C.M.F. Engineering, Inc.

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Longmeadow, MA 01106
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December 9, 2018

RE: Evaluation of Chelsea and Apple Hill sites

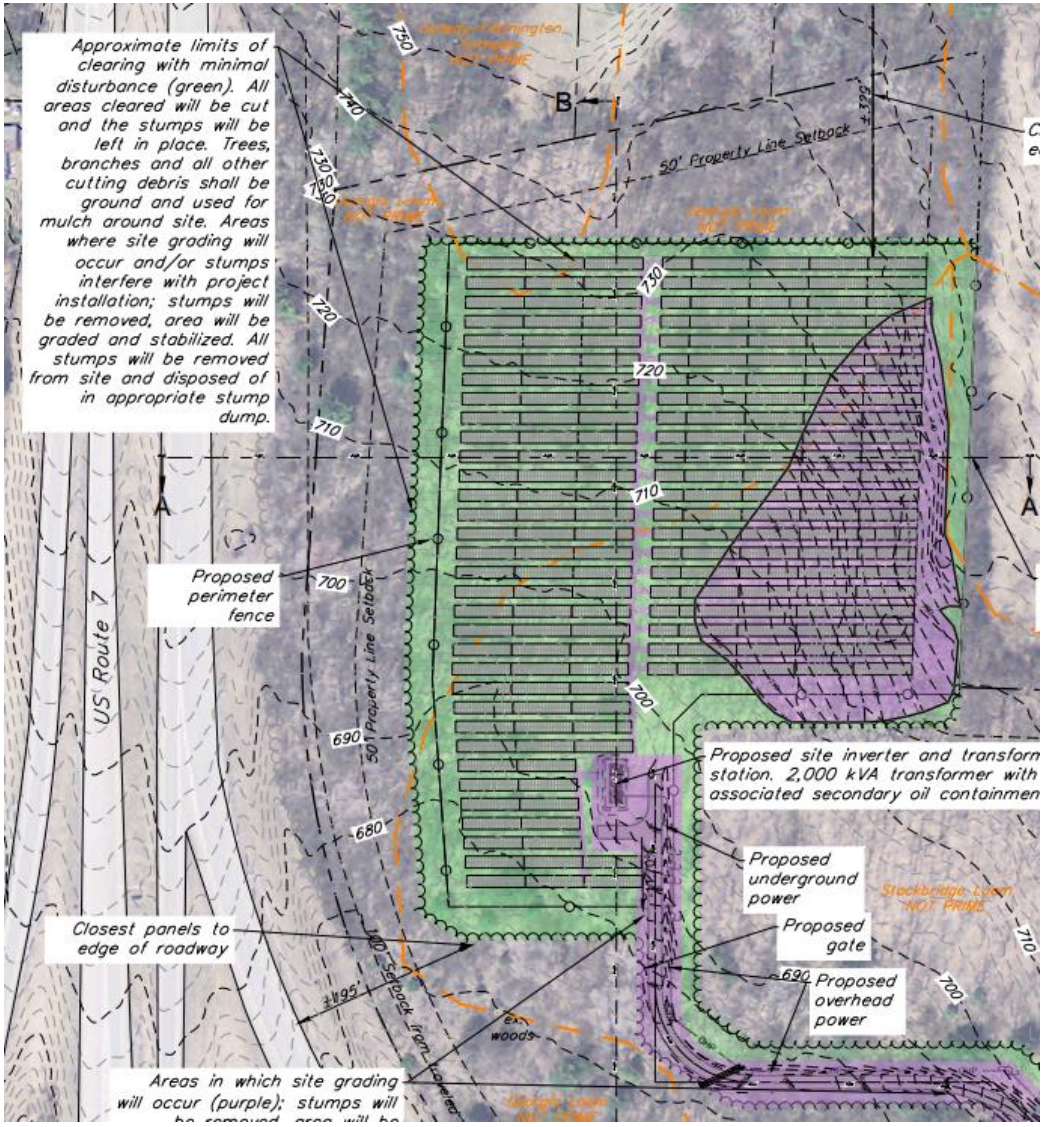
Enclosures:
Exhibit CS-BW-57, Docket 8302
Prefile Testimony of Brad Wilson, PUC Docket 17-5024-PET, 11/27/2017
Prefile Testimony of Ian Jewkes, PUC Docket 17-5024-PET, 11/27/2017

Annette Smith
Vermonters for a Clean Environment
789 Baker Brook Road
Danby, Vermont 05739

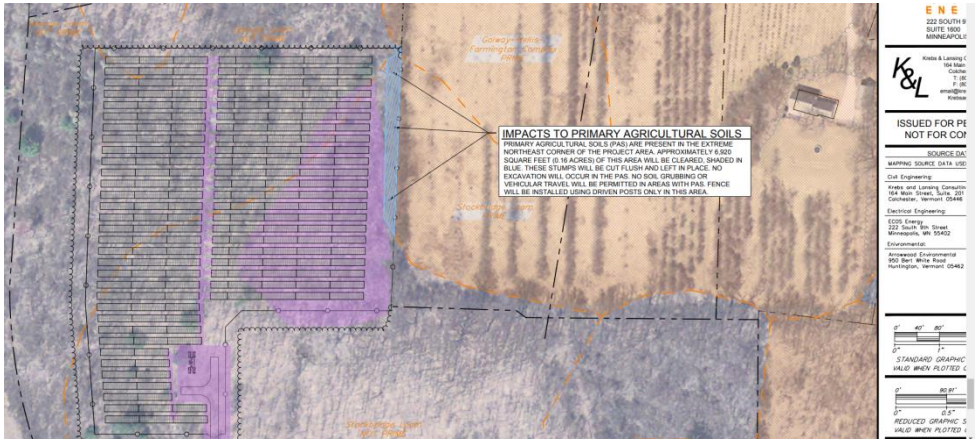
Dear Ms. Smith:

An analysis of expected photovoltaic solar farm performance was completed for the proposed "***Chelsea***" and "***Apple Hill***" sites adjacent to Willow Road and Route **7** in Bennington, Vermont.

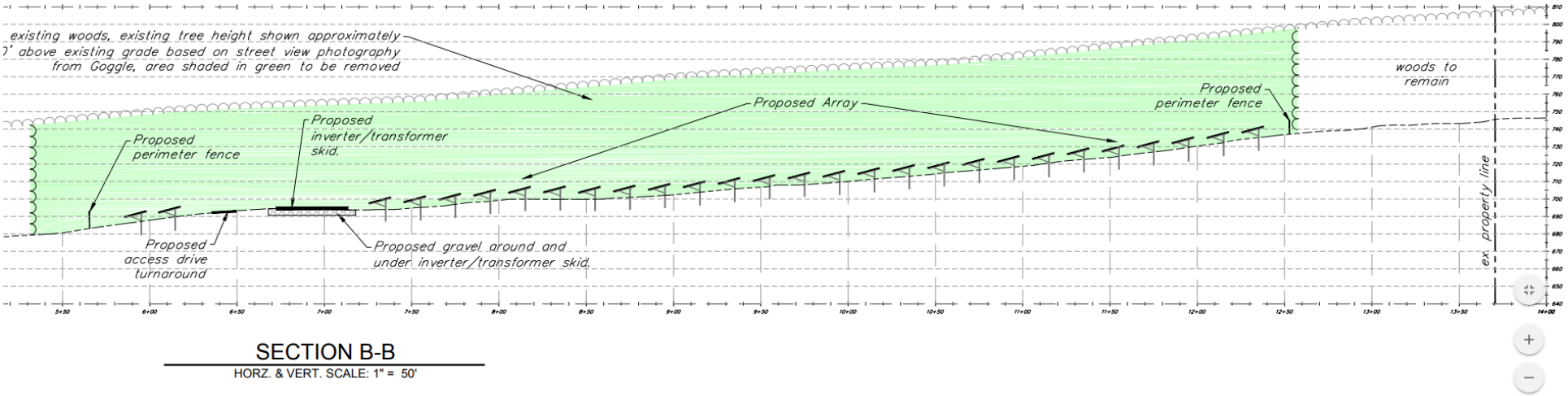
A sensitivity analysis was done for solar panels located at **43.9°** North latitude facing true south and pitched at: **15°, 20°, 25°, 30°, 35°,** and **40°** above the horizontal. Based on reported information, the overal gradient of the site is **8**% upwards from front to rear.



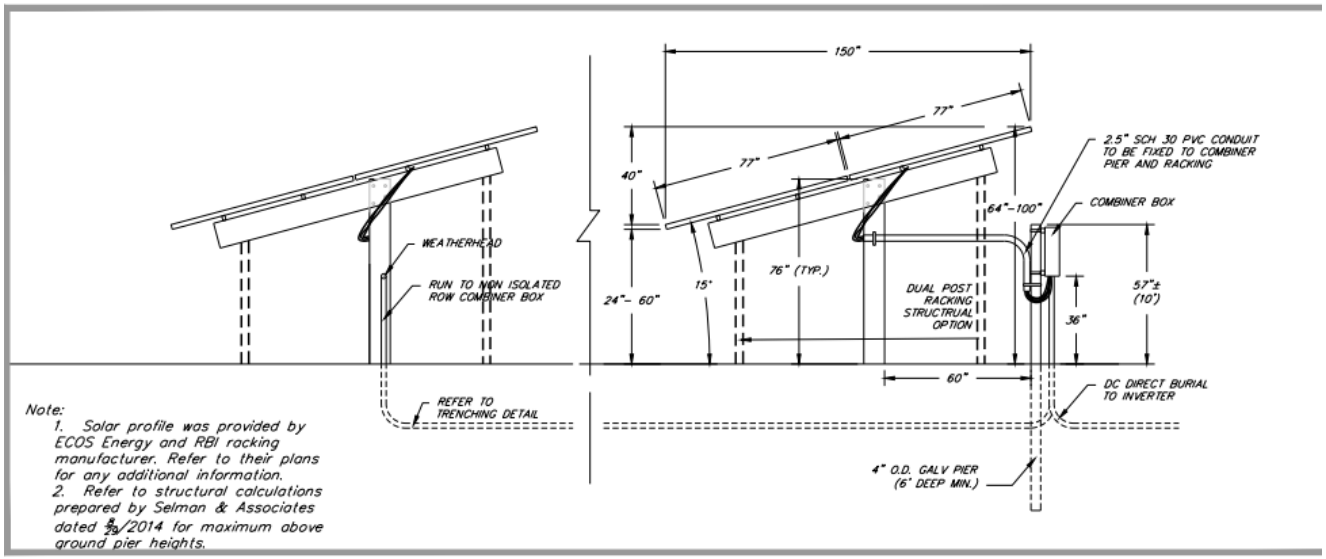
Site Plan for Chelsea Solar Farm



Proposed "***Chelsea***" and "***Apple Hill***" arrays



Profile of subject solar farm documenting an 8% gradient



TYPICAL SOLAR ARRAY CROSS SECTION - COMBINER BOX MOUNTING DETAIL

n.t.s.

Note: Distance between panel rows was reported to be 7.6 feet. Each panel measures approximately 77" long by 39" wide.

Beta (Degrees)	Panel Base (Ft)	Δ Space (Ft)	Per Row (Ft)	15° Row Compare (Ft)	Revised Δ Space (Ft)
15	12.4	7.6	20.00	0.00	
20	12.1	7.6	19.66	0.34	
25	11.6	7.6	19.23	0.77	
30	11.1	7.6	18.71	1.28	8.88
35	10.5	7.6	18.11	1.88	
40	9.8	7.6	17.43	2.57	

Based on a review of the subject file information, it was determined that the panel quantities are as follows:

	# Panels		Totals		Totals		Area (sf)
Chelsea	7,200	@330 watts	2,376,000	Watts	2.38	MW	151,600
Apple Hill	7,776	@330 watts	2,566,080	Watts	2.57	MW	163,729
	14,976		4,942,080	Watts	4.94	MW	315,329

The performance of solar panels has been based on its manufacturer's performance rating and its temperature coefficient.
A solar panel that is typically black or dark blue in color and not only produces electricity, its surface becomes heated by the sunlight.
As the solar panel surface becomes warmer, its performance is reduced.
This analysis used a nominal panel efficiency of 17% and a typical temperature coefficient of **-0.0041** per **1°C** above **25°C (77°F)** [1].

Example:

Solar Insolation: 300 Btu/(hr-sf)

Surface Temperature: 35°C; Increase above rating: 35°C – 24°C = 10°C

Temperature coefficient factor: 10°C x -0.0041/°C = -0.041; its performance would be as follows:

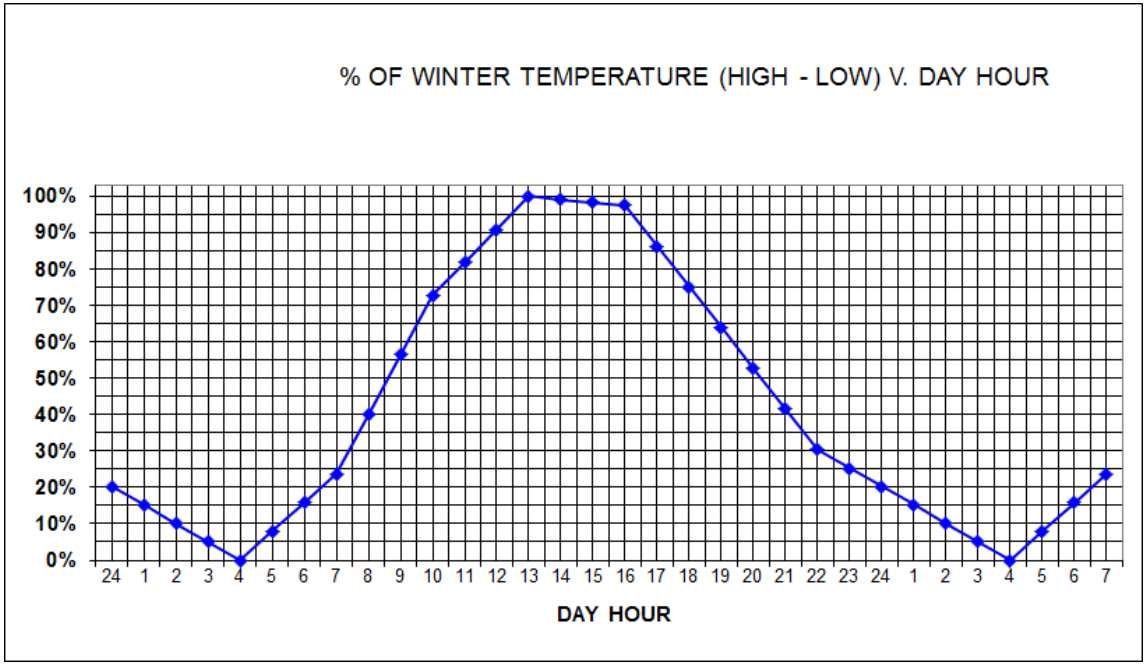
300 Btu/(hr-sf) x watt/(3.412 Btu/hr) x 17% x (1-0.041) = 14.3 watts/sf

The following climatic data was utilized in the analyis:

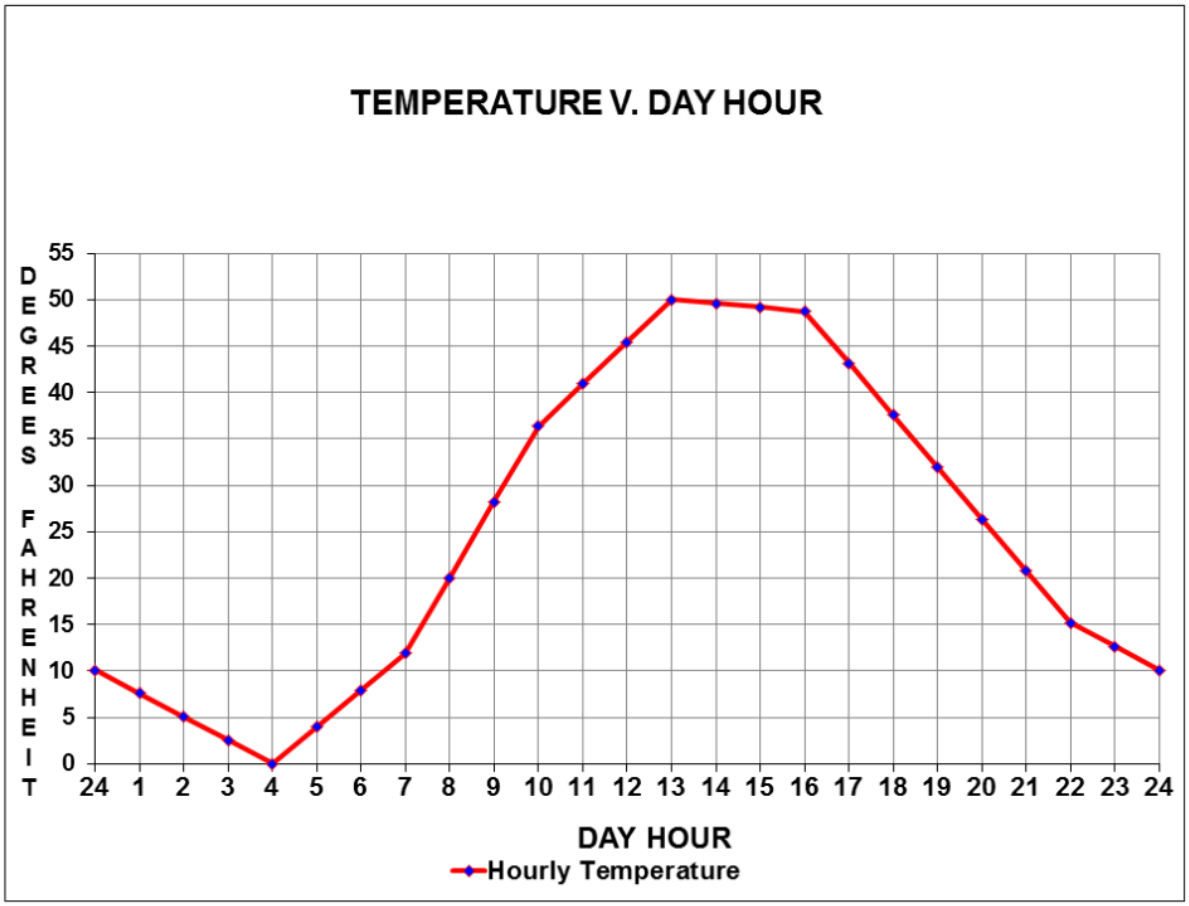
	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	Dec
% Sunshine:	46%	52%	54%	54%	56%	60%	64%	61%	57%	52%	37%	39%
High Temp (°F):	31	35	44	57	67	75	79	78	70	59	47	36
Low Temp (°F):	12	15	23	34	43	52	57	55	47	36	30	20

Note 1: % Sunshine for Albany, NY
Note 2: High & Low Temperatures for Bennington, VT

Based on review of more than 20 years of weather data, the following temperature profiles have been determined:

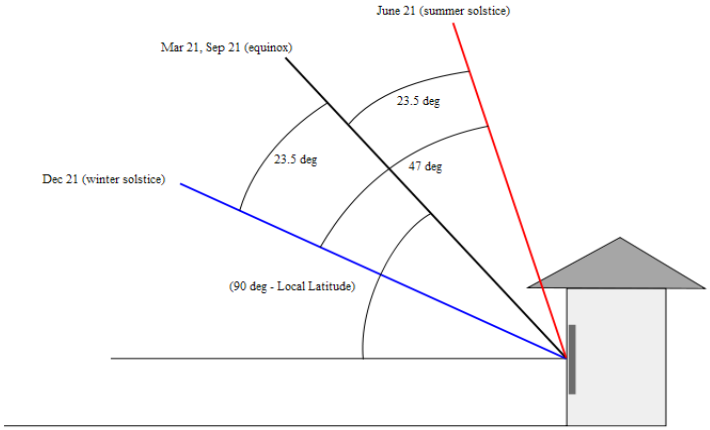


Example: For a low of 0°F and a high of 50°F, a daily temperature ramp would be as follows:

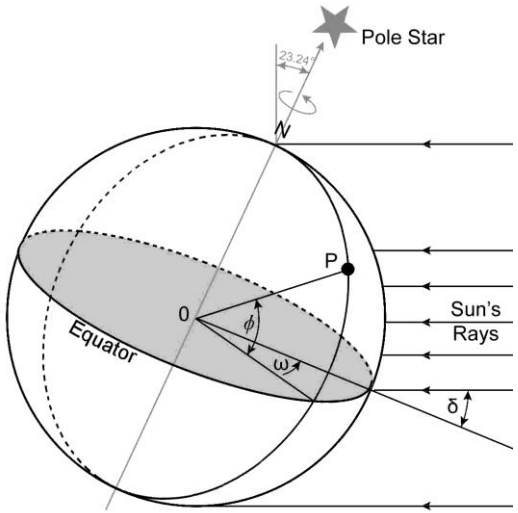


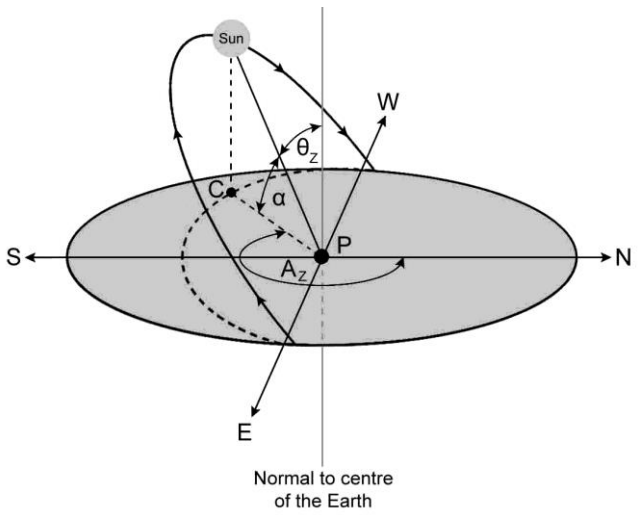
Solar Insolation was determined based on ASHRAE Clear Sky equations using conventional extinction coefficients as well as updated values using the adjusted air mass values based on the cosine effect. The modified evaluation establishes greater solar insolation intensity when θ_z has greater values or when the sun is lower on the horizon. Please see references No. 2 through No. 4 below.

MONTH	DATE	DAY NO.	A (BTU/(HR-SF)	A' (W/SM)	B (Dim Less)	C (Dim Less)	DECLINA-TION (DEG)	EQT (MIN)
JANUARY	21	21	390	1230	0.142	0.058	-19.76	-11.26
FEBRUARY	21	52	385	1215	0.144	0.060	-10.73	-14.19
MARCH	21	80	376	1186	0.156	0.071	0.00	-7.84
APRIL	21	111	360	1136	0.180	0.097	11.78	1.19
MAY	21	141	350	1104	0.196	0.121	20.17	3.54
JUNE	21	172	345	1088	0.205	0.134	23.45	-1.45
JULY	21	202	344	1085	0.207	0.136	20.57	-6.05
AUGUST	21	233	351	1107	0.201	0.122	12.13	-2.80
SEPTEMBER	21	264	365	1152	0.177	0.092	0.40	7.71
OCTOBER	21	294	378	1193	0.160	0.073	-11.09	15.83
NOVEMBER	21	325	387	1221	0.149	0.063	-19.97	13.43
DECEMBER	21	355	391	1234	0.142	0.057	-23.43	1.38

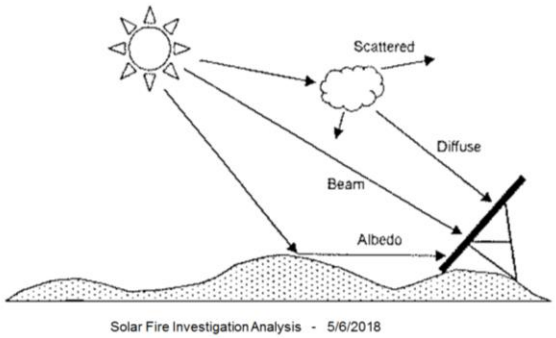


ASHRAE Clear Sky Parameters

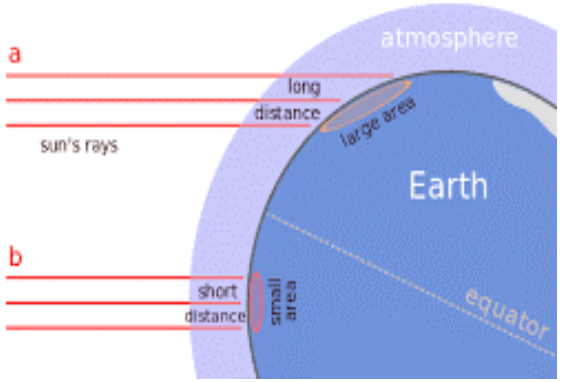




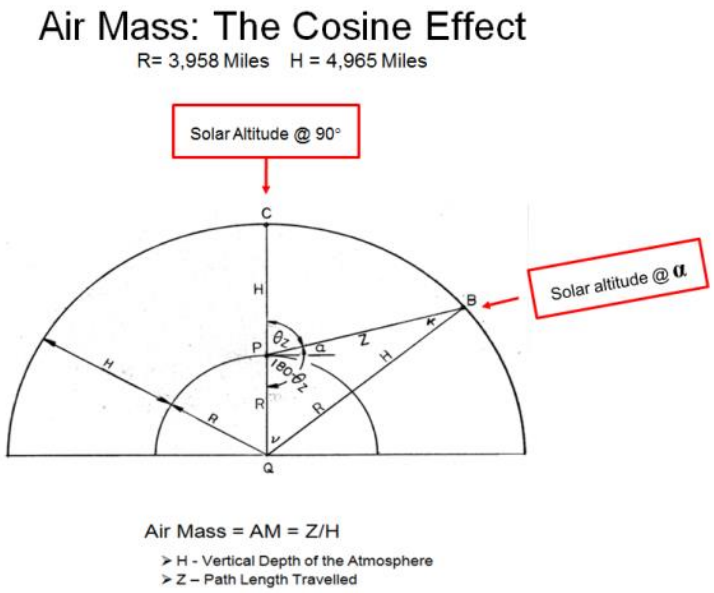
$$I_{Total} = I_{Beam} + I_{Ground} + I_{Diffuse}$$

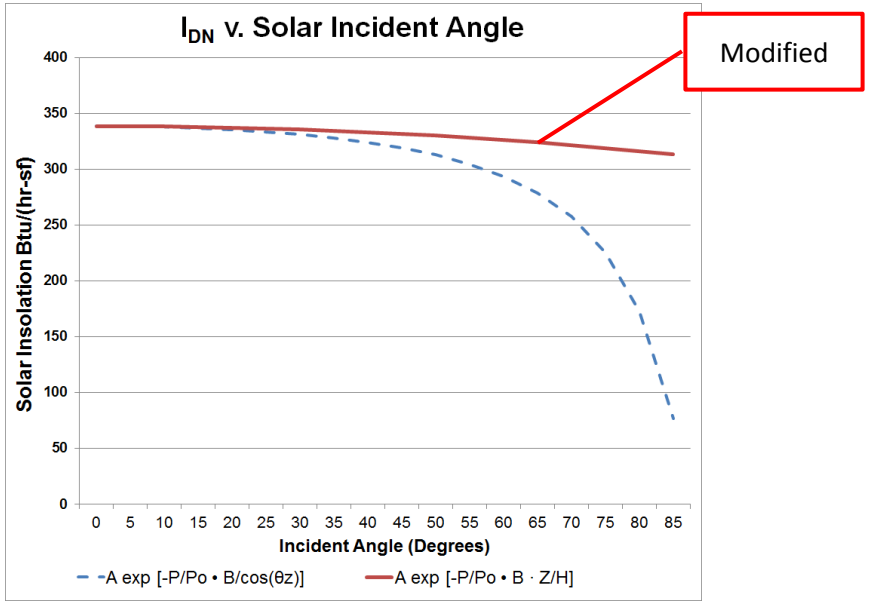


Three Solar Insolation Components



The Cosine Effect





The proposed pitch of 15° in Blue font has been compared to other panel positions.

[The values below are presented in the ideal case when there is no shading caused by one solar panel to another]

			Watt-hr/sf based on ASHRAE Clear Sky Equations and Previous Extinction Coefficients														
			[No shading from one panel to another]												Ave	Ave	
															Watt-hr/Day	Watt-hr/Month	Comparison
			JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	Dec	per sf	per sf	to 15° Pitch
Panel Pitch			31	28	31	30	31	30	31	31	30	31	30	31			
15	Degree	Daily:	27.8	43.3	53.8	60.1	66.0	71.0	72.6	63.6	51.6	39.2	21.3	19.9	49.2		
		Monthly:	862	1,211	1,668	1,804	2,045	2,130	2,251	1,973	1,548	1,214	640	616		1,324	100.0%
20	Degree	Daily:	30.3	45.9	55.8	60.8	65.7	70.2	72.2	64.3	53.4	41.6	21.4	21.9	50.3		
		Monthly:	939	1,286	1,729	1,825	2,036	2,105	2,238	1,993	1,603	1,288	642	679		1,345	101.6%
25	Degree	Daily:	32.6	48.3	57.4	61.1	65.0	69.0	71.3	64.5	54.9	43.7	25.0	23.8	51.4		
		Monthly:	1,011	1,352	1,780	1,834	2,014	2,070	2,212	2,000	1,647	1,355	749	737		1,367	103.2%
30	Degree	Daily:	34.7	50.3	58.7	61.1	64.0	67.5	70.2	64.4	56.1	45.6	26.5	25.5	52.1		
		Monthly:	1,075	1,409	1,820	1,834	1,983	2,025	2,176	1,997	1,684	1,412	796	791		1,376	104.0%
35	Degree	Daily:	36.5	48.4	59.6	60.7	62.6	65.7	68.7	63.9	56.9	47.1	27.9	27.1	52.1		
		Monthly:	1,133	1,356	1,847	1,822	1,940	1,971	2,130	1,982	1,708	1,459	838	839		1,378	104.1%
40	Degree	Daily:	38.2	53.4	60.2	60.0	60.9	63.5	66.7	63.1	57.4	48.4	29.1	28.4	52.4		
		Monthly:	1,183	1,496	1,866	1,801	1,888	1,905	2,069	1,955	1,722	1,499	874	880		1,372	103.6%

With Modified Cosine Factor Extinction Coefficient Correction:

[The values below are also presented in the ideal case when there is no shading caused by one solar panel to another.]

It is noted that there is little if any increase in performance on an annual basis with panel pitch greater than 30°.

			Watt-hr/sf based on ASHRAE Clear Sky Equations and modified Cosine Factor Extinction Coefficient Correction															
			[No shading from one panel to another]															
Panel Pitch			JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	Dec	Ave Watt-hr/Day per sf	Ave Watt-hr/Month per sf	Comparison to 15° Pitch	Ave Cosine Factor Increase
			31	28	31	30	31	30	31	31	30	31	30	31				
15	Degree	Daily:	34.2	47.4	56.5	62.9	69.4	76.5	80.1	71.8	59.6	55.0	32.9	31.5	56.5			15%
		Monthly:	1,059	1,327	1,752	1,886	2,152	2,295	2,482	2,226	1,788	1,706	987	978		1,521	100.0%	
Cosine Factor Increase >>:			**23%**	**10%**	**5%**	**5%**	**5%**	**8%**	**10%**	**13%**	**16%**	**41%**	**54%**	**59%**				
20	Degree	Daily:	37.6	50.4	58.6	63.5	68.8	75.4	79.2	72.3	61.7	58.6	36.2	35.1	58.1			16%
		Monthly:	1,165	1,412	1,818	1,904	2,131	2,261	2,457	2,242	1,852	1,818	1,085	1,087		1,555	102.2%	
Cosine Factor Increase >>:			24%	10%	5%	4%	5%	7%	10%	12%	16%	41%	69%	60%				
25	Degree	Daily:	40.7	53.2	60.3	63.6	67.8	73.8	78.0	72.4	63.5	61.8	39.1	38.3	59.4			16%
		Monthly:	1,262	1,489	1,870	1,909	2,102	2,213	2,419	2,244	1,905	1,917	1,174	1,188		1,578	103.8%	
Cosine Factor Increase >>:			25%	10%	5%	4%	4%	7%	9%	12%	16%	41%	57%	61%				
30	Degree	Daily:	43.6	52.0	61.7	63.5	66.6	71.9	76.5	72.1	64.8	64.6	41.9	41.2	60.0			15%
		Monthly:	1,351	1,456	1,912	1,904	2,065	2,158	2,372	2,235	1,945	2,004	1,256	1,278		1,594	104.8%	
Cosine Factor Increase >>:			26%	3%	5%	4%	4%	7%	9%	12%	16%	42%	58%	62%				
35	Degree	Daily:	46.1	53.9	62.6	63.0	65.1	69.8	74.6	71.3	65.8	67.0	44.2	43.8	60.6			16%
		Monthly:	1,430	1,509	1,942	1,889	2,017	2,095	2,312	2,211	1,974	2,078	1,327	1,359		1,600	105.2%	
Cosine Factor Increase >>:			26%	11%	5%	4%	4%	6%	9%	12%	16%	42%	58%	62%				
40	Degree	Daily:	48.3	59.2	63.2	62.0	63.1	67.3	72.3	70.2	66.3	68.9	46.3	46.2	61.1			17%
		Monthly:	1,497	1,657	1,960	1,861	1,956	2,018	2,240	2,175	1,989	2,136	1,390	1,431		1,596	105.0%	
Cosine Factor Increase >>:			27%	11%	5%	3%	4%	6%	8%	11%	16%	42%	59%	63%				

It is noted that there is little if any increase in performance on an annual basis with panel pitch greater than 30°.

As solar panels become more elevated, the preceding solar panel will cast a shadow on subsequent panels.

Determination of Solar Panel Shaded Areas:

α - Solar Altitude

L – Solar Panel Length

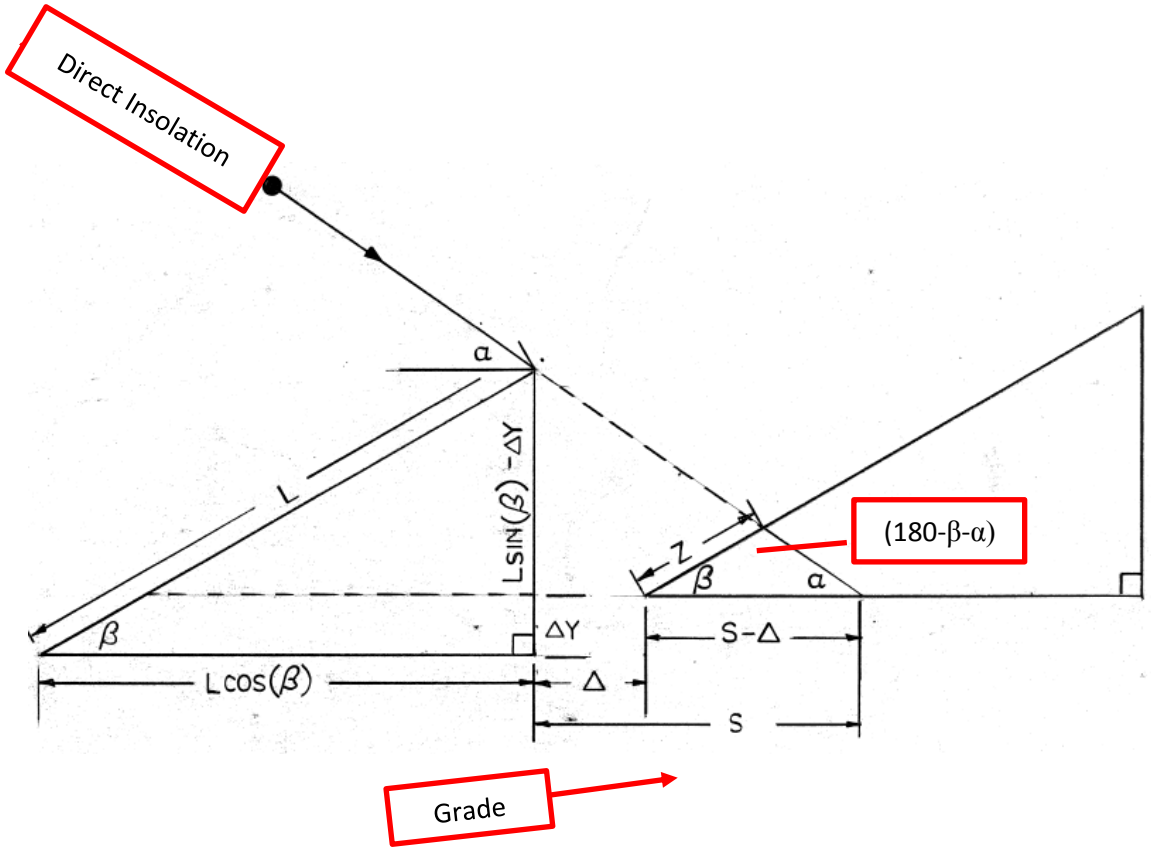
β - Pitch above horizontal

Δ - Distance between panel rows

$\Delta Y = [L\cos(\beta)] + \Delta] \bullet [\text{Grade}]$

$$\tan(\alpha) = \frac{[L\sin(\beta) - \Delta Y]}{S}$$

Shadow Length (S), $S = \frac{L\sin(\beta) - \Delta Y}{\tan(\alpha)}$



Shadow projected onto panel by Sine law:

$$\frac{Z}{\sin(\alpha)} = \frac{(S-\Delta)}{\sin(180° - \beta - \alpha)}$$

Solving for Z, the shaded portion of the solar panel is:

$$Z = \frac{(S-\Delta) \bullet \sin(\alpha)}{\sin(180° - \beta - \alpha)}$$

Based on a panel spacing of **7.6** feet, the shading factors are as follows:

	L:	12.8	FT			
	Delta:	7.6	FT			
	% shade	% shade	% shade	% shade	% shade	% shade
Panel Pitch:	**15°**	**20°**	**25°**	**30°**	**35°**	**40°**
Jan	0.0%	0.0%	0.0%	8.5%	15.9%	22.3%
Feb	0.0%	0.0%	0.0%	0.0%	1.1%	7.0%
Mar	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
April	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
May	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
June	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
July	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aug	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sept	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oct	0.0%	0.0%	0.0%	0.0%	1.8%	7.8%
Nov	0.0%	0.0%	0.0%	8.2%	15.5%	22.0%
Dec	0.0%	0.0%	5.3%	14.1%	21.6%	28.1%

Based on a panel spacing of **8.9** feet, the shading factors are as follows:

	L:	12.8	FT			
	Delta:	8.9	FT			
	% shade	% shade	% shade	% shade	% shade	% shade
Panel Pitch:	**15°**	**20°**	**25°**	**30°**	**35°**	**40°**
Jan	0.0%	0.0%	0.0%	2.1%	9.8%	16.5%
Feb	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Mar	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
April	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
May	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
June	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
July	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aug	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sept	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oct	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
Nov	0.0%	0.0%	0.0%	1.8%	9.5%	16.2%
Dec	0.0%	0.0%	0.0%	8.1%	16.0%	22.7%

It was previously noted that there was little if any increase in performance on an annual basis with panel pitch greater than **30°**.

Panel Spacing:	7.6 Ft														
		Watt-hr/sf based on ASHRAE Clear Sky Equations and Cosine Factor Extinction Coefficient Correction													
		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	Dec	Ave	Ave	
		31	28	31	30	31	30	31	31	30	31	30	31	Watt-hr/(Day-sf)	Watt-hr/(Month-sf)	Ave (+/-) to 15°
Panel Pitch																
15 Degree	Daily:	34.2	47.4	56.5	62.9	69.4	76.5	80.1	71.8	59.6	55.0	32.9	31.5	56.5		
	Monthly:	1,059.3	1,326.8	1,751.8	1,886.0	2,152.4	2,294.8	2,481.6	2,225.7	1,788.4	1,706.3	986.9	977.8			
Shade Reduction:		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	net:	**1,059.3**	**1,326.8**	**1,751.8**	**1,886.0**	**2,152.4**	**2,294.8**	**2,481.6**	**2,225.7**	**1,788.4**	**1,706.3**	**986.9**	**977.8**		1,719.8	0.00%
20 Degree	Daily:	37.6	50.4	58.6	63.5	68.8	75.4	79.2	72.3	61.7	58.6	36.2	35.1	58.1		
	Monthly:	1,165.3	1,411.8	1,817.9	1,903.9	2,131.3	2,260.5	2,456.7	2,242.4	1,851.7	1,817.9	1,085.2	1,087.0			
Shade Reduction:		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	net:	**1,165.3**	**1,411.8**	**1,817.9**	**1,903.9**	**2,131.3**	**2,260.5**	**2,456.7**	**2,242.4**	**1,851.7**	**1,817.9**	**1,085.2**	**1,087.0**		1,769.3	2.88%
25 Degree	Daily:	40.7	53.2	60.3	63.6	67.8	73.8	78.0	72.4	63.5	61.8	39.1	38.3	59.4		
	Monthly:	1,262.3	1,488.9	1,869.7	1,909.1	2,101.6	2,213.4	2,419.0	2,244.4	1,904.5	1,917.0	1,173.9	1,187.7			
Shade Reduction:		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%			
	net:	**1,262.3**	**1,488.9**	**1,869.7**	**1,909.1**	**2,101.6**	**2,213.4**	**2,419.0**	**2,244.4**	**1,904.5**	**1,917.0**	**1,173.9**	**1,125.0**		1,802.4	4.80%
30 Degree	Daily:	43.6	52.0	61.7	63.5	66.6	71.9	76.5	72.1	64.8	64.6	41.9	41.2	60.0		
	Monthly:	1,350.8	1,455.8	1,912.0	1,903.9	2,064.9	2,158.0	2,371.9	2,235.1	1,945.1	2,003.5	1,255.8	1,277.8			
Shade Reduction:		8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.2%	14.1%			
	net:	**1,235.9**	**1,455.8**	**1,912.0**	**1,903.9**	**2,064.9**	**2,158.0**	**2,371.9**	**2,235.1**	**1,945.1**	**2,003.5**	**1,153.0**	**1,097.7**		1,794.7	4.36%
35 Degree	Daily:	46.1	53.9	62.6	63.0	65.1	69.8	74.6	71.3	65.8	67.0	44.2	43.8	60.6		
	Monthly:	1,429.6	1,509.2	1,942.0	1,888.7	2,017.1	2,095.4	2,311.6	2,211.2	1,973.8	2,077.8	1,327.3	1,359.3			
Shade Reduction:		15.9%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	15.5%	21.6%			
	net:	**1,202.7**	**1,493.1**	**1,942.0**	**1,888.7**	**2,017.1**	**2,095.4**	**2,311.6**	**2,211.2**	**1,973.8**	**2,041.3**	**1,121.0**	**1,065.9**		1,780.3	3.52%
40 Degree	Daily:	48.3	59.2	63.2	62.0	63.1	67.3	72.3	70.2	66.3	68.9	46.3	46.2	61.1		
	Monthly:	1,497.3	1,657.3	1,960.3	1,861.0	1,955.6	2,018.1	2,240.2	2,175.5	1,989.1	2,136.2	1,389.8	1,431.0			
Shade Reduction:		22%	7%	0%	0%	0%	0%	0%	0%	0%	8%	22%	28%			
	net:	**1,163.1**	**1,540.5**	**1,960.3**	**1,861.0**	**1,955.6**	**2,018.1**	**2,240.2**	**2,175.5**	**1,989.1**	**1,970.1**	**1,084.1**	**1,029.2**		1,748.9	1.69%

Panel Spacing:	8.9 Ft															
		Watt-hr/sf based on ASHRAE Clear Sky Equations and Cosine Factor Extinction Coefficient Correction														
		JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	Dec	Ave	Ave	
		31	28	31	30	31	30	31	31	30	31	30	31	Watt-hr/(Day-sf)	Watt-hr/(Month-sf)	Ave (+/-) to 15°
Panel Pitch																
15 Degree	Daily:	34.2	47.4	56.5	62.9	69.4	76.5	80.1	71.8	59.6	55.0	32.9	31.5	56.5		
	Monthly:	1,059.3	1,326.8	1,751.8	1,886.0	2,152.4	2,294.8	2,481.6	2,225.7	1,788.4	1,706.3	986.9	977.8			
Shade Reduction:		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	net:	**1,059.3**	**1,326.8**	**1,751.8**	**1,886.0**	**2,152.4**	**2,294.8**	**2,481.6**	**2,225.7**	**1,788.4**	**1,706.3**	**986.9**	**977.8**		1,719.8	0.00%
20 Degree	Daily:	37.6	50.4	58.6	63.5	68.8	75.4	79.2	72.3	61.7	58.6	36.2	35.1	58.1		
	Monthly:	1,165.3	1,411.8	1,817.9	1,903.9	2,131.3	2,260.5	2,456.7	2,242.4	1,851.7	1,817.9	1,085.2	1,087.0			
Shade Reduction:		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	net:	**1,165.3**	**1,411.8**	**1,817.9**	**1,903.9**	**2,131.3**	**2,260.5**	**2,456.7**	**2,242.4**	**1,851.7**	**1,817.9**	**1,085.2**	**1,087.0**		1,769.3	2.88%
25 Degree	Daily:	40.7	53.2	60.3	63.6	67.8	73.8	78.0	72.4	63.5	61.8	39.1	38.3	59.4		
	Monthly:	1,262.3	1,488.9	1,869.7	1,909.1	2,101.6	2,213.4	2,419.0	2,244.4	1,904.5	1,917.0	1,173.9	1,187.7			
Shade Reduction:		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
	net:	**1,262.3**	**1,488.9**	**1,869.7**	**1,909.1**	**2,101.6**	**2,213.4**	**2,419.0**	**2,244.4**	**1,904.5**	**1,917.0**	**1,173.9**	**1,187.7**		1,807.6	5.11%
30 Degree	Daily:	43.6	52.0	61.7	63.5	66.6	71.9	76.5	72.1	64.8	64.6	41.9	41.2	60.0		
	Monthly:	1,350.8	1,455.8	1,912.0	1,903.9	2,064.9	2,158.0	2,371.9	2,235.1	1,945.1	2,003.5	1,255.8	1,277.8			
Shade Reduction:		2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	8.1%			
	net:	**1,321.8**	**1,455.8**	**1,912.0**	**1,903.9**	**2,064.9**	**2,158.0**	**2,371.9**	**2,235.1**	**1,945.1**	**2,003.5**	**1,233.0**	**1,174.0**		1,814.9	5.53%
35 Degree	Daily:	46.1	53.9	62.6	63.0	65.1	69.8	74.6	71.3	65.8	67.0	44.2	43.8	60.6		
	Monthly:	1,429.6	1,509.2	1,942.0	1,888.7	2,017.1	2,095.4	2,311.6	2,211.2	1,973.8	2,077.8	1,327.3	1,359.3			
Shade Reduction:		9.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.5%	16.0%			
	net:	**1,289.1**	**1,509.2**	**1,942.0**	**1,888.7**	**2,017.1**	**2,095.4**	**2,311.6**	**2,211.2**	**1,973.8**	**2,077.8**	**1,201.4**	**1,142.4**		1,805.0	4.95%
40 Degree	Daily:	48.3	59.2	63.2	62.0	63.1	67.3	72.3	70.2	66.3	68.9	46.3	46.2	61.1		
	Monthly:	1,497.3	1,657.3	1,960.3	1,861.0	1,955.6	2,018.1	2,240.2	2,175.5	1,989.1	2,136.2	1,389.8	1,431.0			
Shade Reduction:		17%	0%	0%	0%	0%	0%	0%	0%	0%	1%	16%	23%			
	net:	**1,249.9**	**1,655.4**	**1,960.3**	**1,861.0**	**1,955.6**	**2,018.1**	**2,240.2**	**2,175.5**	**1,989.1**	**2,117.0**	**1,165.0**	**1,105.9**		1,791.1	4.14%

Conclusion

Performance Summary:

										[B - A]
						[A]			[B]	
										30°
					15°	15°	30°	30°		Additional
					Ave	Annual	Ave	Annual		Annual
			Totals		Area	(Watt-hrs)/sf	Production	(Watt-hrs)/sf	Production		Production
	# Panels		(MW)		(sf)	per month	(MWH)	per month	(MWH)		(MWH)
Chelsea	7,200	@330 watts	2.38		151,600	1,719.8	3,129	1,814.9	3,302		173
Apple Hill	7,776	@330 watts	2.57		163,729	1,719.8	3,379	1,814.9	3,566		187
	14,976		4.94		315,329		6,508		6,867		360

The average monthly performance per square foot of the solar panels increases from **1,720** Watt-hrs/Month per sf to **1,808** Watt-hrs/Month per sf KWH/day (**5.5%** increase) when the solar panel pitch is increased from **15**° to **30°**.

With a **30°** panel pitch, the base distance of the panels is reduced by **22.5**". If the spacing is increased by **22.5**" (increased from 7.6 feet to 8.9 feet), the shading is reduced and the land allocation remains the same.

QUALIFICATIONS

If any additional information is encountered which relates to this evaluation, ***CMF Engineering, Inc***. reserves the right to alter the opinions contained in this report. In some cases, additional studies may be warranted to fully evaluate the concerns noted.

The engineering services have been performed using that degree of skill and care ordinarily exercised under similar conditions by reputable professional practice.

Any verbal statements made before, during, or after the course of the investigation were made as a courtesy only and are not considered a part of this report.

CLOSING

CMF Engineering, Inc. appreciates this opportunity to provide consulting services in this matter. Please feel free to contact me should any questions arise concerning this report, or if I may be of further assistance.

Submitted by:

Curt M. Freedman

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Curt M. Freedman, PE, CEM, CEA, LEED AP
Vermont PE No. 7295

References:

1. ASHRAE, American Society of Heating, Refrigeration and Air-Conditioning Engineers, HVAC Systems, pg. 37.2, 2016.
2. Solar Thermal Engineering, Peter J. Lunde, pg. 62, 1980.
3. Photovoltaics, Design and Installation Manual Solar Energy International, pg. 30, 2004.
4. ASHRAE, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Application Handbook, pg. 35.1, 2015.

Certifications:

~ Registered Professional Engineer in: CT, MA, MD, ME, NH, NJ, NY, OH, PA, RI, & VT
~ Certified Energy Manager (**CEM**) as endorsed by the Association of Energy Engineers
~ Certified Energy Auditor (**CEA**) as endorsed by the Association of Energy Engineers
~ **LEED** Accredited Professional as endorsed by the U. S. Green Building Council
~ Adjunct Professor of Energy Management, Western New England University
~ The National Academy of Forensic Engineers, Senior Member
~ Tau Beta Pi - The Engineering Honor Society