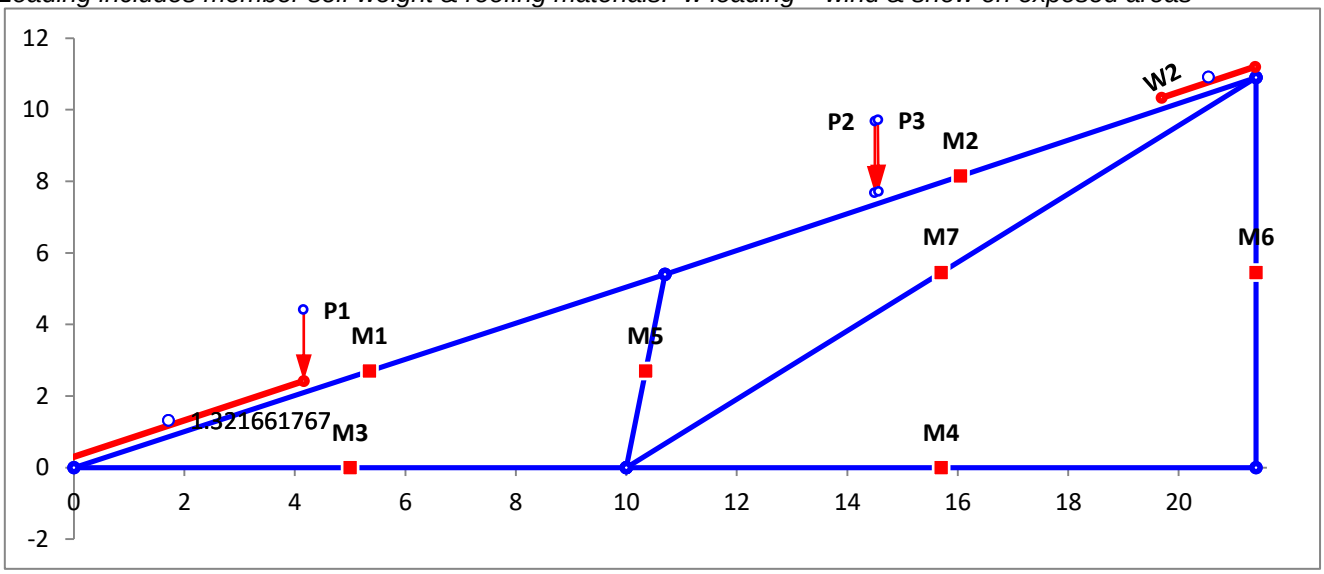
Truss Data and Loading for MP 1

Roof slope (degrees)	27.00		Length of roof plane	24.00
Top ridge height above floor plane	10.90		Length of floor plane	21.42

Truss Segments

Roof Plane		*Floor Plane*		*Diagonals*		*Diagonals*	
Mem #	*Mem Type*	Mem #	*Mem Type*	Mem #	*Mem Type*	Mem #	*Mem Type*
1	2x4	3	2x4	5	2x4	7	2x4
2	2x4	4	2x4	6	2x4		

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



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	=	20	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	=	**12.6**	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	=	**20**	When Pg <=20 psf, then use Pf = Pg x Is

p_f	=	**20**	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	=	**20.00**	**psf**	Roof snow load

FEA Calculation Results for Roof Plane MP 1 for Sunergy Client TAVITA PONCE

IDSPL - 2D Frame Analysis of a 2D frame subject to distributed loads, point loads and moments

Equilibrium check	FX	FY
Total applied forces	0.00	2740
Total output reactions	0.00	-2740
Output error	3.69E-13	9.09E-13

1.5E-05

# of segments/beam	1

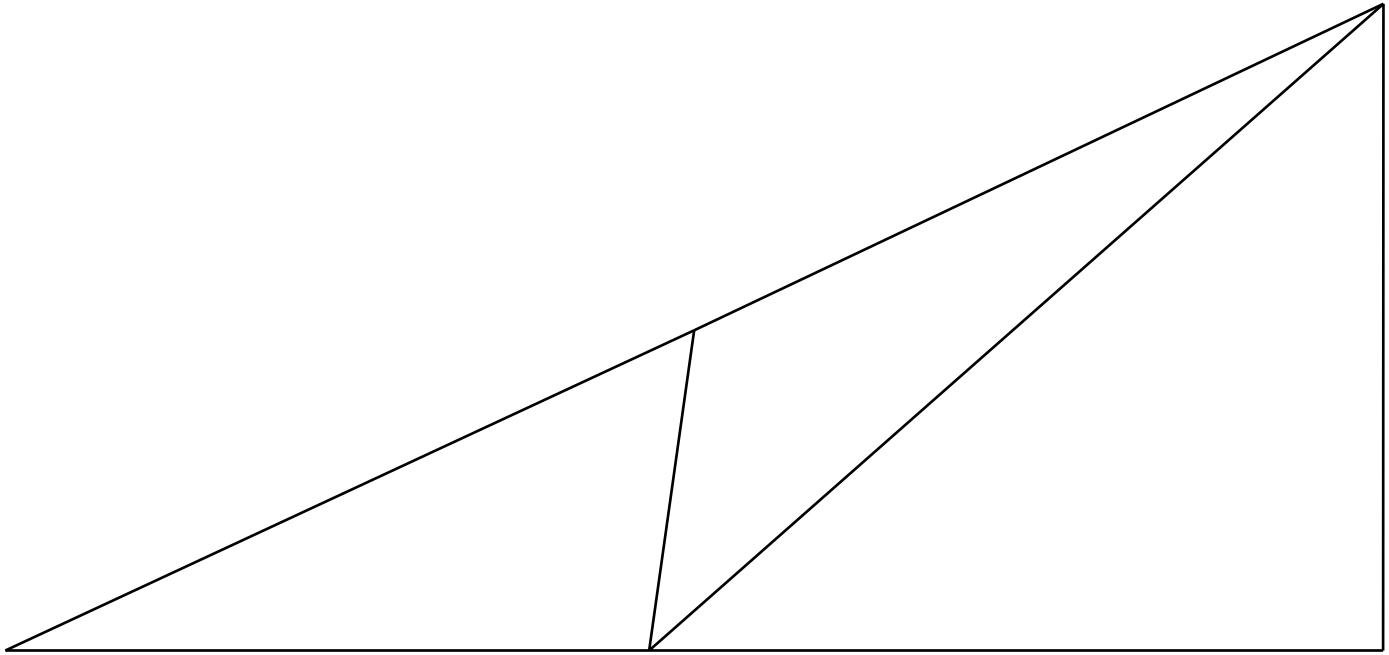
Maximum Deflections	
2.86E-03	-2.11E-03

** vertical deflections do not take into account any supporting intermediate walls*

Node Results			Beam End Results			
Direction	Deflection	Reaction	Beam	Shear	Ax	BM
DX1	0.00E+00	-400	1-1	-1196	1051	4663
DY1	0.00E+00	-1405	1-2	-805	854	-7926
RZ1	-2.80E-04	0	2-1	-4959	1288	-17451
DX2	3.33E-04	0	2-2	-3471	523	-70417
DY2	2.11E-03	0	3-1	137	0	-4663
RZ2	-2.30E-03	0	3-2	535	0	1120
DX3	2.86E-03	0	4-1	0	0	0
DY3	0.00E+00	3992	4-2	0	0	0
RZ3	0.00E+00	-68817	5-1	-2012	3688	1428
DX4	0.00E+00	595	5-2	-2010	3668	-9525
DY4	0.00E+00	-5307	6-1	196	21	-1066
RZ4	0.00E+00	-5	6-2	196	-49	1066
DX5	0.00E+00	-196	7-1	21	1261	-303
DY5	0.00E+00	-21	7-2	123	1164	533
RZ5	0.00E+00	1066				

Beam	X	Shear	Mom	Ax	DX	DY	RZ
1	0.00	-1196	4663	1051	0.00E+00	0.00E+00	-2.80E-04
1	11.99	-894	-7465	898	3.10E-04	-2.10E-03	-2.64E-03
2	0.00	-4959	-17451	1288	3.33E-04	-2.11E-03	-2.30E-03
2	12.03	-4072	-57025	832	2.21E-03	3.35E-04	-4.65E-02
3	0.00	137	-4663	0	0.00E+00	0.00E+00	-2.80E-04
3	10.00	453	1547	0	0.00E+00	1.08E-19	1.84E-04
4	0.00	0	0	0	0.00E+00	0.00E+00	0.00E+00
4	11.40	0	0	0	0.00E+00	0.00E+00	0.00E+00
5	0.00	-2012	1428	3688	0.00E+00	0.00E+00	0.00E+00
5	5.45	-2010	-9524	3673	3.33E-04	-2.11E-03	-2.38E-03
6	0.00	196	-1066	21	0.00E+00	0.00E+00	0.00E+00
6	10.90	196	1066	-39	2.86E-03	5.66E-07	3.02E-05
7	0.00	21	-303	1261	0.00E+00	0.00E+00	0.00E+00
7	15.77	112	539	1175	2.86E-03	3.94E-07	6.53E-06

* vertical deflections do not take into account any supporting intermediate walls



Scaled 2X Deflected Truss Plot
Roof Plane MP 1 for Sunergy Client TAVITA PONCE