VALUE OF SOLAR ANALYSIS FOR EASTERN MENNONITE UNIVERSITY 104 KILOWATT SOLAR PROJECT

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Overview of HEC's Business Structure

Harrisonburg Electric Commission (HEC) is a non-generating municipal utility in Harrisonburg Virginia. The company is a contract member of the Virginia Municipal Electric Association (VMEA), an intermediary between Dominion Virginia Power (DVP), an investor-owned utility company in Virginia, and VMEA members, for the wholesaling of DVP electric power to VMEA members. HEC owns, operates, and services Harrisonburg's entire electricity infrastructure. HEC purchases all electricity from DVP under a 20-year VMEA contract agreement, and then sells this electricity to Harrisonburg residents and businesses.

As of 2014, HEC purchases electricity from DVP at a rate of $.0195 per kilowatt-hour (/kWh). In addition, HEC pays DVP a coincident demand charge. DVP calculates the demand charge for each month based on the kilowatts (kW) that HEC contributes to DVP's peak load—that is, what HEC contributes in kW during the one-hour period each month when DPV operates at its peak capacity. HEC pays $17.80/kW that they contribute to DPV's peak load.

Although HEC incurs other costs associated with electricity, HEC management asserts that they are pass-through charges and do not result in additional costs. In consultation and agreement with HEC management, we do not include these additional costs in the analysis. The costs that we incorporate into this case study are HEC's cost per kWh and their coincident peak demand costs.

Eastern Mennonite University (EMU) is currently billed under HEC's schedule 525 tariff rate for commercial customers with demand billing in excess of 1000 kW, available on HEC's website. Each month, HEC bills its schedule 525 customers for their kWh use and peak demand. Per HEC management's suggestion, we do not incorporate the demand component into the commercial net benefit analysis. In the case of EMU and the limited availability of data, we cannot calculate the reduction in billed peak demand for 2011, 2012, and 2013.

METHODS

Net Benefit Analysis

The method for this analysis was developed in consultation with HEC management. The cost-benefit model is taken from the municipal utility point of view. We examine the costs that a commercial scale solar array poses to HEC in the form of lost electricity sales, and we examine the benefits to HEC in the form of reduced electricity purchased and reduced coincident demand charges. HEC provided data for wholesale power rates and coincident demand charges, as well as coincident demand times for the years 2011, 2012, and 2013. We retrieved hourly output data for the EMU solar array from the Locus Energy solar database. The tariff rate for commercial schedule 525 customers is publicly available through HEC's website. We conduct the cost-benefit analysis for the years 2011, 2012, and 2013.

Benefits

The benefits resulting from EMU's solar array are HEC's avoided kWh costs to DPV Power and the kW coincident demand reduction. The avoided kWh cost is calculated by multiplying total yearly solar PV output (kWh) by HEC's wholesale power rate. The kW coincident demand reduction is calculated by summing the kW produced at the hour in which DPV reaches their peak demand hour each month and multiplying it by HEC's cost per kW.

$$\mathrm{B} = y\sum_{i=1}^{n} PiD + y\sum_{i=1}^{n} XiW$$

Where:

B = Benefit
y = Year
n = Number of months -12
i = Month (1=Jan, 2=Feb)
Pi = kW coincident demand reduction in month *i*
D = Peak demand charge
Xi = Solar electricity output in month *i*
W = Wholesale power rate

Table: 1 summarizes the benefit results. The benefits are derived from avoided electricity kWh costs, and avoided demand kW costs.

Table: 1

	Annual Benefit to HEC per solar kW installed	Total Annual Benefit to HEC for 104 kW solar system
EMU 2011	$79.50	$8,268
EMU 2012	$68.21	$7,094
EMU 2013	$66.17	$6,882
EMU Avg	$71.29	$7,415
NREL	$65.61	$6,823

These results show that the EMU solar array benefited HEC in the three years following installation. The total annual benefits in 2011, 2012, and 2013 were $8,268, $7,094, and $6,882 respectively. The average benefit over these three years is $7,415. Using NREL data, we estimate a total annual benefit of $6,823. We divide the total annual benefit by the system size of 104 to calculate the benefit per kW installed solar DC nameplate capacity. Our results show that the benefits per kW installed solar capacity in 2011, 2012, and 2013 were $79.50, $68.21, and $66.17 respectively. The average benefit over these three years is $71.29. Using NREL data, we estimate the total annual benefit and the annual benefit per kW installed solar capacity to be $6,823 and $65.61 respectively.

Costs

The cost component of the analysis is HEC's lost revenue resulting from the EMU solar array. This is calculated by multiplying total yearly solar PV output (kWh) for 2011, 2012, and 2013, by HEC's schedule 525 kWh tariff rate.

$$\mathrm{C} = \mathrm{y}\sum_{i=1}^{n} XiT$$

Where:

C = Cost
Y = Year
n = Number of months - 12
i = Month (1=Jan, 2=Feb)
Xi = Solar electricity output in month *i*
T = Schedule 525 published tariff rate

Table 2 summarizes the cost results. The costs are derived from lost revenue in the form of kWh sold.

Table 2

	Annual Cost to HEC per solar kW installed	Total Annual Cost to HEC for 104 kW solar system
EMU 2011	$50.30	$5,231
EMU 2012	$50.79	$5,282
EMU 2013	$44.44	$4,622
EMU Avg	$48.51	$5,045
NREL	$48.08	$5,001

These results show that the EMU solar array resulted in costs for HEC in the three years preceding installation. The total annual costs in 2011, 2012, and 2013 were $5,231, $5282, and $4,622 respectively. The average cost over these three years was $5,045. Using NREL data, we estimate a total annual cost of $5,001. We divide the total annual cost by the system size of 104 kW to obtain the cost per kW installed solar DC nameplate capacity. Our results show that the cost per kW installed solar capacity for 2011, 2012, and 2013 was $50.30, $50.79, and $44.44 respectively. The average cost per kW installed solar capacity was $48.51. Using NREL data, we estimate an annual cost per kW installed of $48.08.

NREL

In addition to the net benefit analysis with EMU data, this case study incorporates a comparative net benefit analysis using data from NREL. We accessed the NREL solar output data through NREL's online solar PVWatts calculator. This calculator predicts solar output based on the following inputs: location, size, tilt, azimuth, and DC-AC conversion rate. For this analysis we use inputs that replicate EMU's solar array—Harrisonburg, Virginia, 104-kW DC system size, 10° tilt, 191° azimuth, and a .85 DC-AC conversion rate. The method for calculating the net benefit using NREL data is the same as mentioned above. However, there is no definitive year to which the NREL data is assigned.

Net Benefits

The net benefit is calculated by subtracting the calculated costs from the calculated benefits.

$$\text{NB} = [y\sum_{i=1}^{n} PiD + y\sum_{i=1}^{n} XiW] - [\text{y}\sum_{i=1}^{n} XiT]$$

$$\text{NB} = B - C$$

Table 3 summarizes the net benefit results.

Table 3

	Annual Net Benefit to HEC per solar kW installed	Total Annual Net Benefit to HEC for 104 kW solar system
EMU 2011	$29.20	$3,036
EMU 2012	$17.42	$1,812
EMU 2013	$21.73	$2,260
EMU Avg	$22.78	$2,370
NREL	$17.53	$1,823

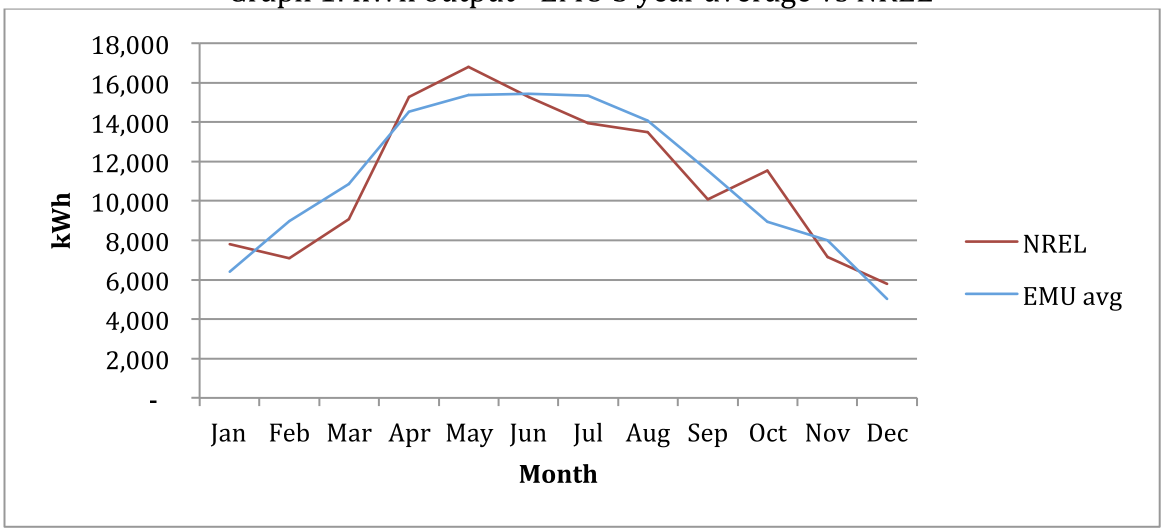
These results show that the EMU solar array resulted in a net benefit to HEC in 2011, 2012, and 2013. The total annual net benefits in each of these three years were $3,036, $1,812, and $2,260 respectively. The average net benefit over these three years was $2,369.50. Using NREL data, we estimate a total annual net benefit of $1,823 for a 104-kW solar PV system. We divide the total annual net benefit by 104 kW to obtain the net benefit per kW installed DC nameplate capacity. Our results show that the net benefits per kW installed solar capacity for 2011, 2012, and 2013 were $29.20, $17.42, and $21.73 respectively. The average net benefit per kW installed over these three years was $22.78. Using NREL data, we estimate an annual net benefit per kW installed of $17.53.

Comparative Analysis

The comparative analysis component of this case study examines the net benefit estimates we calculate using the NREL PVWatts calculator data as well as the net benefit that we calculate using empirical data. In addition, we inspect raw NREL data alongside data obtained from EMU. This analysis examines the reliability of NREL data, given certain inputs, in predicting the effect that future commercial scale solar PV installations have on the HEC.

Graph 1 (below) shows the three-year average actual output data for the EMU solar array alongside projected output from the NREL PVWatts calculator using identical solar array specifications. The graph shows that the EMU three-year average kWh output exceeded the NREL estimate for seven out of twelve months.

Graph 1: kWh output - EMU 3 year average vs NREL



Graph 2 (below) shows EMU's three-year average coincident peak contribution in kW, alongside NREL PVWatts projected coincident peak contribution. The graph shows that the EMU three-year average exceeds the NREL estimation in ten out of twelve months.

Graph 2: Coincident peak - EMU 3 year average vs NREL

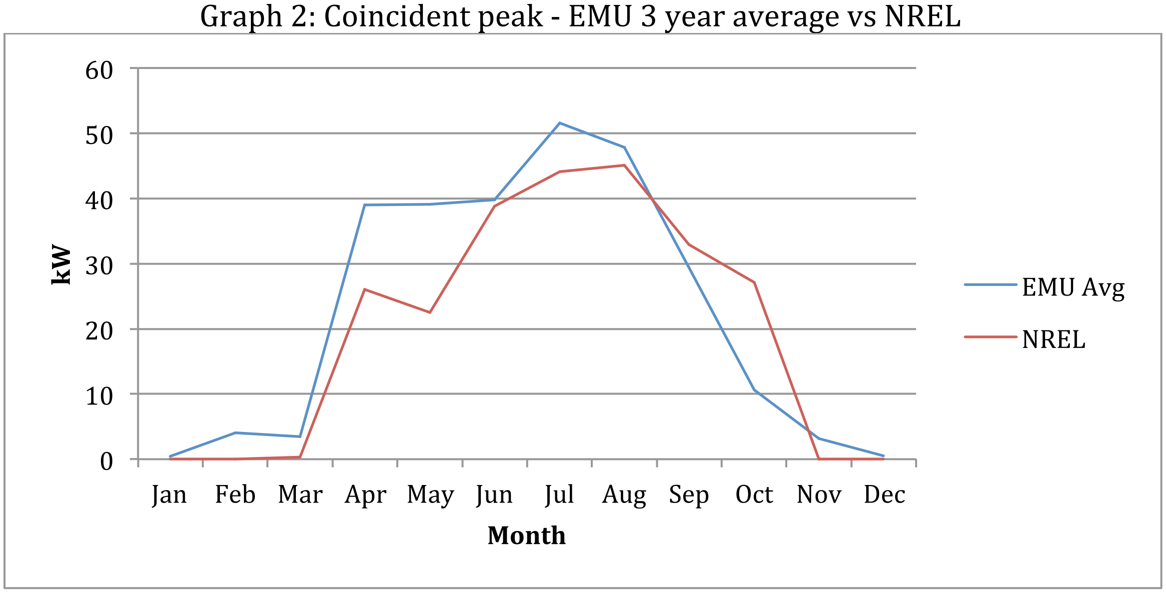


Table 4 summarizes the comparative analysis results for coincident kW output, kWh output, and overall net benefit. The table shows the EMU three-year average as a percentage of the NREL estimates. The EMU three-year average exceeds the NREL estimate for coincident kW, kWh output, and total net benefit by 113%, 101%, and 130% respectively.

Table 4

	EMU avg / NREL ratio*
Coincident kW	113%
Output kWh	101%
Net Benefit	130%

Comparative Analysis

The comparative analysis component of this case study examines the actual output and net benefit of the EMU solar array alongside the predicted output and net benefit using NREL data. The purpose of this analysis is to examine whether NREL data and resulting net benefit results, at a .85 DC to AC conversion rate, closely represent actual solar output data and net benefit results in the Harrisonburg area.

RESULTS

Net Benefit Analysis

As mentioned earlier, this paper examines the effect of commercial scale solar on one stakeholder—HEC. We quantify this effect using data from Eastern Mennonite University's solar array and data from NREL's PVWatts calculator. Our case study incorporates a net benefit analysis and comparative analysis. Tables 1, 2, 3, and 4 in Appendix A show the benefit calculations and results, cost calculations and results, and net benefit calculations and results.

DISCUSSION

A growing body of research examines the true value of solar as it relates to all stakeholders within the electricity grid (Beach & McGuire, 2013; Clean Power Research, 2014; Energy and Environmental Economics Inc., 2014; Farrell, 2014; Keyes & Rabago, 2013; Rocky Mountain Institute, 2013). These studies use tangible valuation metrics such as energy, capacity, grid support services, financial risk, and security risk as well as less tangible valuation metrics such as environmental benefits and social benefits to arrive at a kWh value for solar. However, not all metrics are used in each study, and not all studies use the same methods for calculating values of the same metrics. Although studies to date differ in various ways, many of them examine the value of solar from the utility perspective. Our study has attempted to take a similar approach, and examine the impact of solar on one stakeholder, HEC, using two valuation metrics, namely avoided energy costs and avoided generation capacity.

Our analysis highlights two important findings. First, although it is clear that solar capacity for a commercial customer with billing demand of more than 1,000 kW imposes costs to HEC, the benefits to HEC outweigh the costs by offsetting some of their coincident demand costs and kWh electricity costs. Second, within the HEC territory, the NREL PVWatts calculator represents a conservative tool that can be used to estimate the net impact of future solar projects on HEC. Although our analysis has limitations, it provides a basic methodology to examine the impact of solar at a high level of granularity within the HEC territory.

Limits of Research

We developed the analytical methodology used in this study per the recommendation of HEC management. The methodology is specifically tailored to the business structure of HEC and commercial customers with billing demand of more than 1,000 kW. It therefore has limitations in generalizing the net impact of solar outside of HEC territory, and for customers within HEC territory who are on a different rate structure.

In addition, this case study is not all-inclusive, and does not include all cost and benefit metrics relating to electricity. We proceeded with the methodology, as HEC suggested, because it provides a conservative measure of the value of solar within HEC territory. Avoided energy costs and avoided generation capacity are just two of many valuation metrics that are used in value of solar studies. Within non-generating utility territory, such as HEC, electricity is the most tangible metric to evaluate the net impact of solar.

Even within this one metric, our study is not all-inclusive, as we do not incorporate the customer's peak demand reduction into our analysis. We exclude this component from the analysis due to a lack of empirical data, and complexities relating to individual customers' demand profiles—EMU does not have the data needed to calculate the impact of solar on peak demand for each year that we conducted the net benefit analysis. We also recognize that many other factors are not included in the valuation of solar, such as indirect distribution savings to the utility company, line losses, and other factors previously mentioned.

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APPENDIX A

Table 1: Net benefit 2011

		Benefits				Costs	
2011		KW Benefits		kwh Benefits	first 750,000		
Month	Coincident KW	Avoided KW costs	kwh Production	Avoided kwh costs	Cost/kwh	kwh Production	Revenue Loss
Jan	0	5	6,545	128	0.0375	6,545	245
Feb	3	52	9,007	176	0.0375	9,007	338
Mar	9	155	10,985	215	0.0375	10,985	412
Apr	57	1,010	13,972	273	0.0375	13,972	524
May	54	970	15,706	307	0.0375	15,706	589
Jun	42	747	16,540	323	0.0375	16,540	620
Jul	66	1,178	17,691	346	0.0375	17,691	663
Aug	48	852	15,404	301	0.0375	15,404	578
Sep	26	467	9,791	191	0.0375	9,791	367
Oct	(0)	(2)	9,108	178	0.0375	9,108	342
Nov	5	93	8,079	158	0.0375	8,079	303
Dec	1	16	6,670	130	0.0375	6,670	250
Total	**311**	**$5,541.85**	**139,499**	**$2,725.81**		**139,499**	**$5,231.21**
Benefit	**$8,267.66**						
Cost	**$5,231.21**						
Net Benefit	**$3,036.45**						
Net Ben / KW installed	**$29.20**						

Table 2: Net benefit 2012

		Benefits				Costs	
2012		KW Benefits		kwh Benefits	first 750,000		
Month	Coincident KW	Avoided KW costs	kwh Production	Avoided kwh costs	Cost/kwh	kwh Production	Revenue Loss
Jan	0	5	7,547	147	0.0375	7,546.50	$282.99
Feb	4	70	10,099	197	0.0375	10,099.08	$378.72
Mar	0	1	13,558	265	0.0375	13,558.27	$508.43
Apr	27	485	15,202	297	0.0375	15,202.02	$570.08
May	8	149	15,356	300	0.0375	15,355.75	$575.84
Jun	53	941	16,134	315	0.0375	16,134.30	$605.04
Jul	41	725	14,612	286	0.0375	14,612.45	$547.97
Aug	73	1,293	14,477	283	0.0375	14,477.41	$542.90
Sep	34	607	12,132	237	0.0375	12,132.42	$454.97
Oct	(0)	(3)	9,271	181	0.0375	9,271.03	$347.66
Nov	3	57	8,053	157	0.0375	8,052.59	$301.97
Dec	1	12	4,405	86	0.0375	4,404.94	$165.19
Total	**244**	**$4,341.78**	**140,847**	**$2,752.15**		**140,847**	**$5,281.75**
Benefit	**$7,093.92**						
Cost	**$5,281.75**						
Net Benefit	**$1,812.17**						
Net Ben / KW installed	**$17.42**						

Table 3: Net benefit 2013

		Benefits				Costs	
2013		KW Benefits		kwh Benefits	first 750,000		
Month	Coincident KW	Avoided KW costs	kwh Production	Avoided kwh costs	tariff/kwh	kwh Production	Revenue Loss
Jan	1	14	5,132	100	0.0375	5,131.56	$192.43
Feb	5	92	7,836	153	0.0375	7,835.66	$293.84
Mar	2	27	8,013	157	0.0375	8,012.63	$300.47
Apr	33	590	14,415	282	0.0375	14,414.59	$540.55
May	55	970	15,107	295	0.0375	15,107.03	$566.51
Jun	25	438	13,668	267	0.0375	13,668.31	$512.56
Jul	48	849	13,697	268	0.0375	13,696.91	$513.63
Aug	23	408	12,340	241	0.0375	12,339.56	$462.73
Sep	28	497	12,723	249	0.0375	12,723.06	$477.11
Oct	32	571	8,459	165	0.0375	8,458.97	$317.21
Nov	1	21	7,869	154	0.0375	7,869.25	$295.10
Dec	(0)	(2)	3,999	78	0.0375	3,999.47	$149.98
Total	**251**	**$4,473.59**	**123,257**	**$2,408.44**		**123,257**	**$4,622.14**
Benefit	**$6,882.03**						
Cost	**$4,622.14**						
Net Benefit	**$2,259.89**						
Net Ben / KW installed	**$21.73**						

Table 4: Net benefit NREL

	Benefits				Costs		
NREL		KW Benefits		kwh Benefits	first 750,000		
Month	Coincident KW	Avoided KW costs	kwh Production	Avoided kwh costs	Cost/kwh	kwh Production	Revenue Loss
Jan	-	-	7,819	153	0.0375	7,819	$293.23
Feb	0.03	1	7,104	139	0.0375	7,104	$266.40
Mar	0.32	6	9,069	177	0.0375	9,069	$340.09
Apr	26.07	464	15,281	299	0.0375	15,281	$573.05
May	22.47	400	16,812	329	0.0375	16,812	$630.46
Jun	38.83	691	15,277	299	0.0375	15,277	$572.88
Jul	44.10	785	13,948	273	0.0375	13,948	$523.06
Aug	45.10	803	13,503	264	0.0375	13,503	$506.35
Sep	32.91	586	10,064	197	0.0375	10,064	$377.40
Oct	27.09	482	11,545	226	0.0375	11,545	$432.94
Nov	0.03	0	7,152	140	0.0375	7,152	$268.19
Dec	-	-	5,773	113	0.0375	5,773	$216.51
Total	**237**	**$4,217.61**	**133,348**	**$2,605.62**		**133,348**	**$5,000.55**
Benefit	**$6,823.24**						
Cost	**$5,000.55**						
Net Benefit	**$1,822.68**						
Net Ben / KW installed	**$17.53**						