

Analysis of Solar Photovoltaic Systems for Intermittent Resource Capacity Treatment in Forward Capacity Auction

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This document presents the results of CSG's analysis of the application of several proposed methods for calculating capacity of solar photovoltaic resources in ISO New England. The proposed methods include:

- A. **Intermittent Resources (IR) "Strawman"**. Under this method we assess the operation of actual and modeled PV resources in New England during broadly-defined seasonal peak periods: the winter peak period is defined as non-holiday hours ending 08-22 from October to May, while the summer peak period is defined as non-holiday weekday hours ending 08-23 from June to September.
- B. **Demand Resources (DR) Proposal**. Under Method B we repeat the analysis in Method A but use the more narrowly-defined peak periods proposed by the DR group: the winter peak period is defined as non-holiday weekday hours ending 17-19 from November to February, while the summer peak period is defined as non-holiday hours ending 13-17 from June to August.
- C. **100 Peak Hours**. Under Method C we look at PV generation during the 100 system peak hours in winter and summer reported from 2003 to 2005.
- D. **Seasonal peak coincidence, OP-4 hours**. Under Method D we confine the analysis to include actual PV generation during winter and summer OP-4 hours reported from 1999 to 2003.

In all seasons and using all methodologies the qualified capacity is defined as the median hourly capacity provided by the PV resource averaged over a 3-year period.

Summary of Calculated Capacity Credit for PV

The table below presents a summary of the calculated PV capacity credit under the each proposed method.

		Credited Capacity (AC capacity of PV credited as % of DC capacity installed)				
Method	Name	Description	Actual Data		Modeled Data	
			Summer	Winter	Summer	Winter
A	Intermittent Resources (IR) "Strawman"	3-year rolling average of median resource peak during broadly-defined seasonal peak periods (Summer 6-9, 800-2300; Winter 10-5, 800-2200)	17.2%	7.5%	17.9%	12.8%
B	Demand Resources (DR) Proposal	3-year rolling average of median resource peak during narrowly-defined seasonal peak periods (Summer 6-8, 1300-1700; Winter 11-2, 1700-1900)	45.2%	0.0%	32.8%	0.0%
C	100 Peak Hours	Median resource peak during seasonal 100 peak hours	45.5%	0.0%	NA	NA
D	OP-4 Hours	Median resource peak during seasonal OP-4 hours	43.5%	0.0%	NA	NA

Source of Actual Data

All actual PV performance data are derived from CSG's 0.0514 MW(dc) PV plant at Middletown, RI. The plant characteristics are as follows:

Actual PV Plant Specifications

Site Name	BJ's Wholesale Club	
Location	Middletown, RI	
Commissioning Date	7/1/1999	
Capacity through summer 2005	50.16 kWdc	0.05016 MWdc
Capacity 10/05-present	64.56 kWdc	0.06456 MWdc
Azimuth	180 degrees	
Tilt	5 degrees	

Source of Modeled Data

The modeled data used in Methods A and B assumes a mock 1 MW(dc) PV system, with a fixed tilt array at latitude tilt and oriented due south, modeled using the National Renewable Energy Laboratory's (NREL) PVWatts software, which utilizes TMY weather data. We did not use modeled data under Methods C and D because modeled data is based on TMY weather data, which would not correlate with system peak hours. The modeled plant characteristics are as follows:

Modeled PV Plant Specifications

City:	WORCHESTER
State:	MA
Lat (deg N):	42.27
Long (deg W):	71.87
Elev (m):	301
Array Type:	"Fixed Tilt"
Array Tilt (deg):	42.3
Array Azimuth (deg):	180
DC Rating (kW):	1000
DC to AC Derate Factor:	0.77
AC Rating (kW):	770

Derating PV Capacity from DC to AC

Unlike most other distributed and intermittent generating resources, PV systems produce direct-current electricity that must be converted to AC by an inverter. For this reason, the “nameplate capacity” of PV systems is most commonly given in DC rather than AC.

Several methods exist for determining the AC capacity of a PV system. Some apply a simple derating factor, such as 90% of DC, while others require more extensive monitoring of PV system performance and weather conditions to yield, through statistical regression, a measure of the system’s AC capacity under defined standard weather conditions. Regardless of the method used, PV system AC capacity is typically between 80 and 90 percent of DC capacity.

For the purpose of this analysis, the calculated AC capacity credit under each methodology is shown as a percentage of the PV system’s rated DC capacity. This percentage may need to be adjusted in order to be applied to other distributed or intermittent resources that are based on an AC nameplate capacity.

Analysis Results

Method A. Intermittent Resources (IR) "Strawman"

Method A. Actual Data

Data presented in this section is derived from CSG's rooftop PV plant in Middletown, Rhode Island. The plant was rated at 50.16 kW(DC_{STC}) until mid-September 2005, at which time the plant size was increased with the addition of modules. The capacity addition was accounted for in the analysis of the 2005 winter period simply by excluding performance data in that year in the period from October through December.

Winter Period Qualified Capacity

<u>Period</u>	<u>Median MW</u>	<u>Hours Operated</u>	<u>On Peak Hours</u>	<u>% Operation</u>
2003				#DIV/0!
2004	0.00256	2472	3645	67.82%
2005*	0.00494	1620	2280	71.05%

Winter period qualified capacity MWac = **0.003749625 Mwac**
 Winter period qualified capacity MWac/MWdc = **7.5% MWac/MWdc**

* Does not include Oct-Dec 2005 due to capacity addition

Summer Period Qualified Capacity

<u>Period</u>	<u>Median MW</u>	<u>Hours Operated</u>	<u>On Peak Hours</u>	<u>% Operation</u>
2003				#DIV/0!
2004	0.00712	1507	1952	77.20%
2005	0.01011	1526	1952	78.18%

Summer period qualified capacity MWac = **0.00861425 Mwac**
 Summer period qualified capacity MWac/MWdc = **17.2% MWac/MWdc**

Method A. Modeled Data

This analysis is based on modeled hourly performance data derived from NREL’s PVWatts (version 1) modeling software assuming a 1 MW DC PV array located in Worcester, Massachusetts and using TMY weather data derived from the WBAN site located in Worcester. The PVWatts analysis assumes a 0.77 DC-to-AC derate factor (the default factor used by the PVWatts model), and a fixed-tilt array with a tilt of 42.27 degrees (latitude tilt) and an azimuth of 180 degrees (due south). We did not exclude weekends and holidays for the purpose of this analysis, though we believe doing so would not significantly affect the results. Since the model uses 1 year of TMY weather data, we used the same model output for each of the three years.

Winter Period Qualified Capacity

<u>Period</u>	<u>Median MW</u>	<u>Hours Operated</u>	<u>On Peak Hours</u>	<u>% Operation</u>
Year 1	0.128094	2465	3645	67.63%
Year 2	0.128094	2465	3645	67.63%
Year 3	0.128094	2465	3645	67.63%

Winter period qualified capacity MW = 0.128094 Mwac
Winter period qualified capacity MWac/MWdc = 12.8% MWac/MWdc

Summer Period Qualified Capacity

<u>Period</u>	<u>Median MW</u>	<u>Hours Operated</u>	<u>On Peak Hours</u>	<u>% Operation</u>
Year 1	0.179094	1407	1952	72.08%
Year 2	0.179094	1407	1952	72.08%
Year 3	0.179094	1407	1952	72.08%

Summer period qualified capacity MWac = 0.179094 Mwac
Summer period qualified capacity MWac/MWdc = 17.9% MWac/MWdc

Method B. Demand Resources (DR) Proposal

Method B. Actual Performance Data

Winter Period Qualified Capacity

<u>Period</u>	<u>Median MW</u>	<u>Hours Operated</u>	<u>On Peak Hours</u>	<u>% Operation</u>
2003				#DIV/0!
2004	0.00000	59	363	16.25%
2005*	0.00000	42	180	23.33%

Winter period qualified capacity MWac = 0 Mwac
Winter period qualified capacity MWac/MWdc = 0.0% MWac/MWdc

* Does not include Oct-Dec 2005 due to capacity addition

Summer Period Qualified Capacity

<u>Period</u>	<u>Median MW</u>	<u>Hours Operated</u>	<u>On Peak Hours</u>	<u>% Operation</u>
2003				
2004	0.02131	460	460	100.00%
2005	0.02401	460	460	100.00%

Summer period qualified capacity MWac = 0.02265825 Mwac
Summer period qualified capacity MWac/MWdc = 45.2% MWac/MWdc

Method B. Modeled Data

Winter Period Qualified Capacity

<u>Period</u>	<u>Median MW</u>	<u>Hours Operated</u>	<u>On Peak Hours</u>	<u>% Operation</u>	
Year 1		0	1118	1789	62.49%
Year 2		0	1118	1789	62.49%
Year 3		0	1118	1789	62.49%

Winter period qualified capacity MW = 0 Mwac
Winter period qualified capacity MWac/MWdc = 0.0% MWac/MWdc

Summer Period Qualified Capacity

<u>Period</u>	<u>Median MW</u>	<u>Hours Operated</u>	<u>On Peak Hours</u>	<u>% Operation</u>
Year 1	0.3283185	460	460	100.00%
Year 2	0.3283185	460	460	100.00%
Year 3	0.3283185	460	460	100.00%

Summer period qualified capacity MWac = 0.3283185 Mwac
Summer period qualified capacity MWac/MWdc = 32.8% MWac/MWdc

Method C. 100 Peak Hours

Method C. Actual Performance Data

Winter Period Qualified Capacity

Winter 2005	PVKW-MRI	% of DC
Min	0	0%
Max	11.9075	24%
Mean	0.502325	1%
Median	0	0%

Summer Period Qualified Capacity

Summer 2005	PVKW-MRI	% of DC
Min	0	0%
Max	37.895	76%
Mean	21.90635	44%
Median	22.81875	45%

Method D. OP-4 Hours

Method D. Actual Performance Data

Data presented in this section are derived from CSG's rooftop PV plant in Middletown, Rhode Island. We used data from 2002-2005 in conducting the analysis.

PV Generation During Winter Period OP-4 Hours

Day	HOUR Ending	SYSTEM LOAD	BJ's M-RI PV KW	%ofDC
2000		Data unavailable		
12/5/2003	18	19,818	0	0%
12/5/2003	19	19,541	0	0%
		Median	0	0%

Mean 0 0%

PV Generation During Summer Period OP-4 Hours

DAY	HOUR Ending	SYSTEM LOAD	BJ's M-RI PV KW	%ofDC
1999-2001		Data unavailable		
7/23/2002	15	25,008	29.19	58%
7/23/2002	14	24,943	32.21	64%
7/23/2002	16	24,133	24.33	49%
8/5/2002	16	23,872	18.24	36%
8/5/2002	15	23,850	23.68	47%
8/5/2002	17	23,840	8.1125	16%
8/5/2002	18	23,616	5.4725	11%
8/13/2002	16	24,954	20.7125	41%
8/13/2002	17	24,901	14.195	28%
8/13/2002	18	24,369	7.8025	16%
8/14/2002	15	25,715	26.9775	54%
8/14/2002	14	25,569	29.995	60%
8/14/2002	16	25,563	21.8225	44%
8/14/2002	17	25,408	15.435	31%
8/14/2002	13	25,154	30.785	61%
8/14/2002	18	24,883	8.445	17%
8/19/2002	15	23,626	27.215	54%
8/19/2002	16	23,533	22.07	44%
8/19/2002	17	23,496	15.325	31%
		Median	21.8225	44%
		Mean	20.106053	40%

Summary: Calculation of PV Capacity Credit Under Various Proposed Methodologies

**Credited Capacity
(AC capacity of PV credited as
% of DC capacity installed)**

Method	Name	Description	Actual Data				Modeled Data			
			Summer		Winter		Summer		Winter	
			MED	AVG	MED	AVG	MED	AVG	MED	AVG
A	Intermittent Resources (IR) "Strawman"	3-year rolling average of median resource peak during broadly-defined seasonal peak periods (Summer 6-9, 800-2300; Winter 10-5, 800-2200)	17.2%	24.8%	7.5%	18.5%	17.9%	22.7%	12.8%	21.1%
B	Demand Resources (DR) Proposal	3-year rolling average of median resource peak during narrowly-defined seasonal peak periods (Summer 6-8, 1300-1700; Winter 11-2, 1700-1900)	45.2%	44.5%	0.0%	0.4%	32.8%	34.5%	0.0%	0.7%
C	100 Peak Hours	Median resource peak during seasonal 100 peak hours	45.5%	43.7%	0.0%	1.0%	NA	NA	NA	NA
D	OP-4 Hours	Median resource peak during seasonal OP-4 hours	43.5%	40.1%	0.0%	0.0%	NA	NA	NA	NA