NY-Sun Solar Photovoltaic Program Impact Evaluation for May 1, 2016 through March 31, 2018

Final Report

Prepared for:

New York State Research and Development Authority

Albany, NY

Dana Nilsson
Project Manager, NYSERDA

Prepared by:

DNV GL

Arlington, VA

Maura Nippert
Senior Engineer, Policy Advisory and Research

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1 Introduction

This report presents the impact evaluation of solar photovoltaic (PV) projects installed under NYSERDA's NY-Sun program from May 1, 2016 through March 31, 2018. A subset of solar PV installations under the NY-Sun program benefitted from support by NY Green Bank (NYGB), a division of NYSERDA. Previous installations under the NY-Sun and predecessor programs were evaluated in the NYSERDA Solar Photovoltaic Program Impact Evaluation for 2008 and 2011-2016.

1.1 Program Description

The NYSERDA NY-Sun PV Incentive Program[1], open August 12, 2010 through December 29, 2025, provides cash incentives and/or financing according to a megawatt (MW) block structure. "Blocks," or specific MW targets per defined sector and geographic region of New York, are active on a rolling basis until fulfilled. The original program goal of installing 3 gigawatts (GW DC) of PV capacity by 2023 was expanded to 6 GW DC by 2030, and NYSERDA's 2019 petition to extend the NY-Sun program and increase funding was approved in 2020. The Long Island region incentive block closed to new residential customer applications in April 2016.[2]

Under the NY-Sun Program, NYSERDA provides cash incentives/and or financing for the installation by contractors of new grid-connected PV systems that are 25 kW or less for residential, and 200 kW or less for non-residential sites (NY-Sun Small Residential/Commercial[3]), as well as incentives for the installation of new PV systems greater than 200 kW (NY-Sun Commercial/Industrial[4]). These incentives apply to systems that are leased, owned, or governed by power purchase agreements (PPA).

A subset of sites installed with incentives from the NY-Sun program also benefited from support from NYGB. Launched in 2014, NYGB is a state-sponsored specialized financial entity whose mission is to accelerate clean energy deployment in New York State by working with the private sector to transform financing markets.

[1] NYSERDA PON 2112
[2] https://www.nyserda.ny.gov/-/media/Files/Programs/NYSun/2018-Performance-Report.pdf
[3] (NYSERDA NY-Sun MW Res/Comm Block Incentive Dashboard, 2016)
[4] (NYSERDA NY-Sun MW C/I Block Incentive Dashboard, 2016)

1.2 Summary of Evaluation Objectives and Methods

Table 1 summarizes the impact evaluation objectives, purposes for the research, and methods employed to satisfy the objectives.

Table 1: Evaluation Objectives, Purpose, and Methods

Objective	Purpose	Methods
Precision	Design samples to meet but not exceed a target of 10% precision level for program gross energy production at 90% confidence.	Collect population tracking data from NY-Sun database in Salesforce; Design and select representative sample according to stratification and precision criteria and expected response rate.
Supplied Power (Nameplate kW DC)	Provide power supplied per site and region for comparison to MW Block Dashboard goals.	Collect nameplate DC capacity (kW) for sites from tracking data; Review reported capacity values for sites with first-year production unexpectedly high or low production.
Energy Impact (kWh Annual Production, Reporting Realization Rate (%), Application-specific Realization Rate (%))	Provide verified, weather-normalized gross impacts for the program overall and for specified segments, including: • Annualized first-year verified gross energy production (kWh) • Verified gross reporting realization rate • Verified gross application-specific realization rate	Collect first-year (first 13 months after interconnection) production data and conduct contractor interviews for sampled sites; Normalize results for weather differences across years of installation; Flag sites with unexpectedly high or low performance for file review; Review NY-Sun project files, production models, and QA/QC files (where available) for sites with unexpectedly high or low capacity factors; Expand sampled site impacts to the program population and calculate realization rates.
Capacity Factor (%)	Determine the ratio of actual output over a period of time (including variations due to weather), to potential output if it were possible for the system to operate at full nameplate capacity continuously over the same period of time.	Calculate site-level capacity factors based on available nameplate and weather normalized first-year production data; Expand site level results to population.
Performance Persistence	Enable collection and cleaning of data for future evaluations of long-term persistence; Determine long-term persistence of evaluated energy production of solar PV at the customer site; Determine the factors contributing to system persistence/ underperformance.	Review response and attrition rates from this and prior evaluation to establish long-term persistence data collection and analysis plan; future evaluations will assess persistence and degradation for longitudinal data collected over 10 years of sampled site system operation. Collect ongoing production data and conduct contractor interviews for persistence sample of sites.
Performance Model Data	Collect data inputs required for performance modeling in National Renewable Energy Laboratory (NREL) System Advisor Model (SAM).[5]	Conduct contractor interviews.

[5] National Renewable Energy Laboratory System Advisor Model Version 2017.9.5 available at https://sam.nrel.gov/

2 Results, Findings, and Recommendations

2.1 Data Collection Results

NYSERDA's goal for this evaluation was to achieve an estimate of production capacity factors with ±10% relative precision and 90% confidence (90/10 precision) for four segmentations of program data: region (Con Ed, Long Island, and Upstate), purchase type (lease, PPA, and purchase), size (above and below 200 kW), and customer sector (residential and non-residential).

The NY-Sun and NYGB program populations and the achieved sample of first-year production data[6] collection are shown in Table 2. To achieve the target precisions for each segmentation, the sample design was stratified by a combination of customer sector (not shown: residential or non-residential), region, system size (kW), and purchase type. Selecting from 29,000 unique records in the sample frame, the resulting sample design has 70 strata and a total target sample of 240 sites, where a site is a single installed solar PV system enrolled through a NYSERDA program. Individual premises may host multiple program sites, such as when multiple solar PV systems are installed at a single address.

Table 2: NY-Sun and NYGB Evaluation Data Collection Results

Region	System Size (kW)	Purch-ase Type	NY-Sun Population Size (N)[a]	NYGB Overlap Population Size (N_{NYGB})	Target Sample	Evaluated Sample (n)	NYGB Overlap Evaluated Sample (n_{NYGB})
Con Ed	Below 200 kW	Lease	2751	1200	33	22	17
		PPA	723	577	22	21	19
		Purchase	1851	420	37	39	26
	Above 200 kW	All	12	0	12	10	0
Upstate	Below 200 kW	Lease	3914	2653	21	18	12
		PPA	1977	1654	33	34	19
		Purchase	6546	482	35	41	21
	Above 200 kW	All	103	0	103	60	0
Long Island	Below 200 kW	Lease	4817	2864	28	23	18
		PPA	1991	1607	23	22	19
		Purchase	4279	233	36	46	16
	Above 200 kW	All	36	0	36	23	0
Overall			**29,000**	**11,690**	**419**	**359**	**167**

[6] First-year production data collection was for the first 13 months of production after system interconnection/ inception of system production. The first, potentially incomplete, month of production data is dropped from the analysis to utilize the first 12 months of complete, consecutive production data.

All projects in the population recieved NY-Sun funding, and a subset included NYGB involvement, as shown in Table 2. The population size (N), target sample, and evaluated sample each include projects that received support from NYGB, that was later confirmed by the impact evaluation team. The NY-Sun and NYGB program overlap sites specified in the table are a subset of the NY-Sun population and evaluated sample. For example, within the Con Ed <200 kW leased group, 22 sites were in the evaluated sample, and of those, 17 sites were identified to have received support from NYGB.

2.1.1 Data Collection Challenges

A total of 58 contractors, representing 359 projects across all sizes and sectors (as shown in Table 2), provided viable data for use in the evaluation. Of 32 companies from whom the evaluation team was unable to collect data, 10 were closed businesses or had outdated contact information for which new site ownership was not found, one declined to participate in the study, and 21 either did not respond or were otherwise unable to provide production data for the requested site(s).

In the over 200 kW group, the evaluation team encountered limitations to availability of site data planned for collection from the Distributed Generation (DG) Integrated Database.[7] While data limitations did not have implications on the precision on the current evaluation, it does impact the long-term data collection for the persistence study. In particular, the collection of persistence data from sites more than three years old was limited by the expiration of requirements to report to the DG Integrated Database. Additionally, the impact evaluation team found that a number of sites over 200 kW opted to apply to the Small Commercial Program rather than the Commercial/ Industrial Program[8]. These sites recieved incentives capped at 200 kW, but avoided the requirement to connect to the DG Integrated Database. Late in this study's evaluation period, the Commercial and Industrial program was preparing to shift the program requirements (and associated DG Integrated Database reporting requirement) to sites over 750 kW, rather than 200 kW. The formal adoption of the new program requirement occured after the evaluation period, but will apply to future evaluations. The transition to new program requirements did not have statistically relevant impacts to the program beyond this data collection issue.

[7] http://dg.nyserda.ny.gov/home/index.cfm?

[8] As of October 25, 2018 (after the current evaluation period), the size requirement for the Commercial and Industrial program shifted from greater than 200 kW to greater than 750 kW.

2.1.2 Persistence Data Collection Results

In addition to the primary production data collection effort for this NY-Sun 2016-2018 evaluation, the impact evaluation team collected production data for persistence sample sites. Data collection brings the persistence study to year six of a ten-year data collection effort. Completion of the persistence study analysis will occur after year 10 (April 2026). A more detailed description of the persistence study and future analysis plan is included in Appendix C. Persistence sample sites are those for which multiple years of data (from installation through October 2017) were successfully collected through the prior (2008 and 2011-2016) NY-Sun impact evaluation. The effort for the present study attempted to collect follow-on years of data for 264 sites. Of these, production data for one or more additional years (from 2017 through 2019) was collected from 213 sites. This is an attrition rate of 20% (response rate of 80%).

Of the 213 sites for which data was collected, up to 75 of the sites' data was incomplete:

- One contractor provided the most recent 13 months of data rather than the requested period for persistence and the evaluation was unable to collect data from the missing months, resulting in a less-than-one-year gap in the time series data for 50 sites.
- The study plan anticipated that all large (>200 kW) sites would have additional years of data available through the DG Integrated Database, as was the case for the prior study. Out of the 114 large sites the evaluators attempted to download, 89 have current data, but 25 system owners stopped providing data to the DG database after their required three-year reporting period ended. This is because there is some burden, in the form of associated cost and staff time investment, that is sufficient to deter some contractors from continuing to post to the DG Integrated Database.

To support future persistence analysis and overcome these data limitations, the impact evaluation team may conduct additional production data collection for systems installed in earlier years of the NY-Sun program.

2.2 Analysis Results

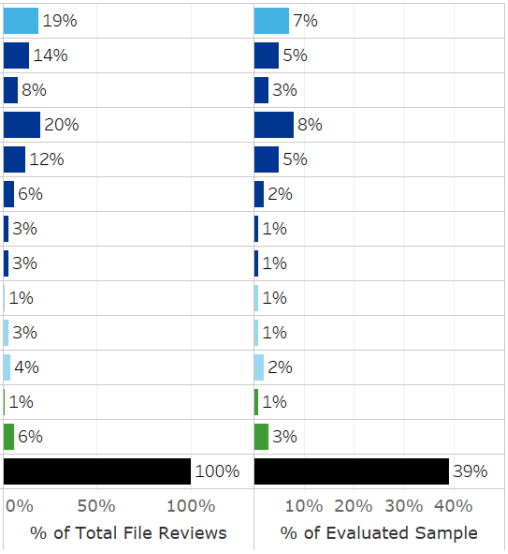
2.2.1 File Review Results

The impact evaluation team collected production data for a total of 359 of the 419 sampled projects. Of this number, 140 (39%) were flagged for additional file review due to performance

criteria outside of the expected range.[9] Table 3 shows the mutually exclusive resolutions from file reviews of sites with capacity factor discrepancies, wherein each project was assigned a discrepancy from the list below.

Table 3: Resolutions from File Reviews of Sites with Capacity Factor Discrepancies

Discrepancy Category	Discrepancy – File Review Disposition	Counts	% of Total File Reviews	% of Evaluated Sample
Normal		26	19%	7%
Low Production	Low production anomaly (3 months or less)	19	14%	5%
	Low production anomaly (4 to 11 months)	11	8%	3%
	Persistent low performance	28	20%	8%
	Shading (persistent)	17	12%	5%
	Shading (winter only)	8	6%	2%
	System fault: broken equipment (confirmed)	4	3%	1%
	System fault: connectivity (confirmed)	4	3%	1%
High Production	High production anomaly (3 months or less)	2	1%	1%
	Installed system larger than reported	4	3%	1%
	Persistent high performance	6	4%	2%
Inconsistent Data	Connectivity issue (unconfirmed)	2	1%	1%
	Unknown	9	6%	3%
Overall	Total	140	100%	39%



Of the 140 files initially flagged, 26 were ultimately determined to be showing normal production (within +/- 4% of modeled output) after detailed review. Projects performed in accordance with design models, but below the 9% performance threshold of the file review. This type of discrepancy was seen more frequently for some participating contractors.

File review dispositions resulting in lower-than-expected productivity that was sustained in the verified production results include:

- Low production anomalies (separated into groups of three months or less, four to eleven months, and persistent) verified to be accurate
- System faults (broken equipment or connectivity issues verified through customer interviews)

[9] Sites with capacity factors above 14% or below 9% were flagged for file review.

- Shading (persistent or winter-only) identified through reviews of project shading analysis files (submitted by contractors with predictive production models), project site plans, and satellite map images of site locations

A total of 8 sites exhibited higher-than-expected production, verified with the following dispositions:

- Larger system size than reported in tracking data and indicated by documentation, causing apparent over-production, then verified by review of plans, satellite imagery, and in some cases, information provided by the end user

- High production anomalies (separated into groups of three months or less and persistent) where precise cause could not be determined

A total of five sites were dropped from the analysis based on results of the file review, as follows: three sites were dropped due to missing or largely incomplete data (Unknown category in Table 3); one site was dropped due to incorrect/erroneous reporting (persistent repetition of identical production values; Unknown category); and one site was dropped due to consistent/excessive production possibly due to a second system installed on site that could not be verified (Installed system larger than report category).

2.2.2 Production Analysis Results

This section provides weather-normalized verified gross impact results of the program: first-year[10] capacity factors, reporting realization rates, and application-specific realization rates. The realization rates are ratios of verified normal-weather gross system production to: reporting production, or production of the same capacity system with a 13.4% capacity factor[11], and application specific production, or contractor estimates of system production calculated per system models submitted with program applications for each site.[12] The impact evaluation team reviews the accuracy of these estimates for different categories relative to the 90/10 precision target.[13] In each table, the categories shown (other than "Overall") are independent of one

[10] All verified gross impact results are based on the first 13 months of production data, starting the month of installation and dropping that first, potentially partial-production month. All results are weather-normalized to account for differences in production caused by weather (solar insolation and precipitation) across years of installation.

[11] The reporting realization rate is the ratio of verified normal-weather gross system production to NYSERDA's estimate of system production (referred to as reporting production) for purposes of program-level progress and benefits reporting to the PSC. The reporting realization rate assesses the difference between reporting production and actual evaluated system production. For the current evaluation, the reporting realization rate is based on a CF of 13.4%.

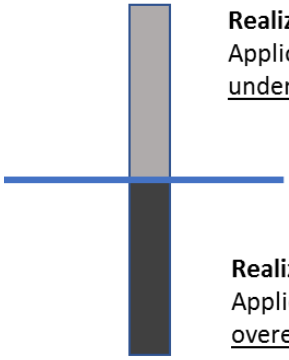
[12] The application-specific realization rate is the ratio of verified normal-weather gross system production to contractor estimates of system production (referred to as application-specific production) calculated per system models submitted with program applications for each site.

[13] 90/10 precision means that the result has a 90% probability of being within ± 10% of the complete population result.

another. Each table of results uses the same weights based on a single stratification, sample, and sample frame. See Section 4.2 for explanation of analysis approach and weighting factor calculation.

Figure 1 illustrates how realization rates are interpreted for overestimation or underestimation of actual production for a given set of data.

Figure 1: Realization Rate Interpretation



Realization Rate > 100%
Application-Specific or Reporting production
underestimates actual production

Realization Rate = 100%
Application-Specific or Reporting production
accurately estimates actual production

Realization Rate < 100%
Application-Specific or Reported production
overestimates actual production

Table 4 shows production analysis results for the two system size categories and overall. The 90/10 precision target was achieved for each segment. The NY-Sun program overall capacity factor was found to be 12.6%, slightly higher than the 12.4% overall program capacity factor evaluated for 2011-2016. There is not a statistically significant difference between large (above 200 kw) and small (below 200 kW) sites. The capacity factor for small sites is slightly higher than the prior evaluation (2011-2016) result of 12.1%, but has gone down for large sites, from 13.2% to 12.7%. Small sites are expected to be more frequently installed at existing buildings, and larger sites at more ideal locations and orientations pre-verified by rigorous planning models, but the lack of statistically significant difference suggests that small sites are well-oriented on average.

The application-specific realization rate for small systems is very close to 100%, with a confidence interval of 98% to 103%, demonstrating that very accurate planning impacts for the program are achieved when based on application-specific production (site-specific models predicting production). This compares to a reporting realization rate confidence interval of 91% to 97%. The difference in application-specific realization rate between large and small systems is statistically significant, with a confidence interval between 94% and 96% for large sites.

Table 4: Production Analysis Results by System Size

System Size	Sample Complete	Capacity Factor	Capacity Factor Relative Precision @90%	Reporting Realization Rate	Report-ing RR Relative Precis-ion @90%	Application-specific Realization Rate	Applicat-ion-specific RR Relative Precision @90%
Below 200 kW	266	12.5%	3.0%	93.6%	3.0%	100.6%	2.7%
≥ 200 kW	93	12.7%	0.9%	95.0%	0.9%	94.7%	1.0%
Overall	**359**	**12.6%**	**2.3%**	**93.9%**	**2.3%**	**99.2%**	**2.1%**

Table 5 shows production analysis results by customer sector. The 90/10 precision target was achieved for each segment. The small non-residential capacity factor exceeds other sectors with a statistically significant difference. The residential application-specific realization rate falls in a confidence interval of 98% to 105%. Generally, the impact evaluation team would anticipate that smaller systems experience more shading and less optimal orientation than large systems. It appears, however, that these types of considerations were effectively captured for application-specific realization rates for residential systems.

Table 5: Production Analysis Results by Customer Sector[14]

Customer Sector		Sample Complete	Capacity Factor	Capacity Factor Relative Precision @90%	Reporting Realization Rate	Reporting RR Relative Precision @90%	Application-specific Realization Rate	Applicat-ion-specific RR Relative Precision @90%
Below 200 kW	Residential	211	12.4%	3.4%	92.6%	3.4%	101.6%	3.3%
	Non-Residential	55	13.1%	1.5%	97.5%	1.5%	95.7%	2.1%
≥ 200 kW	Non-Residential	93	12.7%	0.9%	94.8%	0.9%	94.6%	1.1%
Overall		**359**	**12.6%**	**2.2%**	**93.9%**	**2.2%**	**98.8%**	**1.9%**

Table 6 provides production analysis results by by region. The 90/10 capacity factor precision target was achieved for all segments. Slightly higher capacity factors were expected on Long Island (observed in the prior evaluation) because the average solar insolation is higher, on average, than in the Upstate region, and there are fewer physical obstructions than in the Con Ed region (especially for smaller sites built on existing buildings with less ideal orientations). The impact evaluation did observe slightly higher capacity factors on Long Island; however, the

[14] Calculations based on sample weighted results rather than the applied ratio results from the population.

difference is not statistically significant, meaning that the observed difference could just be due to the random samples of this study rather than the expected physical causes.

Table 6: Production Analysis Results by Region

Region		Sample Complete	Capacity Factor	Capacity Factor Relative Precision @90%	Reporting Realization Rate	Reporting RR Relative Precision @90%	Application-specific Realization Rate	Application-specific RR Relative Precision @90%
Below 200 kW	Con Ed	82	12.4%	3.4%	92.4%	3.4%	101.8%	3.6%
	Upstate	93	12.5%	4.1%	93.0%	4.1%	99.1%	4.2%
	Long Island	91	12.7%	6.1%	95.1%	6.1%	102.3%	4.8%
≥ 200 kW	Con Ed	10	12.7%	3.4%	94.9%	3.4%	94.9%	3.4%
	Upstate	60	12.7%	1.0%	94.5%	1.0%	94.1%	1.2%
	Long Island	23	13.0%	2.0%	97.0%	2.0%	96.8%	1.8%
Overall		**359**	**12.6%**	**2.3%**	**93.9%**	**2.3%**	**99.2%**	**2.1%**

Table 7 shows the production analysis results for different system purchase types. The 90/10 precision target was achieved for each segment. Looking at differences across capacity factors from low to high, the small PPA group shows the lowest capacity factor (driven by particularly low production for several Long Island residential PPA sites), but it is not statistically different from small leased or large PPA segments. The large leased segment has the highest capacity factor at 13.5%, and also achieves a 100% realization rate, but this segment includes only a single site. The purchased system segment performs better than PPA models for both large and small groups.

Table 7: Production Analysis Results by Purchase Type

Purchase Type		Sample Complete	Capacity Factor	Capacity Factor Relative Precision @90%	Reporting Realization Rate	Reporting RR Relative Precision @90%	Application-specific Realization Rate	Application-specific RR Relative Precision @90%
Below 200 kW	Lease	63	12.3%	6.0%	91.5%	6.0%	103.9%	4.3%
	PPA	77	11.6%	8.9%	86.5%	9.0%	90.8%	7.4%
	Purchase	126	13.1%	3.0%	98.0%	3.0%	102.5%	3.8%
≥ 200 kW	Lease	1	13.5%	0.0%	100.6%	0.0%	100.6%	0.0%
	PPA	37	12.6%	1.3%	94.3%	1.3%	93.8%	1.5%
	Purchase	55	12.8%	1.2%	95.8%	1.2%	95.7%	1.1%
Overall		**359**	**12.6%**	**2.3%**	**93.9%**	**2.3%**	**99.2%**	**2.1%**

2.2.3 Detailed Findings

Estimated production, realization rates, and capacity factors from the impact evaluation of the March 2016- May 2018 NYSERDA Solar PV program installations are shown in Table 8, by region, size, and purchase type, and overall.

Application-specific realization rates are 99% for the program overall, for small systems overall, and for most segments within the small group (excluding PPA and non-residential sites). All other segments (excluding PPA) show application-specific realization rates in the mid-90s. These results are consistent with the prior (2011-2016) evaluation result, demonstrating high application-specific realization rates for nearly seven (7) years of the NY-Sun program.

Production realization rates for the program overall (94% for reporting and 99% for application-specific) show that both methods are providing relatively accurate estimation of generation for the program population, but the application-specific production is the better approach. The program realized an overall 12.6% capacity factor during the evaluation period, which is slightly higher than that of the 2008/2011-2016 evaluation result of 12.4%. Capacity factors for all groups but small purchase sites are below the planned capacity factor of 13.4% for the program.

Among small units, the evaluation found high capacity factors for purchased units and low capacity factors for PPA. Breaking these results down by region, the purchased model is consistently higher than other ownership models in all regions, while the overall low capacity factor for PPA is predominantly due to extremely low values on Long Island. Low producing sites were reviewed closely; Long Island included three sites with especially low capacity factors (below 5%) due to inverter failure, a low production anomaly, and extensive shading.[15] Small purchased and leased sites and large sites on Long Island perform more in line with expectations.

Table 8: Total Production by Region, Size, and Purchase Type

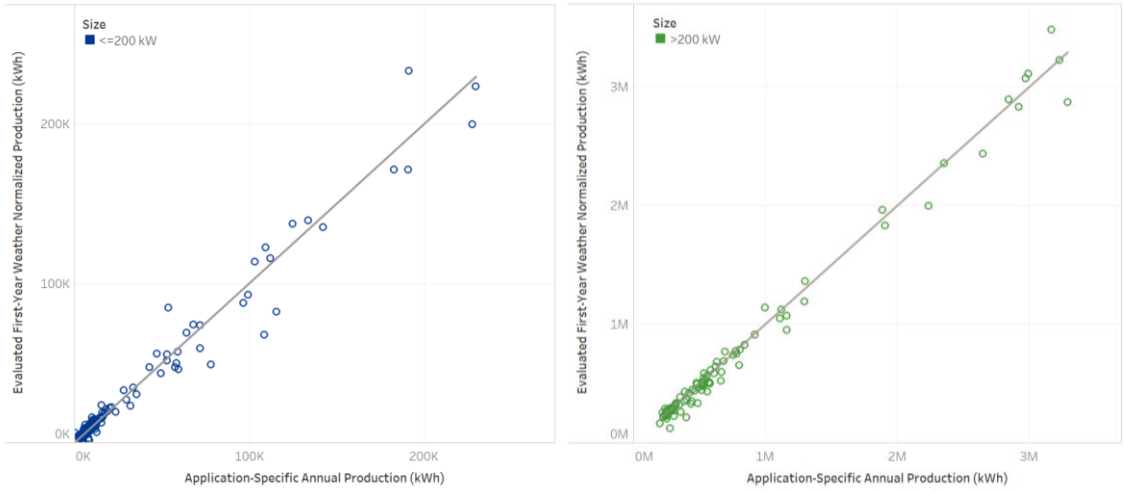
Region	System Size (kW)	Purchase Type	Sample Frame (N)	Evaluated Sample (n)	Total System Size (kW)	Annual Reporting Production (kWh)	Verified Gross First-year Production (kWh)	Reporting Realization Rate	Application-Specific Realization Rate	Capacity Factor
Con Ed	Below 200 kW	Lease	2751	22	19,518	22,910,482	20,779,807	90.7%	100.3%	12.2%
		PPA	723	21	5,056	5,935,246	5,454,491	91.9%	101.3%	12.3%
		Purchase	1851	39	16,099	18,897,258	17,857,909	94.5%	103.8%	12.7%

[15] The owner of one of the sites verified that the inverter was down multiple times, totaling 8 months of lost production. Owners of the other sites could not be contacted but, based on available data and information, one site had only three months of production followed by zero production due to an unknown cause. The third appeared to be functioning normally with no anomalies but was subject to extensive shading.

	≥ 200 kW	All	12	10	8,190	9,613,535	9,123,245	94.9%	94.9%	12.7%
Upstate	Below 200 kW	Lease	3914	18	32,205	37,803,721	33,796,527	89.4%	104.6%	12.0%
		PPA	1977	34	33,544	39,375,720	35,123,142	89.2%	91.0%	12.0%
		Purchase	6546	41	67,035	78,688,482	76,091,762	96.7%	100.5%	13.0%
	≥ 200 kW	All	103	60	56,107	65,860,183	62,266,439	94.5%	94.1%	12.7%
Long Island	Below 200 kW	Lease	4817	23	31,459	36,928,262	34,749,495	94.1%	105.4%	12.6%
		PPA	1991	22	13,776	16,170,292	12,612,827	78.0%	87.0%	10.5%
		Purchase	4279	46	43,861	51,485,290	52,103,114	101.2%	105.0%	13.6%
	≥ 200 kW	All	36	23	13,567	15,925,188	15,442,562	97.0%	96.8%	13.0%
Overall			**29,000**	**359**	**340,416**	**399,593,659**	**375,401,320**	**93.9%**	**99.2%**	**12.6%**

Figure 2 displays plots of evaluated production vs. application-specific production for all sampled sites, as a representation of how well production was estimated by installers. Note that the two plots have different scales: 0 to 300,000 kWh for smaller sites and 0 to 3,000,000 kWh for larger sites. The plots show the relationship between evaluated production and application specific production for each site. The line in each plot corresponds to a realization rate of 100%. The vertical distance from a point on the plot to the line is the error associated with the site. Sites above the line have realization rates above 100% and sites below have realization rates below 100%.

Figure 2. Plot of Evaluated Production vs. Application-specific Production



2.3 Key Findings and Recommendations

Key findings and recommendations from the impact evaluation are summarized in Table 9.

Table 9: Findings and Recommendations

#	Key Findings	Recommendations
1	Capacity factor results for all groups but Long Island small purchase sites are somewhat lower than the planning value of 13.4%. The residential capacity factor of 12.4% is higher than the 2011-2016 NY-Sun residential impact of 12.1%. Small non-residential sites show an increased capacity factor of 13.1% (previously 12.1%), while the overall non-residential group performance has decreased from 13.2% to 12.7%.	NY-Sun plans to begin using application-specific production estimates in the NYSERDA reporting system for gross impact estimation in future years. This change, which carries over from a prior evaluation recommendation, should improve the accuracy of gross impacts estimates and effectively increase realization rates for the program.[16] Further accuracy could be instituted by applying the application-specific realization rates from this evaluation.
2	Application-specific realization rates for most results categories, especially small systems (less than 200 kW) are more accurate than reporting estimates. This finding is consistent with prior evaluation results. The application-specific realization rates for small systems (excluding PPA sites) are near 100%, reflecting that the slightly lower verified capacity factor (due to less optimal physical characteristics, such as orientation and shading) for this segment is effectively captured in residential system planning models. The reporting realization rates for both large and small systems are below 100%, indicating that the NYSERDA reporting production overestimates system production (due to finding #1, capacity factors below the reporting assumption of 13.4%).	

[16] This recommendation carries over from the prior NY-Sun solar PV impact evaluation (2008 and 2011-2016).

#	Key Findings	Recommendations
3	Data collection through the DG integrated database was lower than expected: • 25 of 114 sites in the persistence sample discontinued reporting of production to the DG Integrated database after the required 3-year post-installation period expired. • Many sites expected to be enrolled in the Large C&I program (due to capacity size) were enrolled in the Small Commercial program instead, which did not require DG Integrated Database data reporting. NY-Sun Contractors were largely unable or unwilling to provide responses to phone surveys that sought to gather system-specific installation and production information, preventing the collection of some information that would help interpret unexpectedly high or low production.	Establish expectations among NY-Sun participants for periodic data collection, especially among the persistence sample. The evaluation team will provide an updated persistence sampling plan for future evaluations to account for increased attrition over original expectations.
4	NYSERDA program tracking data has improved considerably in quality and completeness since the prior evaluation, which bridged a shift and update of tracking systems and protocols. Some additional improvements would benefit tracking and evaluability of the program and related programs. Related findings include: Under the current reporting production estimation scheme and program design, the planned capacity factor differs by array type for large commercial systems. Most array type information was unavailable for sites in this evaluation period. Contractor contact information was sometimes incomplete or outdated. Several sites with unexpected capacity factors (which required additional detailed review) were co-located. These sites sometimes reported inaccurate capacity per system, but in some cases, the total system size was accurate.	• Confirm that array type is consistently available in tracking data for future evaluations (as expected per program manager information). • Per program manager information, bi-facial module installation has begun and thus will be included in future program evaluation populations, but is not tracked in program tracking data. Consider adding a field to the application (if not currently available) and to Salesforce for tracking of this information. • Updating contractor information when contractor companies or contacts are known to have changed would improve evaluation success. Similarly, standardizing contractor company names would improve evaluability and reduce burden to contacts listed for multiple non-standardized company names. • Consider adding identifiers for co-located sites. • Consider tracking site participation in other NYSERDA and NY State programs, such as NYGB and Clean Energy Communities programs. This would strengthen tracking records and improve evaluability of other solar PV programs.

3 Methods

This section summarizes the methods employed to collect production data for sampled sites and analyze program performance.

3.1 Data Collection Approach

NYSERDA's NY-Sun tracking database in SalesForce provided site-level account information, including installed capacity (kW), application-specific (modeled) production estimations (kWh), Total Solar Resource Fraction (TSRF), array type, system completion date, customer name and contact information, purchase type, installation contractor, and region. The evaluation sample frame was built from project information in this database.

The production data collection effort for this study sought to efficiently coordinate outreach among contractors and, as a secondary source ultimately deemed unnecessary, participants. The objectives of the data collection effort were two-fold:

- Collect production data (in kWh): first-year monthly (13 months) and pre-installation annual energy use for net-metered sites
- Of lesser priority, the impact evaluation team sought to complete a short survey with installation contractors to obtain any additional information required to understand the system and production data.

Data collection surveys and communication were conducted by experienced program evaluators with expertise in solar photovoltaic systems.

3.1.1 Large C&I Data Collection

Large Commercial and Industrial (>200 kW non-residential) sites with publicly incentivized generation systems provide internet-connected monitoring data to NYSERDA and the public through the DG Integrated Database. Some large C&I projects' production data was not available through this resource, in which case the site was added to the list for contractor data collection described under the small business sector data collection plan.

3.1.2 Residential and Small Business

Residential and small business participating sites' production data was collected through outreach to installation contractors. Follow-up outreach to residential homeowners (for sites with non-

responding sites) was deemed unnecessary because data collection from contractors was sufficient to meet precision requirements.

The impact evaluation team developed advance letters (provided in Appendix E) for initial communication to contractors to state the purpose of the study, formalize the data request, and provide instructions for obtaining the data from PV system(s).

NYSERDA provided a solar PV program evaluation website[17] to encourage participation in the study and provide a medium for email communication.

Finally, the impact evaluation team developed a recruitment script, survey script, and data collection instrument to inventory and track collected data and to standardize the communication from multiple evaluators. The survey script is provided in Appendix D.

3.2 Analysis Approach

All verified gross impact results for this evaluation are based on the first 13 months of production data, starting the month of installation and dropping that first, potentially partial-production month. All results are weather normalized to account for differences in production caused by weather (solar insolation and precipitation) across years of installation.

The analysis of program data included cleaning and annualization of production data, calculation of case weights for expansion of site data to the program population, and ratio estimation to generate capacity factors with appropriate standard errors. Once the data collection and initial analysis were complete, the impact evaluation team conducted a file review for sites with particularly high or low capacity factors (above 14% or below 9%).

3.2.1 Production Data Analysis

The analysis calculated two key values from the production data for each evaluated site: capacity factor and realization rate. Capacity factor provides a measure of system performance relative to rated capacity. Many factors can influence capacity factor, such as installation direction and angle, shading, temperature, and insolation. Capacity factor (CF) is calculated as:

$$= \frac{\sum \quad h\_}{\sum \quad *8{,}760\ h \quad *}$$

Where:

[17] https://www.nyserda.ny.gov/About/Publications/Program-Planning-Status-and-Evaluation-Reports/Solar-Photovoltaic-Impact-Evaluation

kWh_eval_j = First-year evaluated production for system j (kWh)

CAP_j = System rated DC capacity j

W_j = Weighting factor for system j

V = Evaluation sample

Realization rates (RR) provide a measure of the degree to which program estimates of production predict first year generation.

$$= \frac{\sum \quad h\_}{\sum \quad h\_}$$

Where:

kWh_eval_j = Evaluated first-year production for system j (kWh)

kWh_rep_j = Program production for system j (kWh)

In the application-specific realization rate, kWh_rep_j is based on the individual system estimates provided by contractors. Application-specific production planning estimates are generated through system models submitted by contractors as part of the program application process. In the reporting realization rate, kWh_rep_j is based on NYSERDA estimated solar PV system production for purposes of external, program-level progress and benefits reporting to the PSC. Reporting production estimates are based on a 13.4% capacity factor applied to the planned system size, which was used by NYSERDA to estimate and report system production.

The method for calculating the sample weights, , for each stratum is described below. In lay terms, the weight is simply the number of units in the sample frame (N) divided by the number of completed units in the sample (n). The interpretation of the weight is that each completed sample unit represents N/n units in the sample frame.

The weight W_x is calculated as

$$W_x = N_x / n_x$$

Where:

N_x = Number of units of analysis in stratum X

n_x = Number of completed sample units of analysis in stratum X

3.2.2 File Reviews

The evaluation team conducted a file and QC data review to determine reasons for capacity factors and realization rates outside of the expected range (capacity factors above 14% or below

9%), and subsequently clean the production data. NYSERDA provided production model files, applications, site documentation, and QC data for these systems, for comparison to collected production data and system details collected through customer surveys. The team reviewed shading analysis and production estimation files from the system design to both the program reported generation and the actual generation collected for this study, to determine whether inaccurate modelled generation or metered data[18] caused the unreasonably high or low capacity factors/ realization rates. The team also reviewed QA/QC documentation, where available, to determine if differences between the designed and built systems were the source of unreasonably high or low realization rates.

Where file reviews did not illuminate the cause or reasonability of site performance outside of the expected range, the team conducted follow-up phone calls with program participants.

3.2.3 Weather Normalization

The evaluation team normalized production and capacity factors for weather differences (solar insolation, temperature, snow, etc.) across installation years. The weather-normalized values represent performance under typical weather conditions and provide a more meaningful basis for comparison against the reported/expected production that was based on modeling.

The normalization approach modeled a set of representative solar PV sites (residential, small commercial and large commercial), in System Advisory Model (SAM) production estimation software, using common characteristics and weather data, including solar insolation, temperature, and snow accumulation. For each month of each year in the first-year production period for evaluated projects (spanning March 2016 through May 2019), the model results were used to calculate the ratio of estimated production for the TMY month to the estimated production using actual weather.[19] The observed production quantity for each site and month was then adjusted to TMY conditions by multiplying each observed monthly quantity by the normalization ratio for that region and month. Weather-normalization factors are provided in Appendix B.

3.2.4 Expansion of Production Results to Sample Frame

The final weather-normalized production results were expanded to the sample frame through a set of sample weights based on the sample design stratification. Each weight is specific to an

[18] Inaccurate metered data could be caused by metering of multiple projects on a single meter, net metered data, or poorly captured data/ meter failure.

[19] Hourly TMY and Actual weather data came from a combination of the Physical Solar Model (PSM) v3 provided by the National Solar Radiation Database (NSRDV) and SolarAnywhere®. Monthly snow accumulation and frequency of events came from NOAA weather data

individual stratum and calculated as the number of units in the sample frame (N) for the stratum divided by the number of completed units in the sample (n) for the stratum. The interpretation of the weight is that each completed sample unit represents N/n units in the sample frame.