Combined Heat & Power – Impact Evaluation

Final Report

Prepared for:

New York State Energy Research and Development Authority

Tracey DeSimone, NYSERDA Project Manager

Prepared by:

West Hill Energy & Computing, Inc.

Brattleboro, VT

Al Bartsch, Principal

Lucas Sanford-Long, Analyst

Lynn DiTullio, Project Manager

NYSERDA Contract 104559

February 2020

NYSERDA Record of Revision

Document Title
Combined Heat and Power-Impact Evaluation, February 2020

Revision Date	Description of Changes	Revision on Page(s)
Add Date	Original Issue	Original Issue

Notice

This report was prepared by West Hill Energy & Computing in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority (hereafter "NYSERDA"). The opinions expressed in this report do not necessarily reflect those of NYSERDA or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, NYSERDA, the State of New York, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. NYSERDA, the State of New York, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

NYSERDA makes every effort to provide accurate information about copyright owners and related matters in the reports we publish. Contractors are responsible for determining and satisfying copyright or other use restrictions regarding the content of reports that they write, in compliance with NYSERDA's policies and federal law. If you are the copyright owner and believe a NYSERDA report has not properly attributed your work to you or has used it without permission, please email print@nyserda.ny.gov

Information contained in this document, such as web page addresses, are current at the time of publication.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

A&A	Aggregation and Acceleration program
cf	cubic feet (natural gas for this report)
CHP	combined heat and power
DERIDS	Distributed Energy Resources Integrated Data System
kW	kilowatt
kWh	kilowatt hours
MW	megawatt
MBtu	Thousand Btu
MMBtu	Million Btu
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
W	watts

Introduction

This evaluation covers two different CHP programs that were merged into a single offering, NYSERDA PON 2568: CHP Program. [1] The two programs are the CHP Aggregation & Acceleration (A&A) Program and the CHP Performance Program.

The CHP Aggregation & Acceleration Program began with Technology and Market Development funds by developing and transforming the marketplace for CHP systems from 50 kW to 1.3 MW. This program served as the foundation for transition to the CEF-funded program in 2016 which expanded to support CHP systems 3 MW and smaller with no minimum size. The CHP Performance Program funds installations of CHP systems using energy, summer peak demand, efficiency, and environmental performance-based payments. A summary of the reported savings for both programs during the evaluation period is included in **Error! Reference source not found.**.

Table 1: Total Program Reported Aggregation & Acceleration and Performance Savings

	Count	Electric Generation (MWh)	Utilized Heat (MMBtu)	Peak kW[a]
Aggregation & Acceleration	52	72,163	93,812	11,830
Performance	5	150,577	195,750	13,840
Total	57	222,740	299,562	25,670

[a] This peak kW is the rated capacity of the CHP system electrical generation with an adder for several systems that included absorption chillers.

This report covers the impact portion of the CHP program evaluation. The primary objective is to determine the savings impacts from the CHP Aggregation and Acceleration and Performance programs. These impacts include electric generation, natural gas savings due to waste heat utilization, and peak electric generation. For the purpose of this evaluation the peak electric generation refers to the maximum electric generation of the CHP system, not to the grid peak period.

The evaluation plan called for calculating the impacts for both program-initiated and replication projects, as shown in Table 2. Replication projects refers to CHP projects installed in the State that did not receive NYSERDA support. However, based on surveys of CHP professionals the market assessment portion of

[1] https://portal.nyserda.ny.gov/CORE_Solicitation_Detail_Page?SolicitationId=a0rt0000000QnqyAAC

the evaluation found that there were very few or no projects completed without involvement from NYSERDA.[2] As a result there are no evaluated savings for the replication projects.

Table 2: Evaluation Objectives

Objective	Purpose	Method
Estimate final gross impacts of the CHP program	Determine the savings impacts for participating CHP	Billing analysis
Estimate any replication impacts of the CHP program	Determine any impacts of the CHP program from non-participants	No non-participants based on market evaluation

Program Data Collection

All CHP Systems larger than 50 kW installed with assistance from NYSERDA were instrumented such that the CHP System performance (including thermal use) could be measured on 1-hour intervals. In addition, NYSERDA sampled the performance of small CHP Systems (50 kW and less) by accessing monitoring systems included within the CHP System by the installer or operator, or, in some instances, by installing monitoring equipment at NYSERDA's expense at select CHP project sites. All performance data is uploaded automatically to NYSERDA's Distributed Energy Resources Integrated Data System (DERIDS) Website, where the data is available to the public. Installations are required to upload performance data daily for at least 3 years. A number of key variables are metered at a 1-hour interval, allowing direct measurement of gross savings.

Typical measurements collected for CHP systems installed through the program included monitoring and verification on the following points.

- Gross electric generation (kWh) - The aggregate electric output of the CHP system
- Parasitic loads (kWh): Electric loads necessary to operate CHP system, including circulating pumps on the DER side of the building load heat exchanger, heat rejection equipment, natural gas compressors, etc. These appear to be included in the field with electric generation as the net CHP kWh
- Fuel input (cf): The volume of natural gas consumed by the CHP system

[2] Combined Heat and Power and Onsite Resilient Power Market Assessment, Prepared for NYSERDA by Opinion Dynamics Corporation, December 2019

- Useful heat (Mbtu): Heat provided to the host facility for beneficial use that displaces heat from other sources, such as domestic hot water, space heating, make-up air heating, pool heating, snow melt, thermal energy supplied to absorption chillers, and steam production

- Rejected heat (Mbtu): Heat that is recovered from the CHP system but rejected to the atmosphere; it does not offset a thermal load on-site

Data Quality

Each CHP system incentivized by NYSERDA is required to have an inspection by NYSERDA agents before the project can be closed and final incentive moneys disbursed. This inspection must verify that pertinent M&V data is being generated and uploaded, and that it is accurate. According to the ERS report: *Best Practices and Lessons Learned as NYSERDA's CHP Inspector* [3]:

> "…the inspector also verified that accurate performance data was being transmitted to NYSERDA's DERIDS website by taking on-site measurements of CHP system generation, utility electrical import, heat recovery performance, and fuel input (depending on configuration of CHP system and site) and later comparing these measurements against data reported to the DERIDS website at the same time period."

These inspections did find some data issues with the DERIDS data not matching direct metering. It is unknown if the issues were fully resolved at the time of the evaluation, but the DERIDS data undergoes a data quality check and data that does not pass is removed.

The data available on NYSERDA's DERIDS website often started before the CHP system was fully operational, as many sites had a lag between when the monitoring system was installed and when the system was fully operational. For example, a number of sites did not produce thermal output until several months after the electrical portion was completed. Because of the potential for unrepresentative data, the data was reviewed by NYSERDA staff to identify the transition from start-up/shakedown to steady-state operation., The startup period before the site was fully operational was removed from the analysis.

[3] Matthew Lockwood, Best Practices and Lessons Learn as NYSERDA's CHP Inspector, International Energy Program Evaluation Conference, 2019

Results, Findings, and Recommendations

This section includes the evaluation savings for both portions of the CHP program and potential reasons for the results. The evaluated gross savings results are shown in the tables below, separated by program as the two programs were analyzed separately. The total evaluated savings are calculated by applying the realization rate from the sites with complete data to the total program reported savings.

Aggregation and Acceleration Results

Table 3 shows a summary of the total results for the A&A sites.

Table 3: Summary of Generation for the Aggregation and Acceleration CHP sites with DERIDS data

	All Evaluated Projects (n=40)			Total Program (n=52)	
	Program Reported	**Evaluated Gross Savings**	**Realization Rate**	**Program Reported**	**Evaluated Gross Savings**
Electric Generation (MWh)	48,770	32,668	67%	72,163	48,338
Utilized Heat (MMBtu)	63,400	136,084	215%	93,812	201,360
Peak kW[a]	7,995	5,922	74%	11,830	8,762

[a] The reported peak kW is the rated kW of the facility with an adder for sites with absorption chillers. The evaluated kW is the maximum kW produced at any time during the available data. No information on cooling performance of the absorption chillers was available to calculate the evaluated savings.

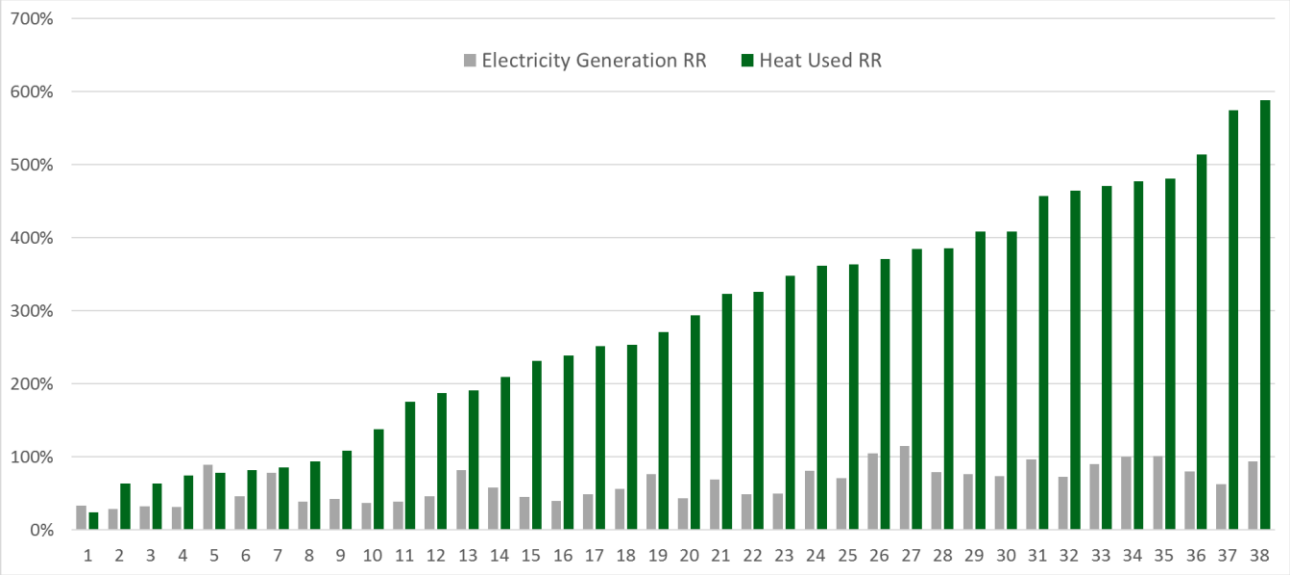
The program reported electric generation and utilized heat were calculated using a prescriptive formula based on the rated kW of the system. The electric generation is overestimated with these equations, while utilized thermal energy is being underestimated.

On average the electrical systems are only operating at 45% of their rated capacity. The overestimation of the electric generation is linked to this low capacity factor, as the kWh assumption is based on the rated kW multiplied by 6,100, the equivalent of a 70% capacity factor. The program reported MMBtu used was based on a more conservative estimate, resulting in a substantially higher realization rate. As the electric generation has a low capacity factor, utilized heat is a higher percentage of energy consumed, partially explaining the high realization rate of utilized heat shown in the results.

Figure 1 shows the range of realization rates across the evaluated sites. Almost all sites have an electric generation realization rate under 100%, while thermal realization rates range from 24% to almost 600%.

Error! Reference source not found.3 (see above) shows the program reported and evaluated savings on average for the sites with data available. The capacity factor is included as it gives an idea of the electrical performance of each site and correlates with the kW and kWh realization rates.

Figure 1: Summary of Electric and Thermal Realization Rates for Evaluated A&A Projects



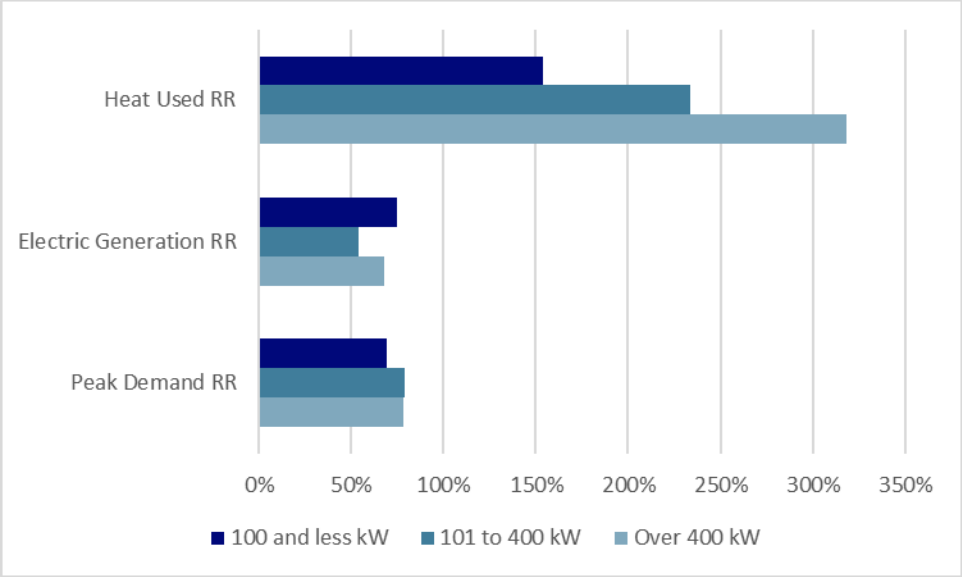
As can be seen from the summary of sites in Table 4, there is a wide range in size and savings across the A&A sites. Figure 2 shows the impacts of rated size on realization rates. As can be seen, the utilized heat realization rate changes with rated size, with the largest overestimates in the largest sites, while electric generation realization rate is relatively constant across sizes.

Table 4: Site Average Generation for A&A CHP sites with DERIDS data (n=40)

	Mean Program Reported Savings	**Median Program Reported Savings**	**Mean Evaluated**	**Median Evaluated**	**Confidence interval (90%)**	**Minimum Evaluated**	**Maximum Evaluated**
Electric Generation (MWh)	1,283	610	860	398	±414	168	7,893
Utilized Heat (MMBtu)	1,668	793	3,581	2,524	±1,260	375	29,356
Peak kW[a]	210	100	156	77	±58	36	1,114
Capacity Factor	70%[a]	70%[b]	48%	47%	±5%	17%	80%

[a] The reported peak kW is the rated kW of the facility with an adder for sites with absorption chillers. The evaluated kW is the maximum kW produced at any time during the available data. No information on cooling performance of the absorption chillers was available to calculate the evaluated savings.
[b] This value is assumed in the kWh calculations by the prescriptive equation.

Figure 2: Variation in Realization Rates of A&A Projects by Rated Capacity



Performance Results

There were only three Performance CHP sites completed during the evaluation period with data available. Table 5 shows the summary and site-specific results for the Performance CHP. The total evaluated savings are calculated by applying the realization rate from the sites with complete data to the total program reported savings. Additional details are included in Appendix A.

Table 5: Summary of Generation for the Performance CHP sites with DERIDS data

	All Evaluated Projects (n=4)			Total Program (n=5)	
	Program Contracted[a]	Evaluated Gross Savings	Realization Rate	Program Contracted	Evaluated Gross Savings
Electric Generation (MWh)	90,577	72,915	84%	150,577	126,202
Utilized Heat (MMBtu)	117,750	527,088	448%	195,750	876,241
Peak kW[b]	10,840	12,978	120%	13,840	16,570

[a] The program contracted only part of the total CHP generation for 3 of the 4 evaluated projects, because of this it was possible for the evaluated peak kW to be greater than the contracted peak kW.

[b] The evaluated kW is the maximum kW produced at any time during the available data.

The Performance sites have higher realization rates than the A&A sites across all three metrics. These sites are large non-catalog projects, unlike the A&A portion of the program which is primarily based on catalog systems. These also do not use prescriptive equations for estimating CHP generation and heat use, although the values appear to be within a similar range depending on system capacity. In addition, 2 of the 3 sites only contracted part of their generation capacity with NYSERDA, and as the DERIDS system measures the entire system, not just the contracted portion, that skews the results for Performance projects.

Findings and Recommendations

As no site visits were conducted as a part of this evaluation, the exact reasons for the low performance of the CHP systems is unclear. The report on inspections completed by ERS as part of the program showed a range of issues that could be causing the low performance.[4] Some of these issues are discussed as they relate to key findings from this evaluation.

- The forecasted electric generation of the CHP systems is consistently overstated, with lower than expected capacity factors.
- The low realization rate of the electric generation suggests that systems may be oversized for site loads, as is supported by findings of lower than expected electric loads in the ERS inspections. The program staff suggested oversizing could be a result of design objectives including the following:
    - Sizing systems for resiliency purposes to accommodate inrush currents during a utility grid outage as opposed to sizing for daily loads
    - Mischaracterization of addressable loads during the design phase, *e.g.*, failing to account for utility-required forward power draw buffering
    - The "lumpiness" of sizes of available equipment, *e.g.*, for a given site where 60 kW might be the ideal size, the closest size generator available in the project developer's product line might be 100 kW
    - In new construction projects, the building may not have reached full occupancy and thus may not yet have the expected electric and thermal loads.

[4] Matthew Lockwood, Best Practices and Lessons Learn as NYSERDA's CHP Inspector, International Energy Program Evaluation Conference, 2019

- The CHP systems take a long time to traverse the start-up/shakedown phase based on the time between the start of data collection and the time of the inspection when the site determines any startup issues have been resolved.

Based on these findings, the evaluation team has several recommendations for further investigation and improvement of future CHP programs.

- The consistent overstatement of savings suggests further investigation into the reasons for underperformance is warranted. Additional site inspections or discussion with site contacts may provide insight into why particular sites may not be performing as expected. Based on the range of results, if prescriptive savings functions are used for future CHP installations, they should be adjusted based on the results presented here.
- Additional effort should be spent on properly sizing the CHPs to each site. In addition to site calculated loads, the assessment should also consider other changes on site, such as other planned energy conservation measures could impact future loads. The ERS report also mentioned a need for minimum import amounts, averaging 10% of the CHP capacity, to avoid tripping relay protection devices as the CHP systems are operating behind the meter. A 10% under-sizing factor may be appropriate to allow for the minimum imports.
- Discussions with contractors and site operators to investigate the obstacles to CHP system startup/shakedown would allow future programs to decrease the time between project initiation and the CHP becoming fully operational and reduce turnaround time with any evaluation efforts of future programs.

Methods

Sampling and Attrition

Program participation required the collection of the generation and utilized heat data for all sites over 50 kW. Because of this no sampling was needed. All sites with data available were included in the analysis. As listed in Table 6, the attrition is only related to sites with insufficient data available, either because it was not yet transmitted to NYSERDA or an insufficient time had passed since the CHP was fully operational (as annual savings were only evaluated for projects with at least a year of data). A few of the program projects occurred at the same address, all projects at the same address are considered the same site.

Table 6: Aggregation and Acceleration Project Attrition

	Remaining Project Count	**Projects Removed**	**Remaining Site Count**
Total Program Projects	52	N/A	N/A
No Data available	47	5	45
Insufficient Data	40	7	38

Hourly data was available for 47 of the 52 A&A projects in the NYSERDA DERIDS database. The projects without data available had not yet begun transmitting or were below the size requirement for data collection (<50 kW). Of the 47 projects with available data, 2 projects were installed at the same location therefore the data was combined in the DERIDS database and they were analyzed as one site with combined savings. This resulted in 45 sites with data available.

Of the projects with data, 7 had insufficient data after the date the system was inspected and confirmed to be "fully operational." They were excluded from the analysis as the available data would not be representative of the final expected operation. This included one site with data quality issues that resulted in all DERIDS data being set to zero. This left 38 sites (with 40 projects) in the final analysis.

The final population analyzed accounts for 73% of the projects and 68% of the total program reported savings. The percent is the same across kW, kWh, and MMBtu as the kWh and MMBtu are calculated proportionally to kW.

There are only five Performance projects in the list provided by NYSERDA that had been completed as of 2017. Data was available from the NYSERDA DERIDS website for four of these projects and the fifth

project was still undergoing commissioning. Two of the projects were completed at the same location so the data and analysis were combined.

Analysis Approach

The IDS database had hourly consumption (cf gas) and generation (kWh, MMBtu heat) data for each tracked site. This allowed a direct calculation of the total consumption and generation for each year as well as average kW. The average kW was divided by the system rated kW to calculate a capacity factor for comparison across sites.

The sites were reviewed for temperature dependent usage and none had a strong correlation of consumption and usage with outdoor temperatures. Because of the lack of clear temperature dependence, the results were not adjusted using normalized temperatures. If multiple years of data were available of the average of the available "fully operational" years was used.

Data is partially missing for some sites. This appears to be because the CHPs are not operating at times and does not indicate an issue with data collection. Therefore, the calculations assume that CHP data with blank generation values and 0 consumption is correctly being recorded as not running. Many of these times were removed from the analysis period as they were prior to the date when the CHP became "fully operational" as determined by the date the site requested an inspection from NYSERDA.

Some sites have not yet requested an inspection. In these sites the most recent complete year was analyzed for a subset for whom it was determined the CHP was operating as expected and had completed the startup and troubleshooting process.

Replication projects were intended to be included in this evaluation based on the results of surveys conducted by the Market Assessment team. Their surveys found no CHP projects that were completed in the 2015-2018 without NYSERDA support, therefore no additional analysis was done for replication savings