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STRUCTURAL ANALYSIS for the

ROOFTOP PV SOLAR INSTALLATION

Project: Arisa Dintcho, 78 Glenwood Court, Spring Lake, NC 28390

Prepared for:



Freedom Solar, LLC 4801 Freidrich Ln, Ste 100 - Austin, TX 78744

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j							

Project Number: 36.111636, Rev. 0

Report Date: 09/12/2023

Report Prepared by:



Richard Pantel, P.E. NC License No. 43326



Digitally signed by Richard Pantel DN: c=US, o=TECTONICORP PC, BFCA00007095, cn=Richard Pantel Date: 2023.09.12 20:13:57 -04'00'

Loading Summary

Exposure and Occupancy Categories					
В	Exposure Category (ASCE 7-10 Table 26.7.3, Page 266)				
	Building Use Occupancy / Risk Category (ASCE 7-10 Table 1.5-1, Page 4)				

	Wind Loading:						
v 118		118 <i>mph</i>	ASCE 7-10, Figure 26.5-1 A, B or C, pp 247-249. [(118 mph, 50				
v		прп	year wind MRI)]				
qz	21.10	psf	Velocity qz, calculated at height z [ASD]				

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

Module Data							
WAAREE ENER	GIES LIMIT	FED: WSME	D-400				
Dimensions	тт	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 Sum	Module Loading Summary				
Support Point Loads		Upward	Upward	Upward	Downward
Roof Zones		1	2	3	All
Net total load / support point	lb	-103	-162	-162	246

Positive values indicate net downward force

Stanchion Fastener Pull-out and Spacing Calculations							
Framing spacing	ft	2.00					
Max stanchion span	ft	6.00]				
# fasteners per stanchion		1	1				
Depth of bolt thread embedment	in	3	1				
Safety Factor		1.25	1				
Pull-out for 5/16 fasteners	lb/in	206	1				
Factored max uplift capacity	lb	495					
	-		-				
Roof Zones		1	2	3			

		1	2	5	
Lift Per Module	lb	103	162	162	
Min depth of bolt thre	ad embedment rq'd	in	0.63	0.98	0.98
Net uplift pressure	7. 0.6D - 0.6W	psf	-2.73	-4.27	-4.27
Allowable lift area / fa	stener	sf	181.51	115.79	115.79
Landscape Modules	5			_	
Length along rafter	ft	3.41			
Maximum stanchion	ft	6.00	6.00	6.00	
Maximum module a	sf	10.2	10.2	10.2	
Factored lift per sup	lb	-28	-44	-44	
Portrait Modules				_	
Length along rafter	ft	6.31			
Maximum stanchion EW spacing		ft	6.00	6.00	6.00
Maximum module area / support point		sf	18.9	18.9	18.9
Factored lift per sup	port point	lb	-52	-81	-81

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

Τ

Conclusions

Princeton Engineering was asked to review the roof of Arisa Dintcho, located at 78 Glenwood Court, Spring Lake, NC, by Freedom Solar, LLC, to determine its suitability to support a PV solar system installation.

The referenced building's roof structure was field measured by Freedom Solar, LLC on 09/01/2023. 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 Freedom Solar, LLC. Loads are calculated to combine the existing building and environmental loads with the proposed new PV array loads.

Freedom Solar, LLC selected the SunPower InvisiMount 6000 series racking with QuickBolt 17662 stanchions for this project. The racking and support stanchions shall be placed as shown on their plans, dated 09/12/2023, 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. The support rail can be cantilevered up to 1/3 of the maximum span between modules. 1/3 maximum span = 24.00 inches.



Google Location Map

Framing Summary

Based upon the attached calculations, the existing roofs framing systems are 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.

Notes: (1) Bolt 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) 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 7-10 Minimum Design Loads for Buildings and Other Structures
- 2) IBC 2015
- 3) 2018 NC Building Code
- 4) American Wood Council, NDS 2018, Table 12.2A, 12.3.3A.
- 5) American Wood Council, Wood Structural Design, 1992, Figure 6.

Roof Structural Calculations for PV Solar Installation Location: MP 1 Member: Truss - Total Length 30 ft, Unsupported 30 ft

Geometric Data						
Θ deg. 39.00 Angle of roof plane from horizontal, in degrees						
L ft. 40.42 Length of roof plane, in feet (meters)		Length of roof plane, in feet (meters)				
W	ft.	22.92	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 Veloc	Wind Velocity Pressure, q_z evaluated at the height z						
$q_z =$	21.10	psf	f Vasd q_z = 12.89 psf Basic wind pressure				
V=	118	mph					

Framing Data						
Wood type	US Sp	oruce				
Wood source, moisture content	White	0.12%				
# Framing Members / Support		1				
Rafter / Truss OC	in	24.00				
Member Total Length	ft	30.00				

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

Member Properties	Member	* Mem properties based upon field measurements
Name	(1) 2x4	Top truss chord
Repetitive Member Factor (Cr)	1.15	

Module Physical Data							
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
Roof Deck & Surface	psf	4.40	Truss members' self weight added to FEA analysis

Rack Support Spacing]				
Across rafters	ft	6.0			
Along rafter slope	ft	6.3			
Area / support point	sf	18.9			
Uphill gap between modules	in	1.0	0.08	ft	

Member Total Length	ft	30.00	
Maximum member free span	ft	30.00	Top truss chord span

ASCE 7-10 Chapter 2 Combinations of Loads, Table 2.4, Page 8 (in psf)							
Zones	1	2	3	1,2&3			
2.2 SYMBOLS AND NOTATION	Module	Module	Module	Downward			
2.2 STMBOES AND NOTATION	Upward	Upward	Upward	Downwaru			
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	-12.04	-14.61	-14.61	11.17			

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.

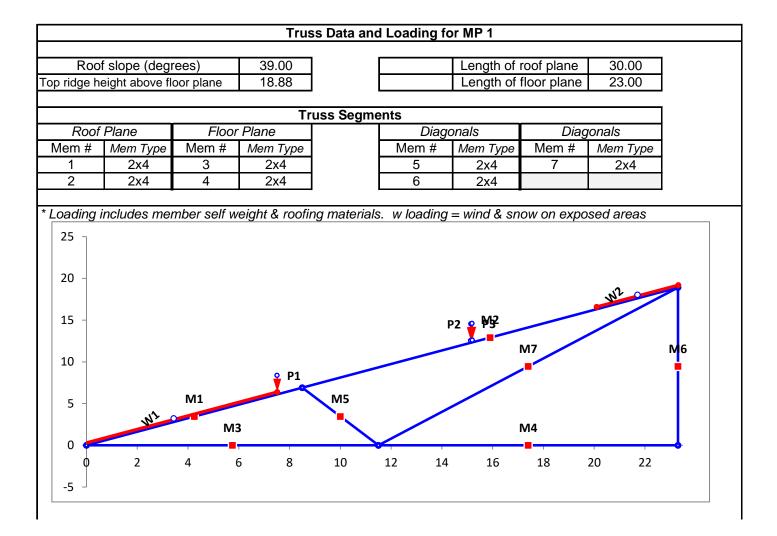
	eeneraerea						
Combination Formulae	Upward	Upward	Upward	Downward			
Use this loading combination for DOWNWARD for Proposed PV Dead Load							
6. D + 0.75L - 0.75(0 or 0.7)eE + 0.75S	12.40	12.40	12.40	14.92			
Module Support point load (lb)	235	235	235	282			
Cr Factored Module Support point load (lb)	204	204	204	246			

Use this loading combination for UPWARD for Proposed PV Dead Load							
7. 0.6D - 0.6W -2.73 -4.27 -4.27 4.50							
Module Support point load (lb)	-52	-81	-81	85			

DOWNWARD

Presume loading directly over member.

		Combined	Dead and W	Vind Pressure Downward Loading	
	Тор	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	9.67		246		Landscape
1	13.08			Support placed on adjoining truss	Landscape
2	13.16			Support placed on adjoining truss	Portrait
2	19.47		246		Portrait
3	19.55		246		Portrait
3	25.86			Support placed on adjoining truss	Portrait



Roof Structural Calculations for PV Solar Installation Location: MP 2 Member: Truss - Total Length 22 ft, Unsupported 22 ft

Geometric Data					
θ	deg.	43.00	Angle of roof plane from horizontal, in degrees		
L	ft.	26.40	Length of roof plane, in feet (meters)		
W	ft.	16.20	Plan view width of roof plane, in feet (meters)		
h ft. 25.00 Average height of roof above grade, in feet (meters)		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								
$q_z =$	21.10	psf	Vasd q _z =	12.89	psf	Basic wind pressure		
V=	118		mph					

Framing Data						
Wood type	US Sp	oruce				
Wood source, moisture content	White 0.12%					
# Framing Members / Support		1				
Rafter / Truss OC	in	24.00				
Member Total Length	ft	22.00				

3	# Rafters / Rack Support Width
6.00	Rack Support Spacing (ft)
72	Max. Rack Support Spacing (in)
1	Max # of mod's / Top truss chord

Member Properties	Member	* Mem properties based upon field measurements
Name	(1) 2x4	Top truss chord
Repetitive Member Factor (Cr)	1.15	

Module Physical Data							
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
Roof Deck & Surface	psf	4.40	Truss members' self weight added to FEA analysis

Rack Support Spacing	and Loadin	g			
Across rafters	ft	6.0			
Along rafter slope	ft	6.3			
Area / support point	sf	18.9			
Uphill gap between modules	in	1.0	0.08	ft	

Member Total Length	ft	22.00	
Maximum member free span	ft	22.00	Top truss chord span

ASCE 7-10 Chapter 2 Combinations of Loads	, Table 2.4,	Page 8 (in	psf)		
Zones	1	2	3	1,2&3	
2.2 SYMBOLS AND NOTATION	Module	Module	Module	Downward	
2.2 STMBOES AND NOTATION	Upward	Upward	Upward	Downwaru	
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	-12.04	-14.61	-14.61	11.17	

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.

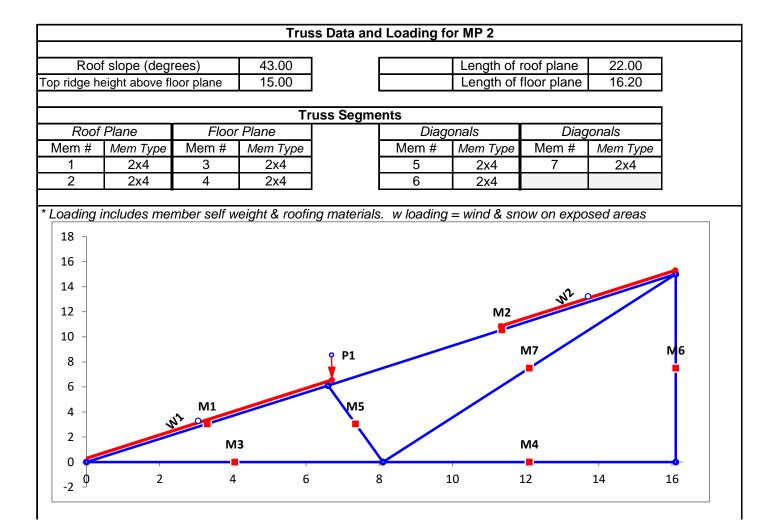
	eeneraerea							
Combination Formulae	Upward	Upward	Upward	Downward				
Use this loading combination for DOWNWARD for Proposed PV Dead Load								
6. D + 0.75L - 0.75(0 or 0.7)eE + 0.75S	12.40	12.40	12.40	14.92				
Module Support point load (lb)	235	235	235	282				
Cr Factored Module Support point load (lb)	204	204	204	246				

Use this loading combination for UPWARD for Proposed PV Dead Load								
7. 0.6D - 0.6W -2.73 -4.27 -4.27 4.50								
Module Support point load (lb)	-52	-81	-81	85				

DOWNWARD

Presume loading directly over member.

	Combined Dead and Wind Pressure Downward Loading									
	Тор	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	9.17		246		Portrait					
1	15.48			Support placed on adjoining truss	Portrait					



Snow Loading Analysis

where:

Ce C Is	st s	= = =	Fully Ex 0.9 1.0 1.0 10	posed Exposure category Exposure Factor, Ce (ASCE 7-10 Table 7.3-1, Page 58) Thermal Factor, Ct (ASCE 7-10 Table 7.3-2, Page 58) Snow Importance Factor, Is (ASCE 7-10 Table 1.5-2, Page 5) Ground Snow Load pg (ASCE 7-10 Table 7.2-1, Page 52-53)
•	9			
р) _f	=	0.7CeCt	IsPg Flat Roof Snow Load, pf (ASCE 7-10 Table 7.3-1, Page 58)
р) _f	=	6.3	psf
				but where Pf is not less than the following:
				Minimum Snow Load pm (ASCE 7-10 Table 7.3.4, Page 53)
p	n	=	10	When $Pg \ll 20 \text{ psf}$, then use $Pf = Pg \times Is$
р) _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 7-10 Table 7.4, Page 54)
				Roof Type Warm Roofs
Roof sl	оре	e fa	ctor Cs fo	or Warm Roofs, where $Ct = 1.0$
				Roof surface condition = Slippery Roof
C	s	=	1.00	Roof Slope Factor, Cs (ASCE 7-10 Table 7-2a, Page 36)

Total Snow Load

p_s = **10.00 psf** Roof snow load

FEA Calculation Results for Roof Plane MP 1 for Freedom Solar, LLC Client Arisa Dintcho IDSPL - 2D Frame Analysis of a 2D frame subject to distributed loads, point loads and moments

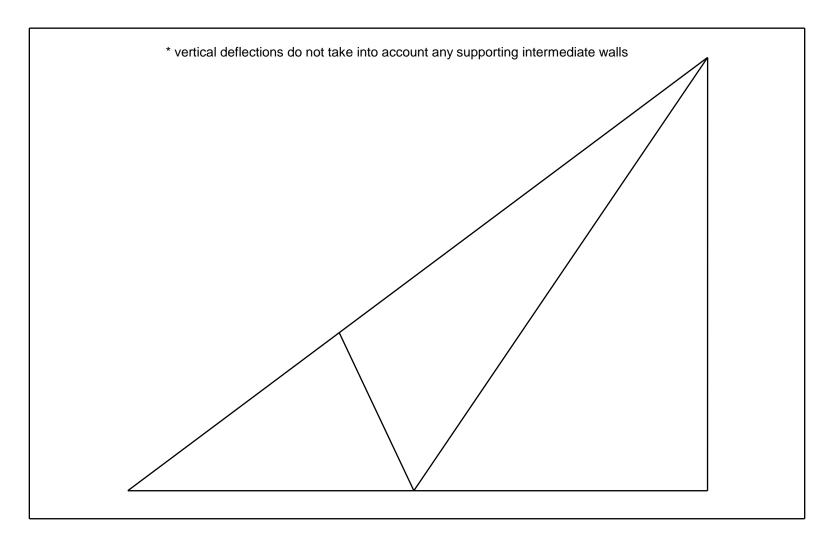
Equilibrium check	FX	FY	1.6E-05
Total applied forces		3278	
Total output reactions	0.00	-3278	
Output error	7.82E-14	-4.55E-13	

		_	Maximum	Deflections
# of segments/beam	1		1.72E-03	-8.07E-04
* vartical deflections d	a not taka	into occo	unt only ounne	rting intorn

Maximum Deflections				
1.72E-03	-8.07E-04			
		• • •		

Node Results				Bean	n End Res	ults
Direction	Deflection	Reaction	Beam	Shear	Ax	BM
DX1	0.00E+00	-187	1-1	-871	948	5100
DY1	0.00E+00	-1155	1-2	-552	689	-4142
RZ1	-1.37E-03	0	2-1	-1133	602	-5817
DX2	7.35E-04	0	2-2	378	-623	-16287
DY2	8.07E-04	0	3-1	120	0	-5100
RZ2	-6.32E-04	0	3-2	543	0	1772
DX3	1.72E-03	0	4-1	0	0	0
DY3	0.00E+00	-685	4-2	0	0	0
RZ3	0.00E+00	-15592	5-1	-225	568	51
DX4	0.00E+00	214	5-2	-239	536	-1675
DY4	0.00E+00	-1377	6-1	27	62	-253
RZ4	0.00E+00	1680	6-2	27	-133	253
DX5	0.00E+00	-27	7-1	-27	458	41
DY5	0.00E+00	-62	7-2	115	231	443
RZ5	0.00E+00	253				

* vertical deflections do not take into account any supporting intermediate walls								
Beam	Х	Shear	Mom	Ax	DX	DY	RZ	
1	0.00	-871	5100	948	0.00E+00	0.00E+00	-1.37E-03	
1	10.95	-621	-3786	745	7.11E-04	-7.88E-04	-9.45E-04	
2	0.00	-1133	-5817	602	7.35E-04	-8.07E-04	-6.32E-04	
2	19.05	-170	-9258	-179	1.25E-03	3.82E-04	-9.49E-03	
3	0.00	120	-5100	0	0.00E+00	0.00E+00	-1.37E-03	
3	11.50	449	2255	0	0.00E+00	1.63E-19	2.76E-04	
4	0.00	0	0	0	0.00E+00	0.00E+00	0.00E+00	
4	11.80	0	0	0	0.00E+00	0.00E+00	0.00E+00	
5	0.00	-225	51	568	0.00E+00	0.00E+00	0.00E+00	
5	7.52	-237	-1676	542	7.35E-04	-8.07E-04	-6.34E-04	
6	0.00	27	-253	62	0.00E+00	0.00E+00	0.00E+00	
6	18.90	27	253	-117	1.72E-03	7.80E-07	4.13E-06	
7	0.00	-27	41	458	0.00E+00	0.00E+00	0.00E+00	
7	22.28	104	447	247	1.72E-03	6.63E-07	5.42E-07	



Scaled 2X Deflected Truss Plot Roof Plane MP 1 for Freedom Solar, LLC Client Arisa Dintcho

FEA Calculation Results for Roof Plane MP 2 for Freedom Solar, LLC Client Arisa Dintcho IDSPL - 2D Frame Analysis of a 2D frame subject to distributed loads, point loads and moments

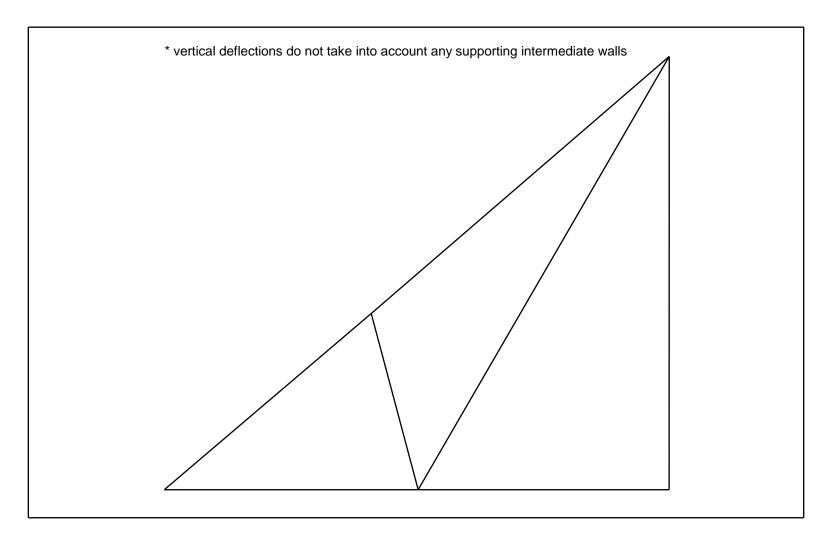
Equilibrium check	FX	FY	1.7E-05
Total applied forces	0.00	1714	
Total output reactions	0.00	-1714	
Output error	1.49E-13	4.55E-13	

# of segments/beam	1

Maximum	Deflections
1.80E-03	-1.14E-03

Node Results				Bean	n End Res	ults
Direction	Deflection	Reaction	Beam	Shear	Ax	BM
DX1	0.00E+00	-84	1-1	-57	167	141
DY1	0.00E+00	-240	1-2	217	-86	-429
RZ1	1.64E-04	0	2-1	-1434	926	240
DX2	-8.29E-04	0	2-2	-763	298	-16987
DY2	1.14E-03	0	3-1	-85	0	-141
RZ2	2.74E-04	0	3-2	26	0	-887
DX3	1.80E-03	0	4-1	0	0	0
DY3	0.00E+00	962	4-2	0	0	0
RZ3	0.00E+00	-16197	5-1	82	1959	164
DX4	0.00E+00	137	5-2	76	1935	669
DY4	0.00E+00	-2396	6-1	53	39	-398
RZ4	0.00E+00	-848	6-2	53	-86	398
DX5	0.00E+00	-53	7-1	11	513	-203
DY5	0.00E+00	-39	7-2	86	372	392
RZ5	0.00E+00	398				

* vertical deflections do not take into account any supporting intermediate walls								
Beam	Х	Shear	Mom	Ax	DX	DY	RZ	
1	0.00	-57	141	167	0.00E+00	0.00E+00	1.64E-04	
1	8.99	-17	-121	130	-8.51E-04	-1.12E-03	1.19E-04	
2	0.00	-1434	240	926	-8.29E-04	-1.14E-03	2.74E-04	
2	13.02	-1095	-12650	609	1.49E-03	2.96E-04	-7.10E-03	
3	0.00	-85	-141	0	0.00E+00	0.00E+00	1.64E-04	
3	8.10	-38	-552	0	0.00E+00	-4.03E-20	-1.91E-04	
4	0.00	0	0	0	0.00E+00	0.00E+00	0.00E+00	
4	8.00	0	0	0	0.00E+00	0.00E+00	0.00E+00	
5	0.00	82	164	1959	0.00E+00	0.00E+00	0.00E+00	
5	6.28	77	668	1940	-8.29E-04	-1.14E-03	2.66E-04	
6	0.00	53	-398	39	0.00E+00	0.00E+00	0.00E+00	
6	15.00	53	398	-73	1.80E-03	6.17E-07	8.18E-06	
7	0.00	11	-203	513	0.00E+00	0.00E+00	0.00E+00	
7	17.00	79	395	385	1.80E-03	5.46E-07	4.21E-06	



Scaled 2X Deflected Truss Plot Roof Plane MP 2 for Freedom Solar, LLC Client Arisa Dintcho