October 7, 2021

Power Home Solar and Roofing
919 North Main Street
Mooresville, NC 28115

Design Criteria:
Design Wind Speed (ASD)- 116 mph
Ground Snow Load- 15 psf
Risk Category- II
Exposure category- C

RE: Structural Roof Evaluation for the ***Fleming Residence: 261 Tower Drive, Broadway, North Carolina***

As per your request, we have evaluated the roof structure under the proposed solar panel array. The information used to evaluate this structure was gathered by Power Home Solar and Roofing on behalf of Right Angle Engineering. The roof structure consists of pre-manufactured trusses spaced at 24" on center. The roof material consists of asphalt shingles. The design criteria used to analyze this structure are listed above and included with this letter. The adopted building codes in this jurisdiction are: *the 2018 North Carolina Building Code, the 2018 North Carolina Existing Building Code,* and *ASCE 7-16*.

North Carolina Existing Building Code (NCEBC) 2018 section 807.4 indicates that alterations to an existing building that results in less than a 10% increase in the total stress may be performed without a structural evaluation of the existing building. As demonstrated in the attached calculations, the additional weight of the solar panels will be less than 10% increase in the gravity loading and the stress on the existing roof framing.

Based on our assessment we have determined that the existing roof framing will safely and adequately support the additional loads imposed by the solar panels without reinforcement. In order for the loads to be evenly distributed, the roof attachments should be staggered and spread evenly throughout the panel array. Attachment points should be spaced at a maximum of 48" on center. The racking system should be installed per the manufacture's specifications. There should be a minimum of 35 L-foot attachment points to the roof. Each attachment should have a 5/16" or 18/8 SS lag screw with 2.5" minimum penetration centered on each truss top chord or rafter. Waterproofing around the roof penetrations is the responsibility of others. Right Angle Engineering assumes no responsibility for improper installation of the solar panels.

Regards,

10/7/21

Robert D Smythe, P.E.
Right Angle Engineering

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Design Criteria:

Design Wind Speed (3 second gust)	116	mph
Exposure Category	C	
Risk Category	2	
Mean Roof Height	30	ft
Roof Type	Gable Roof	
Building Type	enclosed	

Roof Dead Load- ASCE Table C3-1

Asphalt Shingles	2	psf
5/8" Plywood Sheathing	2	psf
Roof Framing	4	psf
Insulation	3.85	psf
Gypsum sheathing	2	psf
Solar Panel Array	3	psf
Dead Load Without Panels	13.85	psf
Dead Load With Solar panels	16.85	psf

Roof Live Load

Existing Roof Live Load	20	psf	ASCE 7-16 Table 4.3-1
Roof Live Load with Solar Panels	0	psf	2018 NCBC 1607.12.5

Roof Snow Load-ASCE 7-16

Ground Snow Load (pg)	15	psf	Section 7.2
Exposure Factor (Ce)	0.9		Table 7.3-1
Thermal Factor (Ct)	1.1		Table 7.3-2
Importance Factor (Is)	1		Table 1.5-2
Flat Roof Snow Load (Pf)	10		Equation 7.3-1
Slippery surface Slope Factor (Cs)	0.62		Figure 7-2
Nonslippery Surface Slope Factor (Cs)	1		Figure 7-2
Roof Snow Load	10	psf	Equation 7.4-1
Reduced Roof Snow Load (Slippery Surface)	6	psf	Equation 7.4-1

Load Combinations - ASCE 7-16 Section 2.4.1

	Without Solar Panels	With Solar panels
D + Lr	33.8 psf	16.8 psf
D + S	24.2 psf	23.3 psf

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Solar Array 1- Roof 1

Roof Slope	33	degrees	
Number of panels	11		
Panel Area	192.5	ft^2	

Wind Calculations- ASCE 7-16

GC_p Zone 1	-1		Figure 30.3-(2A-5B)
GC_p Zone 2	-1.8		Figure 30.3-(2A-5B)
GC_p Zone 3	-2.8		Figure 30.3-(2A-5B)
Gcpi	0.18		Table 26.13-1
Velocity Pressure (q_h)	28.7	psf	
$q_h = .00256K_hK_{ht}K_dV^2$			Equation 26.10-1
K_h	0.98		Table 26.10-1
K_{ht}	1		Equation 26.8-1
K_d	0.85		Table 26.6-1
Designed wind pressure (P)		psf	Equation 30.8-1
$P= q_h(GC_h) - (GC_{hi})$			
Zone 1 Pressure (P)	-33.9	psf	
Zone 2 Pressure (P)	-56.8	psf	
Zone 3 Pressure (P)	-85.5	psf	

Roof Connection

Shear Capacity	190	lbs	NDS 2015 Table 12K
Shear tributary area	37.1	ft^2	
Pullout Capacity	266	lbs/in	
Lag screw embedment	2.5	in	
Total pullout capacity	665	lbs	NDS 2015 Table 12.2A
Pullout max tributary area	11.7	ft^2	
Factor of Safety	1.41		
Minimum number of connections	**18**		

Beam Stress NCEBC 2018 Section 806.2

Beam Span	16	ft
Spacing	2	ft
Roof Framing type	pre-manufactured trusses	
Panel Orientation	portrait	
Number of Panels per rafter	2	
Panel distance from eave	4	

	Without Solar Panels	With Solar Panels	Percent Increase	
Bending Moment	2166.4 ft-lbs	1549.3 ft-lbs	71.5%	Less than 105%
Vertical Reaction (V1)	541.6 lbs	399.2 lbs	73.7%	Less than 105%
Vertical Reaction (V2)	541.6 lbs	351.96 lbs	65%	Less than 105%

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Solar Array 2- Roof 2

Roof Slope	33	degrees	
Number of panels	6		
Panel Area	105	ft^2	

Wind Calculations- ASCE 7-16

GC_p Zone 1	-1		Figure 30.3-(2A-5B)
GC_p Zone 2	-1.2		Figure 30.3-(2A-5B)
GC_p Zone 3	-1.2		Figure 30.3-(2A-5B)
Gcpi	0.18		Table 26.13-1
Velocity Pressure (q_h)	28.7	psf	
$q_h = .00256K_hK_{ht}K_dV^2$			Equation 26.10-1
K_h	0.98		Table 26.10-1
K_{ht}	1		Equation 26.8-1
K_d	0.85		Table 26.6-1
Designed wind pressure (P)		psf	Equation 30.8-1
$P= q_h(GC_h) - (GC_{hi})$			
Zone 1 Pressure (P)	-33.9	psf	
Zone 2 Pressure (P)	-39.6	psf	
Zone 3 Pressure (P)	-39.6	psf	

Lag Screw Connection

Shear Capacity	190	lbs	NDS 2015 Table 12K
Shear tributary area	37.1	ft^2	
Pullout Capacity	266	lbs/in	
Lag screw embedment	2.5	in	
Total pullout capacity	665	lbs	NDS 2015 Table 12.2A
Pullout max tributary area	16.8	ft^2	
Factor of Safety	2.01		
Minimum number of connections	**10**		

Beam Stress NCEBC 2018 Section 806.2

Beam Span	16	ft
Spacing	2	ft
Roof Framing type	pre-manufactured trusses	
Panel Orientation	portrait	
Number of Panels per rafter	1	
Panel distance from eave	8	

	Without Solar Panels	With Solar Panels	Percent Increase	
Bending Moment	2166.4 ft-lbs	1572.1 ft-lbs	72.6%	Less than 105%
Vertical Reaction (V1)	541.6 lbs	380.9 lbs	70.3%	Less than 105%
Vertical Reaction (V2)	541.6 lbs	380.9 lbs	70.3%	Less than 105%

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Solar Array 3- Roof 3

Roof Slope	36	degrees	
Number of panels	4		
Panel Area	70	ft^2	

Wind Calculations- ASCE 7-16

GC_p Zone 1	-1		Figure 30.3-(2A-5B)
GC_p Zone 2	-1.2		Figure 30.3-(2A-5B)
GC_p Zone 3	-1.2		Figure 30.3-(2A-5B)
Gcpi	0.18		Table 26.13-1
Velocity Pressure (q_h)	28.7	psf	
$q_h = .00256K_hK_{ht}K_dV^2$			Equation 26.10-1
K_h	0.98		Table 26.10-1
K_{ht}	1		Equation 26.8-1
K_d	0.85		Table 26.6-1
Designed wind pressure (P)		psf	Equation 30.8-1
$P= q_h(GC_h) - (GC_{hi})$			
Zone 1 Pressure (P)	-33.9	psf	
Zone 2 Pressure (P)	-39.6	psf	
Zone 3 Pressure (P)	-39.6	psf	

Lag Screw Connection

Shear Capacity	190	lbs	NDS 2015 Table 12K
Shear tributary area	34.4	ft^2	
Pullout Capacity	266	lbs/in	
Lag screw embedment	2.5	in	
Total pullout capacity	665	lbs	NDS 2015 Table 12.2A
Pullout max tributary area	16.8	ft^2	
Factor of Safety	2.01		
Minimum number of connections	**6**		

Beam Stress NCEBC 2018 Section 806.2

Beam Span	12	ft
Spacing	2	ft
Roof Framing type	pre-manufactured trusses	
Panel Orientation	portrait	
Number of Panels per rafter	1	
Panel distance from eave	4	

	Without Solar Panels	With Solar Panels	Percent Increase	
Bending Moment	1218.6 ft-lbs	918 ft-lbs	75.3%	Less than 105%
Vertical Reaction (V1)	406.2 lbs	285.8 lbs	70.4%	Less than 105%
Vertical Reaction (V2)	406.2 lbs	285.8 lbs	70.4%	Less than 105%