

iRoofA™

Instant Roof Framing Analysis

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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

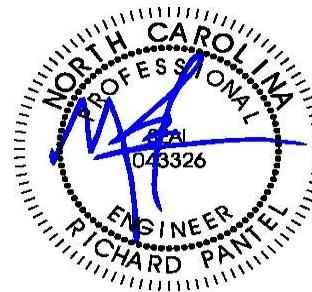
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Project Number: 36.111636, Rev. 0

Report Date: 09/12/2023

Report Prepared by:



Richard Pantel
Ver. 20230907

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Loading Summary

Exposure and Occupancy Categories		
B		<i>Exposure Category (ASCE 7-10 Table 26.7.3, Page 266)</i>
II		<i>Building Use Occupancy / Risk Category (ASCE 7-10 Table 1.5-1, Page 4)</i>

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

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

Module Data			
WAAREE ENERGIES LIMITED: WSMD-400			
Dimensions	<i>mm</i>	<i>ft</i>	<i>in</i>
<i>Length</i>	1,923	6.31	75.70
<i>Width</i>	1,039	3.41	40.90
<i>Area (m², ft²)</i>	2.0	21.50	
Weight	<i>kg</i>	<i>lb</i>	
<i>Module</i>	22.00	48.50	

Roof Panel (Cladding) Loading Summary		Module Loading Summary			
<i>Support Point Loads</i>		<i>Upward</i>	<i>Upward</i>	<i>Upward</i>	<i>Downward</i>
Roof Zones		1	2	3	All
Net total load / support point	<i>lb</i>	-103	-162	-162	246

Positive values indicate net downward force

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

Roof Zones			1	2	3
Lift Per Module	<i>lb</i>		103	162	162
Min depth of bolt thread embedment req'd	<i>in</i>		0.63	0.98	0.98
Net uplift pressure	7. 0.6D - 0.6W	<i>psf</i>	-2.73	-4.27	-4.27
Allowable lift area / fastener		<i>sf</i>	181.51	115.79	115.79
Landscape Modules					
Length along rafter	<i>ft</i>		3.41		
Maximum stanchion EW spacing	<i>ft</i>		6.00	6.00	6.00
Maximum module area / support point	<i>sf</i>		10.2	10.2	10.2
Factored lift per support point	<i>lb</i>		-28	-44	-44
Portrait Modules					
Length along rafter	<i>ft</i>		6.31		
Maximum stanchion EW spacing	<i>ft</i>		6.00	6.00	6.00
Maximum module area / support point	<i>sf</i>		18.9	18.9	18.9
Factored lift per support point	<i>lb</i>		-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

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

Array AR-1

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)
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 Velocity Pressure, q_z evaluated at the height z			
$q_z=$	21.10	psf	$V_{asd} q_z=$ 12.89 psf Basic wind pressure
V=	118		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	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
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	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 Loading			
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	<i>Module Upward</i>	<i>Module Upward</i>	<i>Module Upward</i>	<i>Downward</i>
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.

<i>Combination Formulae</i>	<i>Upward</i>	<i>Upward</i>	<i>Upward</i>	<i>Downward</i>
Use this loading combination for DOWNWARD for Proposed PV Dead Load				
6. $D + 0.75L - 0.75(0 \text{ or } 0.7)eE + 0.75S$	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					
Top truss chord span					
PV Module Row	Point load loc's from Left support	Point Load #'s	Module Support Point Load	Comment	Module Orientation
	<i>ft from left</i>		<i>lb</i>		
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

Truss Data and Loading for MP 1

Roof slope (degrees)	39.00
Top ridge height above floor plane	18.88

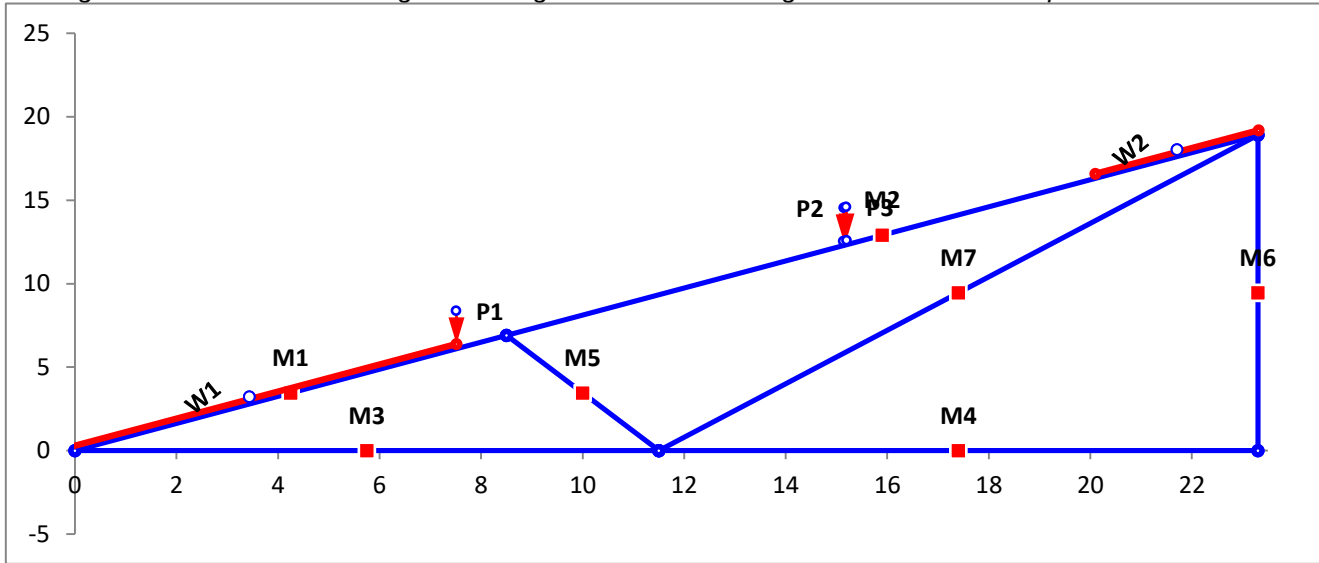
Length of roof plane	30.00
Length of floor plane	23.00

Truss Segments

Roof Plane		Floor Plane	
Mem #	Mem Type	Mem #	Mem Type
1	2x4	3	2x4
2	2x4	4	2x4

Diagonals		Diagonals	
Mem #	Mem Type	Mem #	Mem Type
5	2x4	7	2x4
6	2x4		

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



Roof Structural Calculations for PV Solar Installation

Array AR-2

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)

Roof Wind Zone Width			
	use, a =	3.00	ft

Wind Velocity Pressure, q_z evaluated at the height z			
$q_z=$	21.10	psf	$V_{asd} q_z=$ 12.89 psf Basic wind pressure
V=	118		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	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
Name	(1) 2x4
Repetitive Member Factor (Cr)	1.15

* Mem properties based upon field measurements

Top truss chord

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Weight	kg	lb	psf load
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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 Loading			
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	<i>Module Upward</i>	<i>Module Upward</i>	<i>Module Upward</i>	<i>Downward</i>
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.

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6. $D + 0.75L - 0.75(0 \text{ or } 0.7)eE + 0.75S$	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					
Top truss chord span					
PV Module Row	Point load loc's from Left support	Point Load #'s	Module Support Point Load	Comment	Module Orientation
	<i>ft from left</i>		<i>lb</i>		
1	9.17		246		Portrait
1	15.48			Support placed on adjoining truss	Portrait

Truss Data and Loading for MP 2

Roof slope (degrees)	43.00
Top ridge height above floor plane	15.00

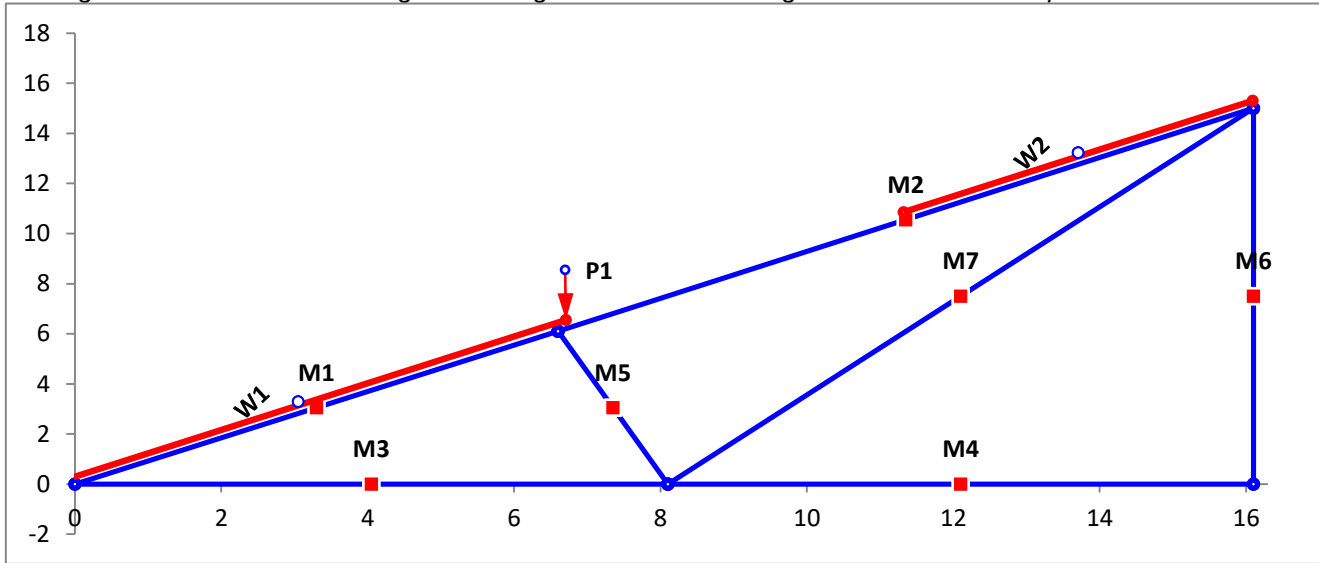
Length of roof plane	22.00
Length of floor plane	16.20

Truss Segments

Roof Plane		Floor Plane	
Mem #	Mem Type	Mem #	Mem Type
1	2x4	3	2x4
2	2x4	4	2x4

Diagonals		Diagonals	
Mem #	Mem Type	Mem #	Mem Type
5	2x4	7	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 |
| C_e = | 0.9 | Exposure Factor, C _e (ASCE 7-10 Table 7.3-1, Page 58) |
| C_t = | 1.0 | Thermal Factor, C _t (ASCE 7-10 Table 7.3-2, Page 58) |
| I_s = | 1.0 | Snow Importance Factor, I _s (ASCE 7-10 Table 1.5-2, Page 5) |
| p_g = | 10 | Ground Snow Load p _g (ASCE 7-10 Table 7.2-1, Page 52-53) |
| p_f = | 0.7C_eC_tI_sP_g | Flat Roof Snow Load, p _f (ASCE 7-10 Table 7.3-1, Page 58) |
| p_f = | 6.3 | psf |
| | | but where P _f is not less than the following: |
| | | Minimum Snow Load p _m (ASCE 7-10 Table 7.3.4, Page 53) |
| p_m = | 10 | When P _g <=20 psf, then use P _f = P _g x I _s |
| p_f = | 10 | psf. Resultant Snow pressure to be used with Roof slope factor below |
| p_s = | C_sp_f | Sloped Roof Snow Load p _s (ASCE 7-10 Table 7.4, Page 54) |
| | | Roof Type Warm Roofs |

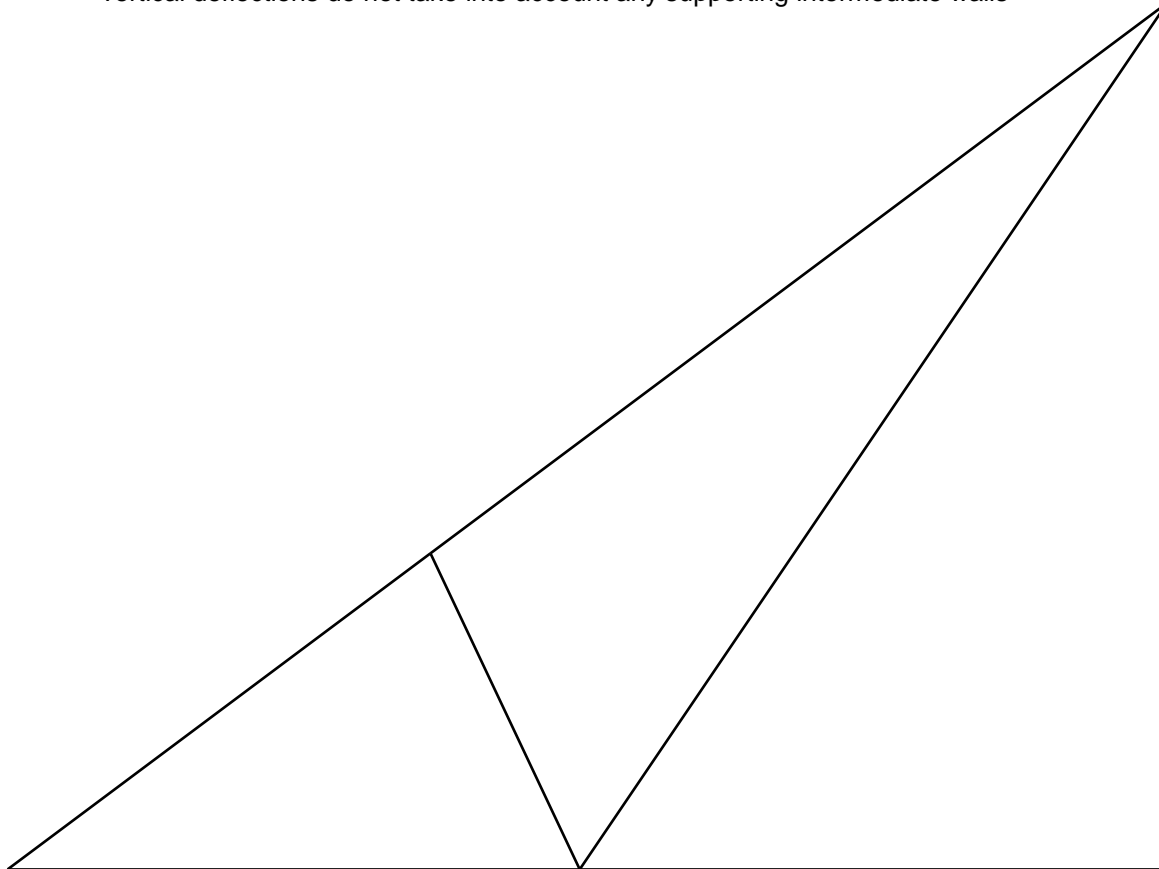
Roof slope factor C_s for Warm Roofs, where C_t = 1.0
 Roof surface condition = Slippery Roof

C_s = 1.00 Roof Slope Factor, C_s (ASCE 7-10 Table 7-2a, Page 36)

Total Snow Load

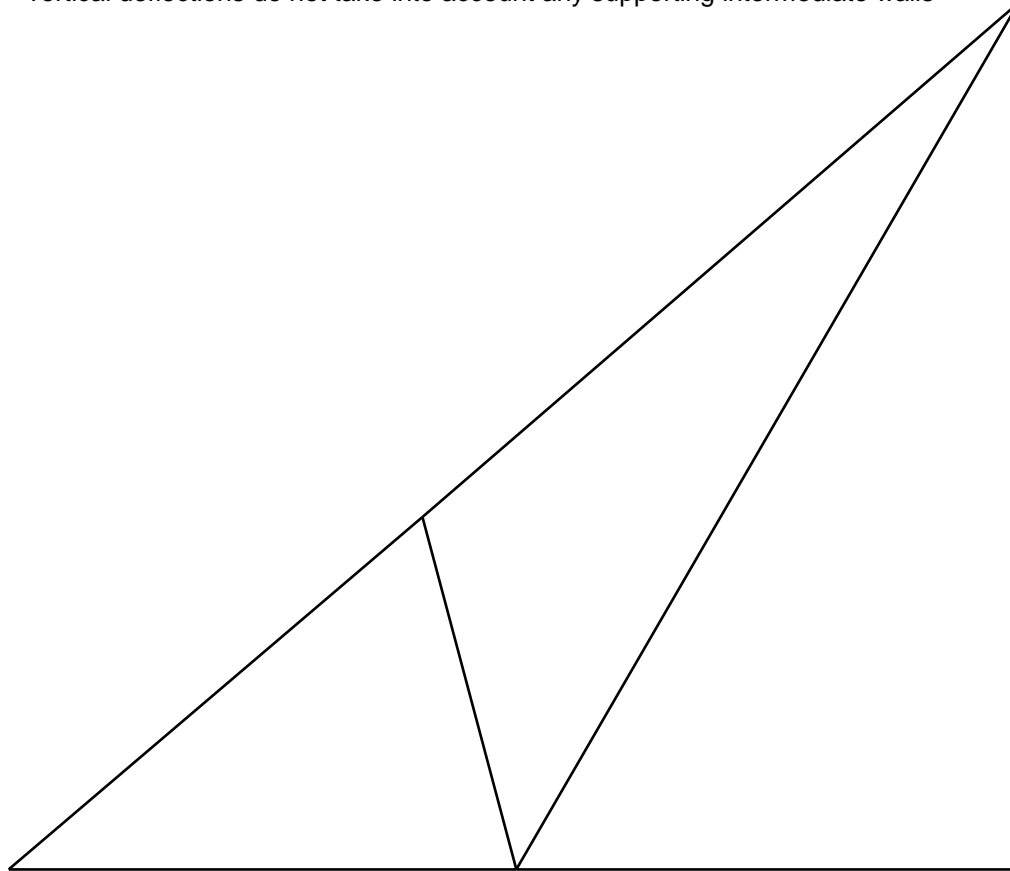
p_s =	10.00 psf	Roof snow load
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* vertical deflections do not take into account any supporting intermediate walls



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

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



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