Opinion Dynamics

AMEREN MISSOURI - PROGRAM YEAR 2023 ANNUAL EM&V REPORT

VOLUME 3: BUSINESS PORTFOLIO

APPENDICES

JUNE 7, 2024

Boston | Portland | San Diego | San Francisco

CONTENTS

TABLES & FIGURES

APPENDIX A. ADDITIONAL INFORMATION: STANDARD LIGHTING

This section provides additional detail on our Hours of Use (HOU) and In-Service Rate (ISR) analysis methods and results for Standard Lighting desk reviews.

The evaluation of Standard Lighting projects included desk reviews for a sample of 54 projects. The main purpose of the desk reviews was to calculate and revise program-specific HOU adjustments and ISRs for application in the program-level deemed lighting analysis. We reviewed supporting project documentation as part of the desk reviews to ensure that HOU data were correctly entered from invoices and other documentation. We also verified measure installation and collected HOU data from participants to inform the estimation of ex post ISRs and an HOU adjustment. In most cases, the evaluation team updated ex ante HOU estimates based on participant feedback and confirmed that installed quantities matched program-tracking data.

DATA COLLECTION

For each sampled Standard Lighting Project, the evaluation team conducted a brief interview with a project representative to collect information on HOU and ISR. We initiated contact through an email to the technical contact, provided background information on the study, and solicited availability for an interview. In this email, we provided a summary of program-tracking data to remind the participant of the project in question and facilitate their preparations for the interview. If we were unable to reach the technical contact, the evaluation team would only reach out to people from the site location knowledgeable of the building's HOU (the survey contact or Trade Ally, for example). During the call, the evaluation team walked through each measure on the application to confirm the HOU inputs through a bottom-up analysis using a series of questions crafted to capture the actual operating hours. We asked the respondents for operating schedules for the following cases: weekdays, weekends, total weeks of lighting operation throughout the year, whether the lighting was shut down for holidays,[1] and finally, if occupancy sensors (if applicable) were accounted for in the hours provided. If the HOU provided by the respondent did not include the occupancy sensors (but occupancy sensors were present), we reduced our total HOU for the site by 24% per the savings factor for occupancy sensors in the Ameren Missouri TRM Appendix F. In cases where the evaluation team could not reach any site contacts after several attempts, the evaluation team reviewed posted business hours and expected hours for the facility type to confirm the general reasonability of the input assumptions. In most cases, this resulted in accepting the ex ante HOU. One project was dropped from the sample because HOU could not be determined to be reasonable.

For the sampled projects, we verified the ISR by reviewing project documents provided by the program team to verify the quantity of installed fixtures with invoices and fixture wattages with the specification sheets for the reported model numbers. In cases where we couldn't verify via project documents already provided, we verified ISRs during the interviews with project contacts.

HOU AND ISR ANALYSIS METHODS

The evaluation team calculated verified ex post HOU and ISR adjustment factors for each sampled project.

For the HOU analysis, the evaluation team calculated a verified HOU from the inputs collected from the site contact interview. The interviews yielded business week (Monday–Friday) HOU, weekend HOU, total weeks of lighting operation for the year, holiday lighting operating schedule (assuming the 11 standard Federal holidays), and the presence and inclusion of occupancy sensors at the site. The scheduling variables were rolled up to a yearly HOU. The presence of occupancy sensors was considered to determine the final verified HOU. The calculated HOU was final if present and

[1] We use the number of weekday holidays the business actually observes if the customer provided it so us, otherwise, we use the standard eleven weekday Federal holidays.

accounted for in the inputs already. If occupancy sensors were present but not accounted for in the inputs, the HOU was reduced by 24% in accordance with the AMO TRM for occupancy sensors; the reduced HOU then became the final verified HOU.

For the ISR analysis, the evaluation team verified or updated the efficient wattage and the quantity of fixtures installed. We primarily relied on the specification sheets matched to the model numbers for the fixtures installed in the program-tracking data and the application to verify efficiency. We verified quantities by comparing the installed quantity with the invoices provided by the program team. As noted above, we also leveraged interviews with project contacts to collect additional information when needed. These verified quantities and wattages were then applied to the AMO TRM's algorithm for business lighting in conjunction with the baseline wattage, baseline quantity, and ex ante HOU from the program-tracking data.

Project-level HOU adjustment factors and ISR adjustment factors are finally extrapolated to the population of Standard Lighting measures based on the savings weights and the stratified random sample design from which they were drawn.

HOU AND ISR ANALYSIS RESULTS

The tables below present the results of the Standard Lighting desk review analysis, including HOU (Table 1) and ISR (Table 2) realization rates by project. We also include a brief description of the primary drivers of realization rates.

Table 1. Summary of Standard Lighting Project HOU Results

Site ID	Ex ante KWH	Ex ante KW	HOU RR	HOU Discrepancy Explanation
1000	457,179	86.8474	100%	
1001	331,418	62.9574	N/A	Unable to reach contact; removed from HOU sample
1002	317,971	60.4029	100%	
1003	307,222	58.3610	100%	
1004	290,799	55.2412	N/A	Lighting was upgraded for resale purposes, the building is unoccupied, but the property manager has signed a lease with a tenant; removed from HOU sample
1005	278,582	52.9204	111%	Customer reported that all lights are on 24/7; no occupancy sensors
1006	270,432	51.3721	133%	Multiple discrepancies between verified hours and application hours
1007	264,720	50.2871	100%	
1008	87,006	16.5280	100%	
1009	86,121	16.3598	100%	
1010	80,678	15.3259	86%	Customer reported 9 hours/day on weekdays and off on holidays.
1011	79,650	15.1305	66%	Application HOU did not account for pre-existing occupancy sensors
1012	78,497	14.9116	22%	Trade Ally reported that lights are on 2 hours/day, 45 weeks/year. The facility is a warehouse for a furniture store; lights are only on when in use.
1013	78,196	14.8544	90%	Reported HOU are 10 hours/day, 7 days/week, and off on holidays. Ex ante HOU also did not account for pre-existing occupancy sensors.
1014	77,764	14.7723	100%	

Site ID	Ex ante KWH	Ex ante KW	HOU RR	HOU Discrepancy Explanation
1015	76,405	14.5142	86%	Contact reported that only 10% of fixtures are on 24/7; the rest are on 15 hours/day on weekdays and minimal weekend hours
1016	73,204	13.9061	100%	
1017	72,876	13.8438	67%	Reported HOU are 10 hrs/day on weekdays and off on weekends and holidays. Ex ante HOU also did not account for pre-existing occupancy sensors.
1018	72,610	13.7932	59%	Customer reported classroom lights are on 35 hours/week and hallway lights are on 45 hours/week
1019	71,916	13.6615	76%	Customer reported lights are on 36 weeks per year.
1020	70,385	13.3706	60%	Lights are not on 24/7. Verified HOU of 11 hours/day on weekdays, off on weekends and holidays
1021	69,774	13.2545	100%	
1022	67,403	12.8041	117%	Auto Services facility: Showroom, breakroom, and offices are open 6 days/week
1023	336,911	64.0008	84%	Verified HOU are 12 hours/day, 252 fixtures on occupancy sensors
1024	299,680	56.9283	39%	Verified HOU are 11 hours/day, 5 days/week, and off on holidays
1025	274,887	52.2185	102%	Customer reported 13 hours/day, 7 days/week. However, hours were reduced by 24% due to pre-existing occupancy sensors
1026	172,678	32.8025	100%	
1027	40,403	7.6751	100%	
1028	67,258	12.7766	155%	Verified HOU are 10.5 hours/day, Monday–Friday, plus 20 fixtures are on 24/7 for security
1029	22,255	4.2276	132%	Verified HOU are 11 hours/day, 5 days/week, and off for holidays
1030	523,928	99.5272	65%	Verified HOU are 11 hours/day, 7 days/week, and lights are off on three holidays.
1031	33,270	6.3200	77%	Application HOU did not account for pre-existing occupancy sensors
1032	11,105	2.1095	256%	This is a 24-hour health facility. 70% of lights are on 24/7, 30% of lights are on 12 hours/day, 7 days/week
1033	161,098	30.6027	45%	Verified HOU are 9 hours/day, Monday–Friday.
1034	353,506	67.1532	149%	Verified HOU are 12 hours/day, Monday–Friday, 52 weeks/year and 5 hours/weekend for 30 weeks/year. Gym and offices have occupancy sensors.
1035	175,466	33.3321	100%	
1037	125,858	23.9084	149%	100 out of 650 fixtures are controlled by pre-existing occupancy sensors. 40 of the 650 fixtures are off on holidays.
1038	10,090	1.9167	127%	Multiple discrepancies between verified hours and application hours
1039	107,486	20.4184	100%	
1040	41,953	7.9695	100%	
1041	67,328	12.7897	130%	Verified HOU are 12 hours /day, Monday–Friday for most of the facility. HOU for classroom and therapy spaces are 8 hours/day, Monday–Friday.
1042	536,955	102.0019	48%	Verified HOU are 16 hours/day, Monday–Friday for warehouse. Office HOU are 10 hours/day, Monday–

Site ID	Ex ante KWH	Ex ante KW	HOU RR	HOU Discrepancy Explanation
				Friday. Ex ante HOU did not account for pre-existing occupancy sensors.
1043	745,069	141.5359	100%	
1044	66,773	12.6843	99%	Ex ante HOU did not account for pre-existing occupancy sensors in the manager's office.
1045	568,030	107.9052	100%	
1046	79,937	15.1851	100%	
1047	246,961	46.9135	100%	
1048	474,105	89.9398	78%	Ex ante HOU did not account for pre-existing occupancy sensors.
1049	117,347	22.2917	100%	
1050	613,131	116.4725	100%	
1051	1,016,768	193.1487	79%	Verified HOU are 24 hours/day, Monday–Friday, and 12 hours/day on weekends. 20% of lights are on occupancy sensors. Lights are turned off on holidays.
1052	1,210,177	229.67	100%	
1053	141,348	26.851	83%	Verified HOU are 11 hours/day, not 12. There are also pre-existing occupancy sensors; however, the facility is continuously in use on weekdays so the hours were only reduced on weekends.
1054	164,082	31.1696	100%	

Table 2. Summary of Standard Lighting Project ISR Results

Site ID	Ex ante KWH	Ex ante KW	ISR	ISR Discrepancy Explanation
1000	457,179	86.8474	111%	Errors in ex ante efficient wattages driving ISR
1001	331,418	62.9574	100%	
1002	317,971	60.4029	100%	
1003	307,222	58.3610	100%	
1004	290,799	55.2412	98%	For occupancy sensors, used controlled kW on the application instead of TRM default of 0.138 kW
1005	278,582	52.9204	100%	
1006	270,432	51.3721	99%	Minor discrepancy in redesign efficient wattage
1007	264,720	50.2871	100%	
1008	87,006	16.5280	100%	
1009	86,121	16.3598	108%	Discrepancies in efficient fixture wattages
1010	80,678	15.3259	100%	
1011	79,650	15.1305	101%	Minor discrepancies in ex ante efficient wattages (spec sheet wattage per lamp is different)
1012	78,497	14.9116	100%	
1013	78,196	14.8544	101%	Minor discrepancies in ex ante efficient wattages (rounding)
1014	77,764	14.7723	100%	
1015	76,405	14.5142	100%	
1016	73,204	13.9061	100%	
1017	72,876	13.8438	100%	
1018	72,610	13.7932	100%	
1019	71,916	13.6615	100%	

Site ID	Ex ante KWH	Ex ante KW	ISR	ISR Discrepancy Explanation
1020	70,385	13.3706	100%	
1021	69,774	13.2545	100%	
1022	67,403	12.8041	100%	
1023	336,911	64.0008	100%	
1024	299,680	56.9283	101%	Minor discrepancies in ex ante efficient wattages (rounding)
1025	274,887	52.2185	110%	Lighting redesign project, total efficient wattage reduced by comparing individual fixture quantities to invoice, and reducing where invoice quantity is lower
1026	172,678	32.8025	100%	
1027	40,403	7.6751	100%	
1028	67,258	12.7766	100%	
1029	22,255	4.2276	100%	
1030	523,928	99.5272	100%	
1031	33,270	6.3200	100%	
1032	11,105	2.1095	100%	
1033	161,098	30.6027	80%	Customer stated that only 80% of fixtures have been installed
1034	353,506	67.1532	100%	
1035	175,466	33.3321	101%	Minor discrepancy in ex ante efficient wattages (rounding)
1037	125,858	23.9084	84%	Customer stated that 650 fixtures have been installed
1038	10,090	1.9167	126%	Some discrepancies in wattages and quantities applied in the redesign workbook. For occupancy sensors, used controlled kW on the application instead of TRM default.
1039	107,486	20.4184	100%	
1040	41,953	7.9695	101%	Ex ante rounded efficient wattage.
1041	67,328	12.7897	101%	Errors in ex ante efficient wattages driving ISR
1042	536,955	102.0019	107%	For occupancy sensors, used controlled kW on application instead of TRM default of 0.138 kW
1043	745,069	141.5359	100%	
1044	66,773	12.6843	100%	
1045	568,030	107.9052	89%	Mostly driven by a discrepancy in downlight kits: 97 invoiced vs. 128 ex ante
1046	79,937	15.1851	100%	
1047	246,961	46.9135	100%	
1048	474,105	89.9398	97%	Discrepancies in installed quantities. For occupancy sensors, controlled kW used on application instead of TRM default of 0.138 kW.
1049	117,347	22.2917	101%	Errors in ex ante efficient wattages driving ISR
1050	613,131	116.4725	105%	For occupancy sensors, used controlled kW on application instead of TRM default of 0.138 kW
1051	1,016,768	193.1487	100%	
1052	1,210,177	229.67	94%	For occ sensors, used controlled kW on application instead of TRM default of 0.138 kW.
1053	141,348	26.851	101%	Minor discrepancy in ex ante efficient wattages (rounding)
1054	164,082	31.1696	100%	

APPENDIX B. DESK REVIEW AND ONSITE REPORTS: CUSTOM INCENTIVE PROGRAM

The evaluation of Custom projects included desk reviews and onsite visits for a sample of 25 HVAC projects and a desk review of one indoor agriculture project. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Table 3. Summary of Custom Project Reviews

Site ID	Enduse/Project Type	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
			Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
2000	HVAC	Desk review with Onsite Verification	1,024,126	1,024,126	100%	932.66	932.66	100%
2001	HVAC	Desk review	300,806	382,613	127%	146.84	181.64	124%
2002	HVAC	Desk review	17,358	14,291	82%	7.71	6.34	82%
2003	HVAC	Desk review	90,458	90,458	100%	40.16	82.38	205%
2004	HVAC	Desk review	240,142	271,193	113%	106.62	134.25	126%
2005	HVAC	Desk review	179,934	179,041	100%	163.86	163.05	100%
2006	HVAC	Desk review	399,223	328,831	82%	330.71	299.46	91%
2007	HVAC	Desk review	152,252	152,252	100%	111.09	111.09	100%
2008	HVAC	Desk review with Onsite Verification	2,209,814	1,982,050	90%	981.12	880.00	90%
2009	HVAC	Desk review with Onsite Verification	1,025,445	214,940	21%	455.30	95.43	21%
2010	HVAC	Desk review	814,031	77,150	9%	361.42	58.89	16%
2011	HVAC	Desk review	220,862	73,473	33%	98.06	32.62	33%
2012	HVAC	Desk review	227,550	184,654	81%	154.01	147.24	96%
2013	HVAC	Desk review	73,687	46,623	63%	32.72	20.70	63%
2014	HVAC	Desk review	210,294	214,301	102%	93.37	129.46	139%
2015	HVAC	Desk review with Onsite Verification	546,069	-	0%	242.45	0.00	0%
2016	HVAC	Desk review with Onsite Verification	99,153	76,528	77%	63.95	49.36	77%
2017	HVAC	Desk review	776,797	776,797	100%	363.72	363.72	100%
2018	HVAC	Desk review	272,140	227,274	84%	247.83	206.97	84%
2019	HVAC	Desk review	241,592	226,584	94%	151.27	137.61	91%
2020	HVAC	Desk review with Onsite Verification	1,214,400	844,347	70%	539.17	374.88	70%
2021	HVAC	Desk review with Onsite Verification	1,201,882	1,075,368	89%	1,094.53	979.32	89%
2022	HVAC	Desk review with Onsite Verification	2,112,387	1,876,368	89%	1,717.23	1,405.91	82%
2023	HVAC	Desk review	398,009	392,261	99%	299.16	285.29	95%
2024	HVAC	Desk review with Onsite Verification	1,006,713	301,605	30%	446.96	274.67	61%
3000	Indoor Agriculture	Desk review	1,145,524	815,954	71%	158.02	112.56	71%

SITE 2000 (CUSTOM HVAC)

A complex of three university buildings, including lab spaces, are currently served by a common chilled water loop, with chillers in one building and the main plant in another building in a primary-secondary arrangement. Prior to the project, the loads were served by three-way valves, requiring more chillers to be enabled to run to satisfy flow than are required to run to satisfy the load. This resulted in a low temperature differential across the chillers and meant they operated at reduced efficiency. Additionally, the building pumping networks had evolved ad hoc over the years, with booster pumps installed at various locations to address flow deficiencies in different buildings. This project unified these buildings to a central cohesive pumping scheme, including a conversion of loads from three-way valves to two-way valves for true flow and load turn-down under part-load conditions. The result is a reduction in pump energy and an increase in chiller operating efficiency.

Table 4. Site 2000 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Education	Not provided	IECC 2018	HVAC	Equipment Replace/ Mod/Add/Remove

Table 5. Site 2000 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Chilled Water Optimization	Cooling	1,024,126	932.66
	Total	**1,024,126**	**932.66**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for the estimated energy savings. An onsite review confirmed the updated pumps and chiller configuration.

ANALYSIS

The ex ante savings were determined through a bin analysis comparing chiller and pump performance in the existing and proposed configurations. To verify the bin analysis, we used whole facility consumption data to perform a pre/post regression analysis based on outside air temperature. The results of the regression analysis aligned closely with the ex ante savings. As such, we determined that the ex ante savings represent a reasonable expectation of project savings and awarded a 100% realization rate.

Table 6. Site 2000 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Chilled Water Optimization	N/A	N/A	N/A

RESULTS

Table 7 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 7. Site 2000 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Chiller Optimization	1,024,126	1,024,126	100%	932.66	932.66	100%
Total	**1,024,126**	**1,024,126**	**100%**	**932.66**	**932.66**	**100%**

Reasons for discrepancies

- N/A

Other Findings and Recommendations

- This was the only Custom HVAC project selected for evaluation this cycle that had enough post-install data available to allow the savings to be verified through a pre/post regression analysis.

SITE 2001 (CUSTOM HVAC)

This project includes the replacement of the current Trane Building Automation System (BAS) with an Automated Logic BAS in the administrative buildings of a school system. It also includes installing new variable frequency drives (VFDs) on the chilled water (CHW) and hot water (HW) pumps that serve 25 air handling units. Energy savings come from a reduction in occupied hours, an increase in the temperature at which the economizer is utilized, the addition of VFDs to the CHW and HW pumps, and allowing the system to cycle on and off during unoccupied periods. The baseline system runs during unoccupied hours, does not efficiently use the economizer, and has constant-speed hot and chilled water pumps.

Table 8. Site 2001 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	End Use Description	Project Type
Office	62,900	2015 IECC	HVAC	Equipment Replace/Mod/Add/Remove

Table 9. Site 2001 Ex Ante Savings Summary

Measure Name	Load Shape	Ex Ante Gross	
		kWh	kW
EEM-1 BAS - HVAC Load Shape	HVAC	272,333	120.91
EEM-2 BAS - Cooling Load Shape	Cooling	28,473	25.93
	Total	**300,806**	**146.84**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The submittals, drawings, and customer invoice confirm the installation of the new BAS system and the VFDs.

ANALYSIS

The ex ante savings are based on bin calculations in Excel. The evaluation team used the following approach:

For Air Handling Units and Rooftop Units:

- Adopted the HVAC bin analysis tool provided by the implementer to apply the changes to the operation of the systems and calculate the associated energy savings. This included modifying the schedule, the economizer set point, and the system cycling status. Some modifications were made to the calculations included in the HVAC bin analysis tool to better represent the system.
- Verified the equipment specifications using the mechanical drawings provided.
- Reviewed the trend data provided to verify the supply fan status at different times of the day.

For CHW and HW pumps:

- Verified the equipment specifications using the mechanical drawings provided.
- Reviewed the implementer's ex ante calculations and adjusted the input values to match the equipment specifications for Ex Post calculations.

Table 10. Site 2001 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline AHU and RTU fan operation	Constant speed, cycles during unoccupied periods	Constant speed, fan runs 24/7	Verified with customer: Fans ran 24/7 (workbook calculations included formula error)
EEM-1	Efficient AHU and RTU fan operation	Constant speed, scheduled	Constant speed, scheduled	Trend data
EEM-1	Baseline pump operation	Constant speed	Constant speed	Project description
EEM-1	Efficient pump operation	Variable speed	Variable speed	Trend data
EEM-2	Baseline Economizer Setpoint	55°F	55°F	Project documentation
EEM-2	Efficient Economizer Setpoint	65°F	65°F	BAS screenshots

RESULTS

Table 11 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 11. Site 2001 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 BAS - HVAC Load Shape	272,333	357,397	131%	120.91	158.68	131%
EEM-2 BAS - Cooling Load Shape	28,473	25,216	89%	25.93	22.96	89%
Total	**300,806**	**382,613**	**127%**	**146.84**	**181.64**	**124%**

Reasons for discrepancies

- HWP calculation uses an HP of 10, but equipment specs reference two pumps for a total HP of 20, resulting in an increase in savings.
- The CHP calculation sheet selected the incorrect use for the pump in the ex ante (CHW/HW) rather than CHW, resulting in a decrease in savings for the pump.
- Outside Air CFM values for the RTUs differ between the calculation spreadsheets provided by the implementer and the equipment specifications. We used the equipment specifications.
- The AHU and RTU calculation sheets show a change from CV to VAV, but the project description only mentions adding VFDs to the CHW and HW pumps.
- The implementer’s calculation of energy use associated with the AHU and RTU fans includes an adjustment factor to run hours based on cooling requirements. We removed this factor in the baseline conditions because the “Unit Cycles” input was set to No, which resulted in significantly higher savings. This is the primary driver behind the overall kWh realization rate.

Other Findings and Recommendations

N/A

SITE 2002 (CUSTOM HVAC)

This project involved the construction of a 270,000 square foot outpatient medical treatment center in St. Louis County. Custom incentives were awarded for energy-efficient lighting and building shell measures; this evaluation encompasses the building shell only. The facility is cooled with three 550-ton variable speed water-cooled centrifugal chillers. Natural gas boilers provide heating. Insulation levels in the roof and exterior walls exceed baseline levels under IECC 2015. Increased insulation reduces conductive heat gain through the building shell during summer months, thus reducing the cooling load and producing electrical energy savings.

Table 12. Site 2002 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Healthcare	271,371	2015 IECC	Envelope	New Construction/Major Renovation

Table 13. Site 2002 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Building Shell	HVAC	17,358	7.7067
	Total	**17,358**	**7.7067**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for estimated energy savings. The submittals, drawings, and customer invoices confirm the building shell measure installation.

ANALYSIS

The ex ante savings are based on eQUEST energy simulation for a baseline scenario and an as-designed scenario. The evaluation team was unable to run the model without errors. The evaluation team attempted to validate the ex ante savings using a bin analysis, adjusting the baseline U-values to the correct values according to IECC 2015, as shown in Table 14.

Table 14. Site 2002 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Above-grade Wall Insulation U-value, Base (including outside air film)	0.081	0.063	IECC 2015, Metal-framed walls + outside air film
EEM-1	Roof Insulation U-value, Base (including outside air film)	0.045	0.032	IECC 2015, Insulation entirely above roof deck + outside air film
EEM-1	Window U-value, Base	0.346	0.380	IECC 2015, Fixed fenestration

RESULTS

Table 15 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 15. Site 2002 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Building Shell	17,358	14,291	82%	7.71	6.34	82%
Total	**17,358**	**14,291**	**82%**	**7.71**	**6.34**	**82%**

Reasons for discrepancies

- The evaluation team requested the energy modeling files used by the trade ally to validate the ex ante savings. The implementation team provided the files, but the evaluation team was unable to run the model without errors. The evaluation team attempted to recreate the ex ante savings using a bin analysis to estimate conductive heat gain over typical weather conditions, using the insulation U-values provided in an exterior surfaces report, but the calculated kWh savings were only 26% of the ex ante value. However, the ex ante modeled savings are likely more accurate than the bin analysis because the models may include effects such as decreased radiative heat gain due to the light-colored roof, solar heat gain through windows, and below grade conductive heat transfer that are not accounted for in the bin analysis. For the ex post analysis, the evaluation team again used a bin analysis but updated baseline U-values for above-grade wall insulation, roof insulation, and windows according to IECC 2015 maximums. This decreased the calculated savings by 3,068 kWh. For the ex post savings, the evaluation team decreased the ex ante savings by this amount to account for the baseline assumption errors.

Other Findings and Recommendations

- The ex ante energy model reports indicate that TMY2 input files were used. In keeping with standard practice, the evaluation team used TMY3 weather data

SITE 2003 (CUSTOM HVAC)

This project includes installation of two dedicated outdoor air system (DOAS) units as part of a new hotel. The DOAS units include a dehumidification mode with modulating hot gas reheat, which is controlled based on an indoor temperature and relative humidity sensor. Dehumidification is accomplished by subcooling the supply airstream below the dewpoint temperature to condense some of the water vapor out of the airstream. The airstream is then reheated to the supply air temperature setpoint using the hot refrigerant gases. The baseline scenario is identical DOAS units but with electric reheat instead of hot gas reheat. Using the hot refrigerant gases leaving the evaporator coil to reheat the airstream provides “free” heating, saving energy versus reheating with electric strip heaters.

Table 16. Site 2003 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	End Use Description	Project Type
Lodging	163,420	2015 IECC	HVAC	New Construction/Major Renovation

Table 17. Site 2003 Ex Ante Savings Summary

Measure Name	Load Shape	Ex Ante Gross	
		kWh	kW
EEM-1 Hot gas reheat - Daikin DPS025A	HVAC	43,554	19.34
EEM-2 Hot gas reheat - Daikin DPS028A	HVAC	46,904	20.82
	Total	**90,458**	**40.16**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for estimated energy savings. The submittals, mechanical schedule, and customer invoices confirm the upgrades to the installation of two dedicated outdoor air systems (DOAS) with hot gas reheat.

ANALYSIS

The ex ante savings are based on bin calculations in Excel. The evaluation team validated the ex ante savings using a psychometric bin analysis with TMY3 weather data for St. Louis to confirm the baseline assumption and key input parameters.

Table 18. Site 2003 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	DOAS annual hours of operation	8760	8760	Reasonable assumption for facility type
EEM-2	DOAS annual hours of operation	8760	8760	Reasonable assumption for facility type
EEM-1	Reheat Temperature Delta	5°F	5°F	Engineering judgment
EEM-2	Reheat Temperature Delta	5°F	5°F	Engineering judgment

RESULTS

Table 19 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 19. Site 2003 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Hot gas reheat - Daikin DPS025A	43,554	43,554	100%	19.34	39.66	205%
EEM-2 Hot gas reheat - Daikin DPS028A	46,904	46,904	100%	20.82	42.71	205%
Total	**90,458**	**90,458**	**100%**	**40.16**	**82.38**	**205%**

Reasons for discrepancies

- The evaluation team analyzed the ex ante savings assumptions and calculations and found them to be reasonable, considering the relative uncertainty in the parameters of the dehumidification and reheat operation. However, the BUS Cooling load shape is a better fit than the ex ante BUS HVAC load shape assumption when calculating the demand savings because we expect dehumidification operation to coincide with the cooling season under typical weather patterns. Therefore, the ex post analysis uses the BUS Cooling coincidence factor (CF), which accounts for the increased kW savings.

Other Findings and Recommendations

- The evaluation team attempted to contact the site contact to verify the indoor temperature and relative humidity setpoints but was unsuccessful. Therefore, we analyzed the dehumidification and reheat savings using an average of typical setpoints ranging from 70°F to 76°F dry bulb temperature and 30% to 50% relative humidity.
- The evaluation team used a psychometric bin analysis with TMY3 weather data for St. Louis to determine the outdoor conditions at which there would not be a call for dehumidification and reheating as the outdoor air is already sufficiently dry. We determined the crossover point is 61°F, close to the ex ante assumption of 60°F.
- The evaluation team previously investigated whether electric reheat is a reasonable baseline assumption for this type of equipment and found that electric reheat is an option. In addition, IECC 2015 does not prohibit using electric reheat for dehumidification. Therefore, this baseline assumption was accepted for this project.

SITE 2004 (CUSTOM HVAC)

This project involved upgrading the BAS and implementing HVAC control measures in an elementary school. It also included installing new variable frequency drives (VFDs) on the chilled water and hot water pumps. Energy savings result from a reduction in occupied hours, an increase in the temperature at which the economizer is utilized, reduced pumping energy due to variable speed pump operation, and allowing the AHU fans to cycle on and off during unoccupied periods rather than run continuously.

Table 20. Site 2004 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	End Use Description	Project Type
Education	54,335	2015 IECC	HVAC	Equipment Replace/Mod/Add/Remove

Table 21. Site 2004 Ex Ante Savings Summary

Measure Name	Load Shape	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls	HVAC	240,142	106.62
	Total	**240,142**	**106.62**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The invoice confirms the purchase of the VFDs. The evaluation team contacted the site and learned that the buildings are closed for approximately two months every summer.

ANALYSIS

The ex ante savings were recreated using the bin analysis calculation workbooks provided by the implementation team.

The evaluation team updated various inputs to these workbooks, as detailed in Table 22 when creating ex post savings.

Table 22. Site 2004 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Operating Hours modified from 24/7 operation to 12 hours/day on weekdays and unoccupied on weekends	12 hours/day on weekdays	Removed 2 months of operation to account for school vacations	Trend data and customer communication
EEM-1	VFDs added to chilled water and hot water pumps	VFDs operating	VFDs operating	Verified by post-project BAS screenshot
EEM-1	Operating Hours modified from 24/7 operation to 12 hours/day on weekdays and unoccupied on weekends	12 hours/day on weekdays	Removed 2 months of operation to account for school vacations	Trend data and customer communication
EEM-1	Economizer setpoint changed from 55°F to 65°F	Economizer at 65°F	Economizer at 65°F	Verified by post-project BAS screenshot

RESULTS

Table 23 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 23. Site 2004 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Controls	240,142	271,193	113%	106.62	134.25	126%
Total	**240,142**	**271,193**	**113%**	**106.62**	**134.25**	**126%**

Reasons for discrepancies

- The implementer's calculation of energy use associated with the AHU and RTU fans includes an adjustment factor based on cooling requirements. We removed this factor from the baseline conditions because the "Unit Cycles" input was set to "No," which resulted in significantly higher savings. This change is the primary driver behind the overall kWh realization rate. The evaluator modified the OA CFM for one of the Rooftop Units, which slightly reduced the cooling savings for that RTU. Finally, the evaluator applied a ratio of 10/12 as a conservative estimate of annual vacation times during which the buildings are shut down.
- For the ex post kW savings, the evaluator disaggregated the kWh savings into Cooling and HVAC loadshapes and calculated the kW savings with corresponding coincidence factors, then added together the results.

Other Findings and Recommendations

- The majority of savings are due to changes in the BAS that reflect a reduction in HVAC operating hours. These changes do not reflect time periods during which schools are typically closed—winter breaks, spring break, and summer. A more thorough treatment of occupied hours would increase confidence in savings values.

SITE 2005 (CUSTOM HVAC)

This project includes installation of a variable refrigerant flow (VRF) system and dedicated outdoor air system (DOAS) units as part of a new senior living facility. The VRF System is the primary cooling and heating system; however, the facility has natural gas backup heating. The installed VRF System is more efficient than a standard efficiency VRF system, resulting in energy savings. Two energy savings mechanisms are associated with the DOAS: (1) Use of a DOAS reduces the air volume needed to be subcooled relative to a traditional mixed air HVAC system, and (2) Modulating hot gas reheat (HGR). HGR is used when the DOAS is in dehumidification mode to reheat the supply airflow after it is subcooled and saves energy compared to a baseline of reheating with electric strip heaters.

Table 24. Site 2005 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	End Use Description	Project Type
Healthcare	63,000	2015 IECC	HVAC	New Construction/Major Renovation

Table 25. Site 2005 Ex Ante Savings Summary

Measure Name	Load Shape	Ex Ante Gross	
		kWh	kW
EEM-1 Efficient VRF	Cooling	30,400	27.68
EEM-2 DOAS with Hot Gas Reheat	Cooling	149,534	136.18
	Total	**179,934**	**163.86**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The submittals, drawings, and invoice confirm that one efficient VRF System and DOAS with Hot Gas Reheat were purchased and installed at the site location.

ANALYSIS

The ex ante savings for the VRF System are based on bin calculations and use 2018 minimum efficiency requirements for air-source heat pumps for the baseline system. The evaluation team applied the minimum efficiency requirement for VRF systems from the federal equipment standards in 10 CFR 431.97 for the baseline system. The evaluation team verified the new system's efficiency from equipment submittals. The ex ante savings for DOAS are also based on bin calculations. The evaluation team validated the ex ante savings using a bin analysis with TMY3 weather data for St. Louis and confirmed the baseline assumption and key input parameters.

Table 26. Site 2005 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Installed VRF System Efficiency	19.2	21.1	Submittal; weighted-average efficiency
EEM-1	Baseline VRF System Efficiency	11.7	13.8	10 CFR 431.97
EEM-2	DOAS Annual Hours of Operation	8,760	8,760	Assumed based on facility type
EEM-2	DOAS Reheat Temperature Delta (°F)	5	5	Engineering judgment
EEM-2	Baseline Mixed Air System Supply Airflow (CFM)	20,123	20,123	Submittals; sum of DOAS and VRF supply airflows

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-2	DOAS Supply Airflow (CFM)	3,320	3,320	Submittal

RESULTS

Table 27 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 27. Site 2005 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Efficient VRF	30,400	29,503	97%	27.68	26.87	97%
EEM-2 DOAS with Hot Gas Reheat	149,534	149,538	100%	136.18	136.18	100%
Total	**179,934**	**179,041**	**100%**	**163.86**	**163.05**	**100%**

Reasons for discrepancies

- For the VRF System, ex ante calculations applied 2015 IECC minimum efficiency requirements for air-source heat pumps, which is not the correct equipment category. Federal equipment standards in 10 CFR 431.97 provide the minimum efficiency requirement for VRF systems. The efficiency standards in place at the time of installation were in units of EER rather than IEER; the latter metric is better suited for calculating energy savings because it is more reflective of seasonal operation than EER, which reflects full load efficiency. In the rulemaking docket for the current standards for VRF systems in 10 CFR 431.97,[2] the DOE presented results of a crosswalk analysis between the existing EER standards and equivalent IEER ratings. This analysis found that for a unit between 135,000 and 240,000 Btu/h, the capacity range for the units in this project, units rated at 10.8 EER had an IEER of 13-16. Therefore, the evaluation team multiplied the baseline EER values by the minimum ratio from the DOE crosswalk analysis (13/10.8) to estimate the equivalent minimum IEER. This resulted in a slightly higher baseline IEER (12.6) than used in ex ante (11.7), producing a realization rate of 97% for EEM-1. .

Other Findings and Recommendations

- The evaluation team attempted to contact the site contact to verify the indoor temperature and relative humidity setpoints but was unsuccessful. Therefore, we analyzed the dehumidification and reheat savings using an average of typical setpoints.
- The evaluation team used a psychometric bin analysis with TMY3 weather data for St. Louis to determine the outdoor conditions at which there would not be a call for dehumidification and reheat, as the outdoor air is already sufficiently dry. We determined that the crossover point is 61°F, close to the ex ante assumption of 60°F. In addition, we analyzed the subcooling temperature delta necessary to achieve common indoor air temperature and humidity conditions and concluded that 5°F is a reasonable assumption. The reheat temperature delta is assumed to be approximately equal to the subcooling delta so that the zones are not over-cooled.
- The evaluation team previously investigated whether electric reheat is a reasonable baseline assumption for this type of equipment and found that electric reheat is an option. In addition, the energy code adopted by St. Louis

[2] EERE-2018-BT-STD-0003-0056. Crosswalk analysis presented on November 5, 2019.

County, 2015 IECC, does not prohibit the use of electric reheat for dehumidification. Therefore, this baseline assumption was accepted for this project.

SITE 2006 (CUSTOM HVAC)

This facility is a two-story 80,800 square-foot office building with an onsite data center for an investment firm. The data center appears to occupy about 40% of the facility. The facility included two measures: high-efficiency chillers and an at-first unspecified condenser water pump (CP) measure determined to be downsized by a factor of about 2.5 (37 hp to 15 hp). This was also a split-incentive project site and included a Standard measure claim that was not evaluated: variable frequency drives (VFD) on three 15 hp condenser water pumps. Table 28 presents project information, and Table 29 presents ex ante measures and energy savings as obtained from the program tracking data.

Table 28. Site 2006 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Office	80,800	2015 IECC	Cooling + HVAC	Equipment Replace/Mod/Add/Remove

Table 29. Site 2006 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 High-Efficiency Chillers	Cooling	328,831	299.4611
EEM-2 Reduced CW Pump Size	HVAC	70,392	31.2529
	Total	**399,223**	**330.7140**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. In lieu of a project, we reviewed multiple documents and were able to determine the claimed measures. EEM-1 involved two new 220-ton high-efficiency, packaged water-cooled chillers, and EEM-2 involved downsizing three 40 hp condenser water pumps to 15 hp. The invoice confirmed that the chillers were purchased for installation at the site location, but the only description of EEM-2 that could be found was on the application: "Change operation of fans/pumps per model." A Trane TRACE® 3D Plus (TRACE3D) building energy model (BEM) was used to estimate the chiller and associated condenser water pump ex ante energy savings. We determined the pre/post pump sizes (hp) from the TRACE3D model and pre-retrofit building plans that were not originally provided with the project documentation but were provided in response to our request for additional information.

ANALYSIS

Our review of the project documentation and TRACE3D BEM revealed the following:

EEM-1 High-Efficiency Chillers. We verified the chiller type, size, and efficiency from project documentation, including building mechanical plans and a specification sheet. We also pulled the IECC 2015 minimum chiller efficiency for this type and size chiller. Path A and Path B efficiencies are presented in Table 30. Path A was chosen as the most applicable for this project due to servicing the data center, which was consistent with the approach used in the ex ante BEM. There was a slight difference in the efficiency value used in the ex ante BEM baseline scenario. Instead of using 0.610 kW/ton, a value of 5.7639 COP (0.61045 kW/ton) was used, probably a conversion from the IECC 2015 kW/ton value. The ex ante model used the correct chiller type, size, and quantity and also used the correct high-efficiency value for the new water-cooled, centrifugal chillers (0.5945 kW/ton). The only ex post change we would have made to this measure was the very slight change from 5.7639 COP to 0.610 kW/ton for better traceability to the IECC 2015 Path A full-load efficiency value. We also observed the chiller optimum part load ratios were different for the baseline and efficient scenarios (53% and 50%, respectively) and could have set both values to 50%. However, both changes would have had minimal impact on the measure savings, and we could not run the TRACE3D model due to a fatal error encountered after conversion to the latest version, as explained below.

Table 30. Site 2006 IECC 2015 Minimum Chiller Efficiency Values

Rating Type	Path A	Path B
Full Load (FL)	≤ 0.610 kW/ton	≤ 0.635 kW/ton
Part Load (IPLV)	≤ 0.6550 kW/ton	≤ 0.400 kW/ton
From Chiller Specification Sheet		
Full Load (FL)	0.5945 kW/ton	Lower than A & B
Part Load (IPLV)	0.3592 kW/ton	<< lower than A & B

EEM-2 Reduced CW Pump Size. This ex ante claim required the most investigation since the measure description on the application and tracking data referred only to the chiller, and a nebulous note on the application described this measure as “changed operation of fans/pump per model.” The first clue came from the Standard measure (which we did not evaluate), which was for VFDs on three 15 hp condenser water pumps. Our subsequent request to the implementer for more information yielded pre-retrofit mechanical schedule plans that showed the previous chiller system consisted of two 500-ton chillers and three 40-hp condenser water pumps. We expected to find this value in the BEM but instead found an unexplained baseline scenario value of 37 hp. The efficient scenario pump size was consistent with the 15 hp pumps for the Standard measure. We were also able to confirm the 15 hp size from post-installation photos provided with the project documentation. Given that the chiller plant and associated condenser water pumps are completely new, the 15 hp pump size should have been used for the baseline instead of the pre-retrofit pump sizes (40 hp/37 hp). For our ex post analysis, we zeroed out the savings for this measure. If we had not encountered a halting error when trying to rerun the TRACE3D model (see discussion below), we would have changed the baseline pump size from 37 hp to 15 hp and rerun. We would have also had to change the ex ante enduse load shape from “HVAC” to “Cooling” to better reflect the condenser water pump application.

Impact of TRACE3D version updates. A recurring evaluation issue for TRACE BEMs is the continuous and frequent updates of the software and the lack of backward compatibility. When an older model is rerun to validate the ex ante claimed savings, the ex ante claimed savings cannot be 100% validated because the models have to be updated to run in the latest version of TRACE3D. The older the original model, the more likely the results for a rerun with the latest TRACE 3D version will differ from the claimed savings. This project was run with v.4.01.97, and the reports are dated November 30, 2021. In this case, conversion to the latest version (v6.00.106) caused an error that prevented us from rerunning the model. Per a note from TRACE3D support: “*Typically, files older than three versions need to be migrated in steps.*” They offered to assist with this process; however, we did not pursue further because changes to the chiller efficiency were minor, the pump measure savings should be zeroed out anyway, and the file provided with the ex-ante project documentation should have been updated before posting since it was so old. For this site, we also found a floor area discrepancy: The application reports a total floor area of 80,800 square feet, while the model uses 74,223 square feet(92%). However, no ex post adjustments were made as that would have required additional and extensive investigation.

Key ex post evaluation parameters and changes are summarized in Table 31. As previously mentioned, we did not evaluate the Standard project that was also implemented at this facility, but for reference, the ex ante savings for that project was 58,032 kWh, about 15% of the savings for this Custom project.

Table 31. Site 2006 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	IECC 2015 Chiller Efficiency (Full Load)	5.7639 COP (0.61045 kW/ton)	0.610 kW/ton but used ex ante	IECC 2015 Path A min. efficiency for chiller type size
EEM-2	Baseline Condenser Water Pump Size	37 hp	15 hp	Inspection photos of new pumps
EEM-2	Condenser Water Pump Savings	70,392 kWh	0	New equipment is the baseline

RESULTS

Table 32 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 32. Site 2006 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Column		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 High-Efficiency Chillers	328,831	328,831	100%	299.46	299.46	100%
EEM-2 Reduced CW Pump Size	70,392	0	0%	31.25	0.00	0%
Total	**399,223**	**328,831**	**82%**	**330.71**	**299.46**	**91%**

Reasons for discrepancies

- For EEM-2: The ex ante savings incorrectly used a baseline condenser water pump much larger (37 hp) than the new pump (15 hp). Since this is not an early replacement scenario, the as-built 15 hp should have been used for both scenarios; therefore, the savings for this measure were zeroed out.

Other Findings and Recommendations

- The project documentation did not include a project narrative/overview clearly describing the measures and summarizing the key parameters and assumptions. Consequentially, the primary project information had to be pieced together from a review of the available project documentation. We recommend providing a clear and concise project narrative, similar to the information in the evaluation Site Report, with every Custom project.
- In addition to the project narrative, TRACE 3D-modeled projects should also include screen captures from the models that show how and where the key parameters were incorporated into the model. Both of these actions will greatly facilitate project review for implementation and evaluation.

SITE 2007 (CUSTOM HVAC)

This project involves the construction of a new visitor center for a public garden center. The one-story building has a gross area of approximately 90,985 square feet. It includes a gift shop, auditorium, conservatory, office areas, dining facilities, and event space. Custom HVAC measures include two 275-ton high-efficiency air-cooled chillers, two dedicated outdoor air systems (DOAS) with demand-controlled ventilation (DCV), and energy recovery wheels. DCV saves cooling and heating energy by reducing ventilation during periods of low occupancy. Energy recovery wheels capture sensible and latent energy from exhaust air streams and use it to pre-condition incoming outdoor air, reducing cooling and heating energy.

Table 33. Site 2007 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	End Use Description	Project Type
Entertainment/Recreation	90,985	IECC 2018	HVAC	New Construction/Major Renovation

Table 34. Site 2007 Ex Ante Savings Summary

Measure Name	Load Shape	Ex Ante Gross	
		kWh	kW
EEM-1 Efficient Chiller	Cooling	66,773	60.81
EEM-2 DOAS Units with DCV	HVAC	59,059	26.22
EEM-3 Energy Recovery	Cooling	26,420	24.06
	Total	**152,252**	**111.09**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The invoice confirms all HVAC equipment except the chillers. The chiller installation was confirmed by post-inspection photos and submittals.

ANALYSIS

The evaluation team was unable to trace ex ante savings to the energy model reports provided with project documentation.

The evaluation team verified the reasonableness of the ex ante savings using algorithms from the Ameren Missouri PY22 Technical Reference Manual (TRM) (EEM-1 and EEM-2) and Minnesota TRM V3.3 (EEM-3) with site-specific inputs from the project documentation. Results from this method suggest that the overall ex ante savings are reasonable. Therefore, the ex ante estimates are accepted.

Table 35. Site 2007 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1 Efficient Chiller	Baseline Chiller Efficiency (IPLV)	Unknown	14.00	IECC 2018 Path A Minimum Efficiency
EEM-1 Efficient Chiller	Efficient Chiller Efficiency (IPLV)	Unknown	21.41	Chiller submittal

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-2 DOAS Units with DCV	DCV Savings Factor (kWh Saved per 1000 Sq Ft of Conditioned Area)	Unknown	652	PY22 AMO TRM; average of office, restaurant, retail, and auditorium
EEM-3 Energy Recovery	DOAS-1 Energy Recovery Wheel Summer Effectiveness	Unknown	65%	DOAS submittal
EEM-3 Energy Recovery	DOAS-2 Energy Recovery Wheel Summer Effectiveness	Unknown	67%	DOAS submittal

RESULTS

Table 36 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 36. Site 2007 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Efficient Chiller	66,773	66,773	100%	60.81	60.81	100%
EEM-2 DOAS Units with DCV	59,059	59,059	100%	26.22	26.22	100%
EEM-3 Energy Recovery	26,420	26,420	100%	24.06	24.06	100%
Total	**152,252**	**152,252**	**100%**	**111.09**	**111.09**	**100%**

Reasons for discrepancies

- N/A

Other Findings and Recommendations

- The evaluation team was unable to trace the claimed savings to the energy model reports provided with the project documentation. We requested and received energy model files from the trade ally but could not run them cleanly. Therefore, we used TRM algorithms to validate the ex ante savings for each measure, with inputs drawn from the equipment submittals and mechanical drawings included in the project documentation. The total savings estimated with this method resulted in a realization rate of 162%, driven by the chiller measure, which had an individual realization rate of 248%. The higher chiller realization rate may be partly explained by the TRM algorithm, which does not account for the reduced cooling loads due to the DCV and energy recovery measures. The TRM estimates from these other measures aligned more closely with the ex ante values. The overall results of the TRM method verification suggest that the ex ante savings estimates are reasonable.
- The evaluation team assessed whether DCV and energy recovery were required by IECC 2018, which would have negated the claimed savings for these measures. We determined that because the DOAS units included energy recovery, DCV was not required for either unit. However, only DOAS-1 appeared to be exempt from the energy recovery requirement; energy recovery was required for DOAS-2 with a minimum effectiveness of 50%. The ex post energy recovery savings for DOAS-2 were calculated with a baseline minimum effectiveness of 50%.

SITE 2008 (CUSTOM HVAC)

This project involved installing a new digital control system in a 25-story office building with electric boilers and water-cooled chillers. Floors 2 through 4 were previously converted to a parking ramp and are unconditioned. Except for floors 2–4, each floor is served by a constant speed air-handling unit with hot and chilled water coils. A dedicated outdoor air unit (DOAU) delivers ventilation air to each AHU.

Before the project, each AHU was controlled manually by the building operator. Analysis of the meter data for the facility suggested that the ex ante assumption of the AHU fans running close to 8760 hours per year is valid. Additionally, the hot and chilled water pumps ran continuously at full speed 24/7 while the DOAU was turned on and off manually by the building operator. With the new digital controls, the AHUs, DOAU, and pumps run according to a pre-programmed schedule. VFDs were also installed on the pumps to enable their speed to modulate according to the heating or cooling load. Even with the new digital controls, significant parts of the old pneumatic controls remain in place, including the thermostats which are installed on each floor.

The project's custom measures include fan, pump, heating, and cooling energy savings associated with implementing automated scheduling. The variable speed pumping was not included in the ex ante modeling nor evaluated herein because the VFDs received prescriptive rebates.

Table 37. Site 2008 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Office	400,000	IECC 2018	HVAC	Equipment Replace/ Mod/Add/Remove

Table 38. Site 2008 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls	HVAC	2,209,814	981.12
	Total	**2,209,814**	**981.12**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for the estimated energy savings. An onsite review confirmed the installation of the controls package and verified the programmed AHU schedules.

ANALYSIS

The ex ante analysis was based on energy modeling using the Carrier Hourly Analysis Program (HAP). Since the project was signed off as completed in September 2023 and began in September 2022, the evaluation team selected 2022 as the baseline year for comparison. We compared the facility's monthly billed usage from January 2022 through December 2022, normalized to TMY3 weather conditions and excluding savings that occurred in September 2022 through December 2022, to the modeled usage. We determined that the ex ante assumption of the AHU fans running nearly 24/7 prior to the project was reasonable, based on the "baseload" consumption during the shoulder months, after factoring in estimated lighting and plug load usage. The ex post analysis recalibrated the total baseline to align with 2022 actuals after making the above adjustments.

Table 39. Site 2008 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	AHU Operation - Baseline	8760	8756	Validated from meter data
EEM-1	AHU Operation - Efficient	Scheduled - 4784 hours/year	Scheduled - 3302 hours/year	BAS, verified during site visit
EEM-1	Baseline Energy	7,537,104 kWh/year	6,434,527 kWh/year	Meter data, Jan-Dec 2022, normalized to TMY3, Sep-Dec savings removed

RESULTS

Table 40 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 40. Site 2008 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Controls	2,209,814	1,982,050	90%	981.12	880.00	90%
Total	**2,209,814**	**1,982,050**	**90%**	**981.12**	**880.00**	**90%**

Reasons for discrepancies

- The primary reason for the savings discrepancy is the baseline energy assumption. For the ex post analysis, the evaluation team calibrated the baseline energy to actual energy consumption in 2022, using a regression model to normalize to TMY3 weather conditions and remove savings that begin accruing in September 2022 when the controls upgrade was started, according to the contractor. The ex post baseline energy is approximately 85% of the ex ante baseline energy, which resulted in lower absolute savings. However, because the post-project occupied hours were verified to be lower than assumed in the ex ante models, the evaluation team increased the fan and pump energy savings to reflect less run time in the efficient condition.
- The final ex post savings are based on an average of two evaluation methods.
  - The first method applied energy savings percentages from the modeling results to the calibrated baseline energy, increasing the savings percentages for fan and pump savings as described above.
  - The second method used the regression model described above to compare actual energy use to the energy use as calculated from the baseline regression model. This method resulted in an average savings of 24% from October 2023 through April 2024; ex ante modeling results showed that total savings were 29% of baseline energy use. Although the actual energy use during this period does not fully include the night setback savings (according to the contractor, there was a functional issue that was not observed initially but was fixed in February 2024), it does reflect the VFD savings that are not part of the savings claim for Custom portion of this project; therefore, the evaluation team considered the post-project meter data reasonable for estimating expected savings. Averaging the results of the two methods together resulted in a realization rate of 90%.

Other Findings and Recommendations

- The incentive application mentions that a new electric boiler was installed. A submittal for the equipment was included in the documentation; however, the evaluation team learned that the new boiler had not yet been installed at the time of the site visit in February 2024. However, the proposed controls were confirmed to be installed, and we do not expect the energy use to change significantly with the new installation of the new boiler.

SITE 2009 (CUSTOM HVAC)

This project involved a major renovation of and additions to a public high school with approximately 2,300 students and 200 staff members. The high school formerly consisted of several individual buildings, but for security reasons, the school was rebuilt as a single structure oriented around a single front entrance. The new structure is mostly new construction, though some of the existing buildings were gut-renovated and integrated into the new structure.

This project included the renovations portion of the overall project; Site 2024 is the new construction portion. The custom HVAC measures herein include low minimum airflow compared to a baseline minimum of 0.4 CFM/ft2 per ASHRAE 90.1-2007 Appendix G.

The project was accepted into the Custom program in 2019 before Saint Louis County adopted IECC 2015, so the applicable baseline energy code is IECC 2009--the code in effect at the time. Construction was completed, and Custom incentives were awarded in 2023. The trade ally stated that ASHRAE 90.1-2007 was used for the baseline requirements, which aligns closely with IECC 2009.

Table 41. Site 2009 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Education	484,500	2009 IECC	HVAC	Equipment Replace/ Mod/Add/Remove

Table 42. Site 2009 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls	HVAC	1,025,445	455.28
	Total	**1,025,445**	**455.28**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for the estimated energy savings. An onsite review confirmed the installation of the air handlers as scheduled and fan speed controls.

ANALYSIS

The basis for the ex ante savings for EEM-1 is energy modeling results using IES software. However, the specific measures implemented were not clear from the project documentation. The incentive application states the following for the base equipment detail:

> “Less efficient fans with minimum turndown of 0.4 cfm / sf. Equipment at end of life”

For the new equipment detail, the application states:

> “Lower lower [sic] minimum flow allowed. Improved fan efficiency.”

In discussions with the engineering firm that performed the energy modeling for the application, the evaluation team learned that 0.4 cfm per square foot corresponds to a baseline model assumption from ASHRAE 90.1-2007 Appendix G. We believe this is a reference to G3.1.3.13, which specifies a minimum volume setpoint for VAV reheat boxes. We were unable to find any evidence of improved fan efficiency, however, from the project documentation. An engineer at the firm, who had not worked on this project (the person who did the modeling left the company soon after he was first contacted by the evaluation team), did not explicitly provide evidence of improved fan efficiency, though he referenced all fan motors being premium efficiency or electronically-commutated motors (ECMs). However, motor efficiency is different from fan efficiency, and premium efficiency has been the federal minimum standard for general-purpose alternating current induction motors since December 2010.[3]

The evaluation team used a bin analysis to estimate the savings achieved by the as-built minimum flow of 0.24 CFM/ft2 compared to the baseline assumption of 0.4 CFM/ft2. This resulted in only a 21% realization rate for this measure. The ex ante savings of 1,025,445 kWh seem too high for this measure: with the AHU fan parameters provided in the AHU schedule, even if all the fans run constantly at full speed, they would only consume approximately 786,400 kWh per year.

Table 43. Site 2009 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline Minimum Airflow for VAV Systems	0.4 cfm/ft2	0.4 cfm/ft2	ASHRAE 90.1-2007 Appendix G
EEM-1	As-Built Minimum Airflow for VAV Systems	Unknown	0.24 cfm/ft2	VAV Unit Schedule

RESULTS

Table 44 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 44. Site 2009 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Controls	1,025,445	214,940	21%	455.28	95.43	21%
Total	**1,025,445**	**214,940**	**21%**	**455.28**	**95.43**	**21%**

Reasons for discrepancies

- The basis for the ex ante savings claims was unclear from the project documentation. The evaluation team used a bin analysis to estimate the savings from the as-built minimum flow of 0.24 cfm/ft2 compared to a baseline assumption of 0.4 cfm/ft2. This resulted in a 21% realization rate for this measure. The project documentation did not include any evidence of improved fan efficiency or identify the basis of comparison. The ex ante savings seem excessively high because even if all fans in the AHU schedule ran at full speed for 8760 hours per year, they would consume less energy than the claimed savings.

Other Findings and Recommendations

- The project description in the incentive application appears to be an excerpt from another document and includes very little information that is relevant to the specific Custom measures in this project.

[3] https://appliance-standards.org/product/electric-motor, accessed February 23, 2024.

- The trade ally's calculations in Excel were partially locked, allowing the cell values and formulas to be viewed but preventing the use of formula tracing in Excel. This made it difficult to understand the calculations.
- At the implementation team's request, the evaluation team met with representatives of the trade ally and implementation team shortly before draft report submission to discuss this project. The trade ally indicated that they would provide additional information to support the ex ante savings claims. When the information is received, we will revisit the ex post savings for this project and share the resulting changes, if any, prior to finalizing the report.

SITE 2010 (CUSTOM HVAC)

This project involves Custom HVAC measures implemented as part of a pharmaceutical facility expansion: runaround heat recovery loops installed in lab HVAC units and implementation of a thermostat setback schedule in office space within the facility.

Water-cooled centrifugal chillers and gas boilers provide cooling and heating for the facility. The laboratory AHUs are 100% outside air systems with chilled water and hot water coils. The runaround loop fluid is a 40% propylene glycol/water mix pumped between two fluid-to-air heat exchangers, one at the exhaust air port and one at the outdoor air intake. The loop recovers sensible energy from the exhaust air and uses it to pre-condition the incoming outdoor air, saving cooling energy (electric) in the summer and heating energy (gas) in the winter.

The baseline condition for the office space was a constant 75°F setpoint in the summer, according to the facility's basis of design. As part of this project, new controls were added to enable a setback schedule to be implemented. Setback schedules reduce the cooling load or heating load during unoccupied hours, thereby reducing cooling or heating energy and fan energy. The office AHUs also contain chilled water and hot water coils.

Table 45. Site 2010 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Industrial	300,000	2015 IECC	Industrial	Equipment Replace/ Mod/Add/Remove

Table 46. Site 2010 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Lab HVAC Heat Recovery	HVAC	253,565	112.58
EEM-2 Office HVAC Scheduling	HVAC	560,466	248.84
	Total	**814,031**	**361.42**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for the estimated energy savings. The invoices and mechanical submittals provided evidence of the lab heat recovery unit installation.

The evaluation team attempted to verify the efficient thermostat settings for EEM-2, Office HVAC Scheduling, with customer facilities staff. However, they were unable to confirm the settings because the names in the models do not match the actual room names. They confirmed we had identified the correct AHUs serving the offices, however.

ANALYSIS

Energy modeling with TRACE 700 was the basis for the ex-ante savings for both measures. For EEM-1, the evaluation team assessed the reasonableness of the ex ante savings claim with a bin analysis. We calculated the summer sensible heat recovery effectiveness of the heat recovery loop from the design parameters given on the equipment submittals. The result of the bin analysis showed only a 21% kWh realization rate. In discussions with the implementation team, we learned that they had assumed the heat recovery units provide make-up air to eight lab AHUs with a combined airflow of

277,500 CFM. However, according to the submittals, the heat recovery airflow is only 47,000 CFM. The implementer agreed that the ex ante airflow was too high.

For EEM-2, Office HVAC Scheduling, the ex ante savings claim seems excessively high for a thermostat setback in 38,265 sq. ft. of office space. A "sanity check" calculation suggested that the ex ante savings claim of 560,466 kWh exceeds the baseline usage of the office HVAC system. In discussions with the implementer, he stated he was unable to find a reason for the unexpectedly high savings. The evaluation team used a simple eQUEST model to estimate the savings, incorporating AHU parameters from the mechanical schedule and using the same chiller efficiency and setback schedule. This resulted in a savings of 24,370 kWh, a realization rate of 4%.

Table 47. Site 2010 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Heat Recovery Effectiveness, Summer	Unknown	22%	Calculated from spec sheets; cooling energy recovered as a percentage of sensible cooling load
EEM-1	Lab HVAC Operating Hours Per Year	8760	8760	Email from Trade Ally
EEM-1	Supply And Exhaust Design Airflow	277,500 CFM	47,000 CFM	Submittals
EEM-2	Baseline Thermostat Setpoint	75°F	75°F	Basis of Design
EEM-2	Efficient Thermostat Setpoints	75°/ 85° F, occupied hours 6:00 a.m.–6:00 p.m., Monday–Friday	75°/ 85° F, occupied hours 6:00 a.m.–6:00 p.m., Monday–Friday	Ex ante energy modeling reports
EEM-2	Office Space Served By Affected Ahus	38,265 sq. ft.	38,265 sq. ft.	Energy modeling reports, floorplan
EEM-1, EEM-2	Chiller Efficiency	0.565 kW/ton	0.565 kW/ton	Ex ante energy modeling reports

RESULTS

Table 48 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 48. Site 2010 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Lab HVAC Heat Recovery	253,565	52,780	21%	112.58	48.07	43%
EEM-2 Office HVAC Scheduling	560,466	24,370	4%	248.84	10.82	4%
Total	**814,031**	**77,150**	**9%**	**361.42**	**58.89**	**16%**

Reasons for discrepancies

- The airflow assumptions are the primary driver for the heat recovery savings (EEM-1) discrepancy.
- The reason for the office scheduling savings (EEM-2) discrepancy is not clear from the modeling documentation.

Other Findings and Recommendations

- N/A

SITE 2011 (CUSTOM HVAC)

This project involved replacing water source heat pump units (WSHPs) that had reached the end of their useful life and upgrading the building automation system (BAS), which included scheduling the HVAC operation and adjusting setpoints. The installed WSHPs are more efficient than new standard efficiency WSHPs, resulting in energy savings. Upgrading the BAS enabled occupancy schedules for spaces serviced by the WSHPs and unoccupied space temperature setpoints. The setback scheduling saves energy by reducing the heating and cooling loads while the building is unoccupied.

Table 49. Site 2011 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Education	144,000	2015 IECC	HVAC	Equipment Replace/Mod/Add/Remove

Table 50. Site 2011 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls	HVAC	126,996	56.38
EEM-2 Efficient WSHPs	HVAC	93,866	41.67
	Total	**220,862**	**98.06**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The invoice, submittals, and BAS screenshots confirm that 48 WSHPs and HVAC controls were purchased and installed at the site location.

ANALYSIS

The ex ante savings are based on bin calculations in Excel and erroneously used IECC 2015 minimum efficiency requirements for water-to-water heat pumps for the baseline system. The correct equipment type is water-to-air heat pumps. The ex ante savings for HVAC controls were calculated with baseline equipment efficiency. The evaluation team applied minimum efficiency requirements for water-to-air heat pumps from IECC 2015 and adjusted for design conditions for the baseline system. The evaluation team verified new system efficiencies from the equipment submittals and baseline and new HVAC operating hours from the BAS Schedule provided by the Trade Ally. The evaluation team verified occupied and unoccupied heating and cooling temperature setpoints from the BAS screenshot. For HVAC control savings, the evaluation team applied new system efficiencies.

Table 51. Site 2011 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline Occupied Hours	8762	8760	BAS Schedule from Trade Ally
EEM-1	Proposed Occupied Hours	3123	4420	BAS Schedule from Trade Ally
EEM-1	Cooling Setpoints, Occupied/ Unoccupied	75 °F / 85 °F	73 °F / 75°F	BAS Screenshot
EEM-1	Heating Setpoints, Occupied/ Unoccupied	75°F / 65°F	69°F / 65°F	BAS Screenshot

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Cooling EER / Heating COP	10.6 / 3.70	11.56 / 4.71	New System Efficiencies at Design Conditions
EEM-2	Baseline Occupied Hours	3123	4420	BAS Schedule from Trade Ally
EEM-2	Proposed Occupied Hours	3123	4420	BAS Schedule from Trade Ally
EEM-2	Cooling Setpoints, Occupied /Unoccupied	75 °F / 85 °F	73 °F / 75°F	BAS Screenshot
EEM-2	Heating Setpoints, Occupied/ Unoccupied	75°F / 65°F	69°F / 65°F	BAS Screenshot
EEM-2	Baseline EER / Heating COP	10.6 / 3.70	10.8 / 4.39	IECC 2015, adjusted for Design Conditions
EEM-2	New EER / Heating COP	11.56 / 4.71	11.56 / 4.71	Submittals, at Design Conditions

RESULTS

Table 52 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 52. Site 2011 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Controls	126,996	32,970	26%	56.38	14.64	26%
EEM-2 Efficient WSHPs	93,866	40,503	43%	41.67	17.98	43%
Total	**220,862**	**73,473**	**33%**	**98.06**	**32.62**	**33%**

Reasons for discrepancies

- For EEM-1, the evaluation team updated HVAC control information based on actual building operation, including occupancy hours and occupied/unoccupied heating and cooling set points, resulting in lower savings. Additionally, because the post-project condition is the efficient equipment operating with the new setback schedule, the evaluation team changed the WSHP efficiency from the baseline efficiency to the new equipment efficiency, which further reduced savings.
- The ex ante calculations for EEM-2 applied the IECC 2015 minimum efficiency requirements for water-to-water heat pumps; however, the correct equipment category is water-to-air heat pumps. The evaluation team applied IECC 2015 minimum efficiency requirements for water-to-air heat pumps and adjusted the baseline efficiency based on design conditions.

Other Findings and Recommendations

- None

SITE 2012 (CUSTOM HVAC)

This project involved the replacement of a working 60-ton two-stage pool dehumidifier with a 35-ton three-stage unit. According to the trade ally, the old unit was replaced because it was oversized. Oversizing causes the compressors to frequently cycle on and off. When combined with constant fan operation, as is required for ventilation and dehumidification, frequent cycling leads to a reduction in the latent heat capacity of the evaporator, which can lead to problems controlling the humidity level in the space.

The pool dehumidifier unit is capable of providing cooling, dehumidification, or gas-fired heating and has a heat recovery feature, allowing it to serve as a heating source for the pool water. It operates continuously to ventilate the pool area and maintain temperature and humidity within acceptable ranges. The facility does not use a pool cover during unoccupied periods. The design conditions are water temperature at 86°F with the air temperature at 88°F and 60% relative humidity.

Table 53. Site 2012 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Fitness Center	37,800	2012 IECC	HVAC	Equipment Replace/ Mod/Add/Remove

Table 54. Site 2012 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Multi-Stage Pool Unit - Fan/Pump Savings	HVAC	114,024	50.62
EEM-2 Multi-Stage Pool Unit - Cooling Energy	Cooling	113,526	103.39
	Total	**227,550**	**154.01**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for the estimated energy savings. Although the specific equipment installed could not be verified from the invoice, post-inspection photos taken by the implementer confirmed the installation of the efficient equipment. The evaluation team obtained pre-inspection photos of the old equipment and its specifications from the trade ally.

ANALYSIS

The ex ante savings claims are based on energy modeling using the Carrier Hourly Analysis Program (HAP). The evaluation team used engineering calculations to verify the reasonableness of the savings claims. For EEM-2, we leveraged an indoor pool calculator from Washington State University[4] to calculate the dehumidification load due to evaporation.

Although several model reports were provided with the project documentation, some key parameters were not apparent, in particular the dehumidification efficiency of the existing and efficient equipment and the pool area. The evaluation team estimated the dehumidification coefficient of performance (COP_d) from the moisture removal capacity and electrical ratings for the units. Without considering oversizing, the existing equipment appeared to have a higher

[4] http://www.energyideas.org/documents/spreadsheets/IndoorPoolCalc.xls, accessed February 3, 2024.

COP_d than the efficient equipment (2.1 versus 1.5); however, the evaluation team estimated the existing COP_d would decrease to 0.7 as a result of loss of latent capacity due to oversizing, referencing a 2004 ASHRAE journal article[5]. Using these COP_d estimates and the estimated pool area, the ex post savings for EEM-2 were 23% higher than the ex ante estimate (i.e., a 123% realization rate).

For EEM-1, we gauged the reasonableness of the ex ante savings claim by estimating the fan energy savings using the rated horsepower of the supply and exhaust fans for each unit, assuming the fans run continuously at full speed with a load factor of 0.65. The ex post savings were only 39% of the ex ante savings (i.e., a 39% realization rate). The reasons for the discrepancy are not clear.

Table 55. Site 2012 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Supply and Exhaust Fan Horsepower: Existing/Efficient Equipment	Unknown	32.5 / 23	Product specifications
EEM-1	Fan Operation: Existing/Efficient Equipment	24/7 operation, constant speed	24/7 operation, constant speed	Modeling reports; product specifications
EEM-1	Fan motor load factor	N/A	0.65	PY2022 AMO TRM
EEM-2	Moisture removal capacity: Existing/Efficient Equipment	Unknown	296 / 217.5 lbs/hr	Product specifications
EEM-2	Dehumidification COP: Existing/Efficient Equipment	Unknown	0.7 / 1.5	Calculated from product specifications; for existing, 65% latent capacity degradation was estimated due to oversizing
EEM-2	Pool surface area	Unknown	3100 ft^2	Estimated from online photos[6]
EEM-2	Pool room design conditions	Water 86°F, Air 88°F 60% relative humidity	Water 86°F, Air 88°F 60% relative humidity	Modeling reports

RESULTS

Table 56 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 56. Site 2012 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Multi-Stage Pool Unit - Fan Savings	114,024	44,837	39%	50.62	19.91	39%
EEM-2 Multi-Stage Pool Unit - Cooling Energy	113,526	139,817	123%	103.39	127.33	123%
Total	**227,550**	**184,654**	**81%**	**154.01**	**147.24**	**96%**

[5] Shirey, D. and Henderson, H. *Dehumidification at Part-Load.* ASHRAE Journal, April 2004.

[6] Photos posted online show the pool has 5 lanes, and a standard lane width is 2.5 meters (8.2 feet). We estimated the pool has a typical length of 25 yards (75 feet), and there is a small entry and exit bump-out we estimate is 25 ft^2. Satellite photos on Google Earth show that these dimensions fit within the footprint of overall pool area.

Reasons for discrepancies

- The reasons for the discrepancies are not clear, as we cannot discern all modeling assumptions from the documentation provided. The ex ante fan energy savings (EEM-1) do not seem reasonable based on the fan motor sizes on the specification sheets: even if the motor load factor were increased to 1.0, the realization rate would only be 60%. Furthermore, there is no description of the supply fan modulating its speed in the new unit's sequence of operations.

Other Findings and Recommendations

- None

SITE 2013 (CUSTOM HVAC)

This project includes installation of demand control ventilation (DCV) controls on rooftop units (RTUs) in a newly constructed charter elementary school. The RTUs have DX cooling and serve fan terminal units with electric resistance heating. Per IECC 2018, the building is required to have demand control ventilation in rooms with an area over 500 square feet and have an occupancy greater than 25 people per 1,000 square feet. Savings are claimed for zones that do not meet these criteria. DCV allows the zone ventilation rates to be reduced during periods of low or no occupancy, resulting in reduced heating and cooling energy compared to a baseline of constant ventilation supply.

Table 57. Site 2013 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	End Use Description	Project Type
Education	61,284	2018 IECC	HVAC	New Construction/Major Renovation

Table 58. Site 2013 Ex Ante Savings Summary

Measure Name	Load Shape	Ex Ante Gross	
		kWh	kW
EEM-1 DCV	HVAC	73,687	32.72
	Total	73,687	32.72

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The evaluation team requested and received nameplate photos from the customer, which allowed the RTU parameters to be verified.

ANALYSIS

The ex ante savings are sourced from a third-party DCV model that assumes electric cooling and gas heating. The evaluation team did a reasonableness check using the TRM algorithm and found that the model savings are within 10% of the savings calculated with the TRM algorithm. The evaluation reviewed room area and occupancy information provided by the trade ally to verify which rooms were required to have DCV and thus were ineligible for claimed savings. In response to questions from the evaluation team to clarify whether the upper floors of the building were occupied, the trade ally provided an updated DCV model with updated area and occupancy inputs. The evaluation team reviewed the updated model and used it as the basis for the ex post savings.

Table 59. Site 2013 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1 DCV	Floor Area	61,284	63,292	Revised DCV calculations from trade ally
EEM-1 DCV	Design Occupancy	1,103	355	Revised DCV calculations from trade ally
EEM-1 DCV	Percent Area not required to have DCV	45.4%	45.2%	Room occupancy/size summary from trade ally with minor adjustments to which rooms were required to have DCV

RESULTS

Table 60 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 60. Site 2013 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 DCV	73,687	46,623	63%	32.72	20.70	63%
Total	**73,687**	**46,623**	**63%**	**32.72**	**20.70**	**63%**

Reasons for discrepancies

- The trade ally provided updated calculations, with revised occupancy and square footage estimates based on questions from the evaluation team.
- The ex ante savings are sourced from a third-party DCV model that assumes electric cooling and gas heating. Because the RTUs have electric resistance heating, the gas savings in therms were converted to kWh within the project application. However, this conversion did not account for the efficiency of the hypothetical gas heating system that produced the gas savings. The ex post calculation assumed heating efficiencies of 80% and 100% for the gas and electric heating systems, respectively.

Other Findings and Recommendations

- Ex ante calculations were sourced from a third-party DCV spreadsheet tool. The evaluation team did a reasonableness check using the TRM algorithm and found that the model savings are within 10% of the savings calculated with the TRM algorithm.

SITE 2014 (CUSTOM HVAC)

This project accompanied the installation of two RTUs at an office building. The RTUs are VAV systems with DX cooling and qualified for incentives under the Standard program. The RTUs serve terminal units with electric reheat. The savings evaluated herein were achieved through modifications to the building HVAC schedule, optimization of the economizer settings, and resetting of the discharge air temperature setpoint. The contractor also implemented standby mode for 20 HVAC zones to reduce airflow and relax temperature requirements when the spaces are vacant during occupied periods, but these savings are not captured within the ex ante or ex post calculations.

Table 61. Site 2014 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Office	33,183	2015 IECC	HVAC	Equipment Replace/Mod/Add/Remove

Table 62. Site 2014 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls / BAS	HVAC	210,294	93.37
	Total	**210,294**	**93.37**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for the estimated energy savings.

ANALYSIS

The ex ante savings are based on bin calculations in Excel. The evaluation team verified system efficiencies from the equipment submittals and new HVAC operating hours from the screenshots provided in the post inspection photos. The evaluation team requested but did not receive screenshots of the BAS graphical user interface from the customer.

Table 63. Site 2014 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline Occupied Schedule	24/7	24/7	Project narrative
EEM-1	Efficient Occupied Schedule	0500 - 2100 on weekdays, 0500 - 1600 Saturdays	0400 - 2000 on weekdays, 0400 - 1500 on Saturdays	Post-inspection, screenshot of system schedule
EEM-1	Baseline Economizer Switchover Temperature	55°F	55°F	Project narrative
EEM-1	Efficient Economizer Switchover Temperature	60°F	60°F	Project narrative
EEM-1	Baseline Discharge Air Temperature	No Reset	No Reset	Project narrative
EEM-1	Efficient Discharge Air Temperature	DAT Reset enabled	DAT Reset enabled	Post-inspection, screenshot of system schedule

RESULTS

Table 64 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 64. Site 2014 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Controls / BAS	210,294	214,301	102%	93.37	129.46	139%
Total	**210,294**	**214,301**	**102%**	**93.37**	**129.46**	**139%**

Reasons for discrepancies

- There was a minor discrepancy associated with the supply fan motor efficiency: 85% was used in the ex ante calculation but 93% is the correct value according to the spec sheets. Incorporating the latter value resulted in slightly higher savings.
- The ex post analysis also disaggregated cooling energy savings and fan energy savings for the purposes of calculating demand savings, multiplying the former by the BUS Cooling coincidence factor and the latter by the BUS HVAC coincidence factor. This increased the overall kW realization rate to 139%.

Other Findings and Recommendations

- The evaluation team attempted to contact the customer to verify key parameters but did not receive a response.
- The project included re-enabling room occupancy sensors to reduce HVAC energy consumption. These savings were not calculated or included in the application, and not enough information was provided to verify completion of this component of the project for the ex post calculations. For this reason, this measure was not included.
- The project model calculated gas reheat savings in Therms. The site actually uses electric reheat. To account for this difference, the reheat efficiency was set to 100% and the baseline and efficient Therm consumption was converted to kWh.

SITE 2015 (CUSTOM HVAC)

This project involved the construction of a new five-story multifamily building. Custom incentives were awarded for packaged terminal heat pumps (PTHPs) in lieu of split systems with electric heat, and PTHPs in lieu of rooftop units with electric heat. However, in reviewing the plans, the evaluation team learned that no PTHPs were installed in the project, and that the baseline systems were in fact installed. This was confirmed by onsite verification. The split systems are installed in individual apartment units, comprise the vast majority of the total heating and cooling capacity, and are SEER 13 minimum efficiency equipment with electric resistance heating. There are also two rooftop units with electric resistance heating that serve common areas.

Table 65. Site 2015 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Multifamily	242,000	2015 IECC	HVAC	New Construction/Major Renovation

Table 66. Site 2015 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 PTHP Replacing Split System with Electric Heat	HVAC	540,351	239.91
EEM-2 PTHP Replacing RTU with Electric Heat	HVAC	5,718	2.54
	Total	**546,069**	**242.45**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The construction plans show that no heat pumps were scheduled for the building with the exception of a single one-ton mini-split; instead, what are identified as the baseline systems for the PTHPs were installed. An onsite review confirmed these findings.

ANALYSIS

The ex ante savings are premised on the use of PTHPs for efficient heating and cooling. However, the construction plans and onsite review verified that with the exception of a single one-ton mini-split, no heat pumps were installed. Instead, the equipment identified as the baseline equipment was installed. Therefore, the verified savings are zero.

Table 67. Site 2015 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	As-Built Systems	PTHPs	Split Systems with Electric Heat	Construction plans, onsite verification
EEM-2	As-Built Systems	PTHPs	RTUs with Electric Heat	Construction plans, onsite verification

RESULTS

Table 68 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 68. Site 2015 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 PTHP Replacing Split System with Electric Heat	540,351	0	0%	239.91	0.00	0%
EEM-2 PTHP Replacing RTU with Electric Heat	5,718	0	0%	2.54	0.00	0%
Total	546,069	0	0%	242.45	0.00	0%

Reasons for discrepancies

- The evaluation team verified from the construction plans and an onsite visit that no heat pumps were installed. Instead, the equipment identified as the baseline equipment in the application, split systems with electric heat, and rooftop units with electric heat, was installed.

Other Findings and Recommendations

- This project received a post-inspection by the implementer, but Custom HVAC incentives were awarded nonetheless for equipment not actually installed. We recommend the implementer review its quality control procedures and inspector training in light of this finding.

SITE 2016 (CUSTOM HVAC)

This new construction project involved custom incentives for energy-efficient HVAC equipment in an independent living, assisted living, and memory care facility with dining, kitchen, activity, parking garage, and support spaces. The independent living facility is a 13-story tower, while the assisted living and memory care facilities are 3-story structures. The majority of equipment in terms of percentage of total cooling capacity is single-packaged vertical heat pumps serving most of the residences. Electric cooling/gas heating rooftop units serve the dining, kitchen, activity, support, and corridor areas. Additional activity, support, and corridor areas in the three-story structure are served by a variable refrigerant flow (VRF) system with heat recovery. A 25-ton dedicated outdoor air unit provides conditioned outside air.

No electric heating savings were claimed for this project. The ex ante savings were based on energy modeling of the proposed design and a baseline design comprised of packaged terminal air conditioning (PTAC) units, in alignment with the baseline system requirements in ASHRAE 90.1-2013 Appendix G, Performance Rating Method.

Table 69. Site 2016 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Healthcare	410,000	2015 IECC	HVAC	New Construction/Major Renovation

Table 70. Site 2016 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Equipment - Cooling Load Shape	Cooling	42,701	38.89
EEM-2 HVAC Equipment - HVAC Load Shape	HVAC	56,452	25.06
	Total	**99,153**	**63.95**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions and the basis for the estimated energy savings. The invoice and submittal confirm that new energy-efficient HVAC systems were purchased and installed at the site location. The onsite review also confirmed the installations.

ANALYSIS

The ex ante savings were developed using TRACE 700 energy modeling software. Although PTAC systems are an acceptable baseline system type for this facility under ASHRAE 90.1-2013 Appendix G, the modeling reports showed that nonstandard-sized PTAC units were modeled, which have a lower efficiency requirement than standard-sized units. Ex post savings were based on standard-sized PTAC units. The ex post calculations used the methodology described in ASHRAE 90.1-2013 Appendix G to estimate the cooling COP of the baseline and proposed equipment with fan energy removed “COPnf” in order to estimate the impact on cooling savings (EEM-1) from increasing the baseline efficiency. The cooling savings realization rate was then applied to EEM-2 to approximate the expected decrease in fan energy savings.

Table 71. Site 2016 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1, EEM-2	Baseline HVAC System	PTACs	PTACs	ASHRAE 90.1-2013 Appendix G
EEM-1, EEM-2	PTAC Type	Nonstandard Size	Standard Size	ASHRAE 90.1-2013, IECC 2015
EEM-1, EEM-2	PTAC Minimum Cooling Efficiency (EER)	10.9 - (0.213 * Cap/1000)	14.0 - (0.300 * Cap/1000)	ASHRAE 90.1-2013, IECC 2015

RESULTS

Table 72 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 72. Site 2016 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Equipment - Cooling Loadshape	42,701	32,958	77%	38.89	30.01	77%
EEM-2 HVAC Equipment - HVAC Loadshape	56,452	43,571	77%	25.06	19.34	77%
Total	**99,153**	**76,528**	**77%**	**63.95**	**49.36**	**77%**

Reasons for discrepancies

- The ex ante baseline energy usage was modeled assuming nonstandard-sized PTAC units, which have a lower efficiency requirement than standard-sized units according to IECC 2015 and ASHRAE 90.1-2013. For nonstandard units, the minimum EER is equal to EER = 10.9 - (0.213 * Cap/1000), where Cap is units of Btu/h; for units greater than 15,000 Btu/h; 15,000 Btu/h is to be used in the formula, which results in 7.7 EER. In contrast, for standard units, the minimum EER is equal to EER = 14.0 - (0.300 * Cap/1000); for units greater than 15,000 Btu/h, 9.5 EER is the minimum. Because this is a new construction project, the baseline model should have selected standard-sized units: both ASHRAE 90.1-2013 and IECC 2015 clearly describe nonstandard-sized PTAC units as applying to replacements only.

Other Findings and Recommendations

- The evaluation team conducted a site visit to verify the installed equipment. While some discrepancies were noted in the make and model number of the installed equipment compared to the mechanical schedules, there was no significant impact on savings.
- The current federal standards for PTAC minimum efficiency in 10 CFR 431.97 are equivalent to the IECC 2015 and ASHRAE 90.1-2013 requirements.

SITE 2017 (CUSTOM HVAC)

This project is the early replacement of an existing building automation system (BAS) that controls the air and water distribution system units served by a central chiller/boiler plant at a 217,488 square foot, two-story, grades 9–12 high school that operates year-round. The air distribution systems include air handling units (AHUs), energy recovery units (ERUs), and fan-coil units (FCUs). The water distribution system units are chilled water/hot water (CHW/HW) pumps. This project is one of three separate projects (two Custom and one Standard) implemented at this facility. It appears to be part of a major renovation of the facility's central plant because the Standard project is the installation of new, high-efficiency chillers. The primary source of energy savings is reducing the HVAC system operation from 7 days/week, 24 hours/day, 365 days/year (7/24/365) to a Monday through Friday schedule and operation that better reflects actual school hours. Project information is presented in Table 73, and energy efficiency measures and ex ante savings are summarized in Table 74.

Table 73. Site 2017 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Education	217,488	2015 IECC	HVAC & Cooling	Equipment Replace/Mod/Add/Remove

Table 74. Site 2017 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 EMS Fan/Pump Savings	HVAC	736,444	326.97
EEM-2 EMS Cooling Savings	Cooling	40,353	36.75
	Total	776,797	363.72

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the scope, including the baseline and proposed equipment and conditions, as well as the basis and approach used to estimate ex ante energy savings. Once learning about the other projects at this facility from this project's documentation, we also reviewed the other Custom project for this facility (Site 2018) since it was also sampled. We also reviewed the tracking data record for the Standard project implemented at this facility for high-efficiency chillers. The Standard project was not sampled; therefore, project documentation was not reviewed. However, the new chiller efficiency in the tracking data was 0.34 kW/ton. Eight Excel bin analysis calculation workbooks were provided but lacked a narrative articulating how they were used to develop the ex ante savings. The invoice that was provided did not detail any equipment and was only a lump-sum fee for services, but it did reference this facility's address. No building plans or schematics were provided for this project; however, another workbook contained screen captures from the building automation system (BAS) showing the AHU configuration. Partial trend data were presented on another tab of this workbook, but there was no explanation for how these data were used for the savings estimation. We also reached out to the customer to try to obtain additional information but never received a response.

ANALYSIS

A bin analysis approach was used to estimate the ex ante energy savings. Individual workbooks were used for eight unique air/water distribution system type equipment groups, including two energy recovery unit (ERU) groups, four air handling unit (AHU) groups, one fan coil unit (FCU) group, and one hot/chilled water pump (HWP) group. The equipment-level workbooks contain multiple calculation scenarios, including a baseline scenario with the HVAC system running

7/24/365, an EEM1 scenario with a reduced operation schedule that varies by unit type and area type served, and up to three additional scenarios such as HVAC unit cycling or temperature resets. While 7/24/365 operation (minus holidays) for a high school seems somewhat unusual, we learned from the school website that this is a year-round, multitrack high school, which was not explained in the workbook. Each scenario builds on the previous one, so the final equipment-level savings is the sum of savings from all scenarios versus the baseline. The pump analysis uses only a single efficiency scenario run that includes schedule changes (5:00 a.m. to 10:00 p.m.). The workbook also indicates that the pumps are used for chilled water and hot water. The BAS screen capture showed both heating and cooling coils in the AHU, so the ex ante "HVAC" enduse loadshape for peak demand is correct.

The 8760 section of the workbooks clearly delineates heating and cooling operation periods. However, BAS dashboard screenshots indicate separate heating and cooling coils in the AHUs, enabling heating and cooling to be provided simultaneously. The basic HVAC system type and the timing of seasonal switchover (if any) for heating/cooling are fundamental to the analysis but not described in the project documentation. Space heating is provided by gas boilers, as shown in a BAS screen capture of the system schematic. For all workbooks, the chiller efficiency is set to 0.35 kW/ton, which is slightly less efficient than the 0.34 kW/ton ex ante value for the Standard project.

Results from each equipment group-level bin analysis workbook were consolidated into a separate workbook to develop the ex ante savings. The aggregated savings results from the ex ante workbook are summarized in Table 75. Equipment group-level results were presented for three end uses: Cooling, Fans, and Pump. For the ex ante claim, the Fan and Pump savings were aggregated into the EEM-1 Fan/Pump savings claim, and EEM-2 represents the Cooling savings. The Cooling savings appear to have been reported separately using the Cooling loadshape instead of the HVAC loadshape, although Cooling savings are only 5% of the total project savings. The HVAC loadshape is appropriate for EEM-1 since the fans and pumps are also used for space heating. The Cooling enduse savings match the savings for EEM-1, and the combined HVAC enduse savings matches the EEM-2 ex ante savings.

Table 75. Site 2017 Summary of Ex Ante Savings by Equipment Groups from Bin Analysis

Equipment Group	Fan kWh Savings	Cooling kWh Savings	Pump kWh Savings	HVAC (Fan+Pump) kWh Savings	Percent of HVAC Savings
ERU-2, 4, 7	42,545	31	0	42,545	6%
ERU-12, 14, 15	33,379	0	0	33,379	5%
AHU 1-3, 7-9	247,489	10,226	0	247,489	34%
AHU-4, 10	79,858	3,048	0	79,858	11%
AHU-5	23,799	5,457	0	23,799	3%
AHU-6	9,908	3,007	0	9,908	1%
FCU's	292,434	18,584	0	292,434	40%
HWP 1 & 2	0	0	7,032	7,032	1%
Total	**729,412**	**40,353**	**7,032**	**736,444**	**100%**

While we found a few discrepancies in the calculations, the bin analysis workbooks were consistent with a general bin analysis calculation approach. The discrepancies we found—like the small difference in chiller efficiency noted previously and starting times that were one hour early versus the start hour (conditioning before occupation makes sense)—if corrected, would have resulted in insignificant changes to the ex ante savings, so savings was not changed.

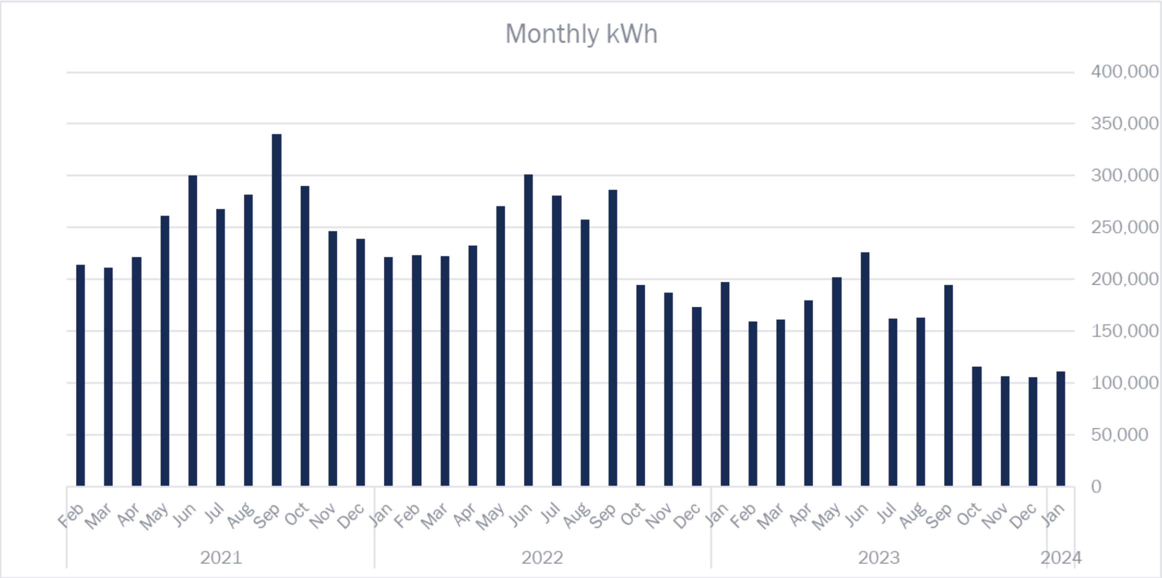
The assumption with the largest impact on energy savings is the baseline assumption of 7/24/365 operation (minus holidays), which makes some sense for this year-round high school. We examined the facility's consumption data to investigate the validity of this assumption and double-check the total savings estimate for all projects implemented at this facility. The savings for this project and the other two split-projects, and each project's relative percent contribution to total facility savings, are presented in Table 76. This project (Site 2017) accounts for the largest share (69%) of the total savings for the central plant replacement and renovation.

Table 76. Site 2017 Summary of All PY2023 Projects and Savings for This Facility

Site ID	Project Type	Measure Description	kWh Savings	Percent of Total Savings
2017	Custom	EMS Air/Water Distribution System	776,797	69.1%
2018	Custom	EMS Chiller Auxiliaries	272,140	24.2%
NA (not sampled)	Standard	High-Efficiency Chillers	75,757	6.7%
		Totals	**1,124,694**	**100%**

The facility's electricity use from February 2021 through January 2024 is shown in Figure 1. Although the project completion date was recorded as November 3, 2023, significant reductions in energy use at the end of 2023 compared to the previous two years indicate that some project elements may have been implemented earlier. In addition, annual energy use for 2021/2022 is very consistent across years, with an average 2,863,284 kWh. Ex ante savings are about 39% of the average baseline energy use, which is very high for an energy efficiency measure. However, comparing the 2023 annual energy consumption to the average 2022/2021 consumption yields a 31% difference, which is relatively close given the uncertainty of the bin analysis models. The full chiller plant project was not operational for all of 2023.

Figure 1. Site 2017 Monthly kWh Consumption Data (February 2021 – January 2024)



Based on our review, we did not make any changes to the ex ante savings, as reflected in Table 77. The estimated savings may be somewhat overstated based on the consumption data analysis, but significant reductions to energy use in 2023 are very apparent and likely, at least partially, if not wholly attributable to these measures and those from the other two split-projects implemented at this facility.

Table 77. Site 2017 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	System operating hours	7/24/365 to M–F, 5–16 (most typical)	N/A	Verified, no change
EEM-2	System operating hours	7/24/365 to M–F, 5–16 (most typical)	N/A	Verified, no change

RESULTS

Table 78 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 78. Site 2017 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 EMS Fan/Pump Savings	736,444	736,444	100%	326.97	326.97	100%
EEM-2 EMS Cooling Savings	40,353	40,353	100%	36.75	36.75	100%
Total	**776,797**	**776,797**	**100%**	**363.72**	**363.72**	**100%**

Reasons for discrepancies

- Minor discrepancies between bin analysis assumptions and actual hours of operation were assessed to have negligible impact on ex ante savings.

Other Findings and Recommendations

- Use a building energy modeling (BEM) tool instead of multiple bin analysis workbooks, and report results as a single Custom project for complex and comprehensive projects like this one. Also, the project documentation should include a project narrative that provides an overview of the HVAC system type, system elements and their operation, the general approach used for savings estimates, and a detailed explanation of each tab within the analysis workbook, including sources of primary data used for the calculations.

SITE 2018 (CUSTOM HVAC)

This project involved the early replacement of an existing building automation system (BAS) serving a 217,488-square-foot, two-story, grades 9–12 high school that operates year-round. The BAS controls the chilled water and condenser water loop systems of a central chiller/boiler plant. The chilled water loop equipment includes two sets of chilled water pumps (CWP), and the condenser water loop equipment includes condenser water pumps (CP) and cooling tower (CT) fans. This project was one of three separate split-projects (two Custom and one Standard) implemented at this facility and appeared to be part of a major renovation of the facility's central plant (the Standard project involved new, high-efficiency chillers). The primary source of energy savings was derived from reducing HVAC system operation from running 24/7/365 to a Monday through Friday schedule that better reflects school hours. The project also included variable frequency drives (VFDs) and free cooling. Project information is presented in Table 79 and energy efficiency measures and ex ante savings are summarized in Table 80.

Table 79. Site 2018 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Education	217,488	2015 IECC	Cooling	Equipment Replace/Mod/Add/Remove

Table 80. Site 2018 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Chiller Plant EMS/VFD	Cooling	272,140	247.8
	Total	272,140	247.83

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis and approach used to estimate ex ante energy savings. Once we learned about other projects at this facility from project documentation, we reviewed the other Custom project for this facility (Site 2017) since it was also sampled. We also reviewed the tracking data record for the Standard project implemented at this facility, which was for high-efficiency chillers. The Standard project was not sampled, so project documentation was not reviewed, but the new chiller efficiency shown in the tracking data were 0.34 kW/ton. Four bin analysis calculation Excel workbooks were provided but without a narrative for how they were used to develop the ex ante savings. However, the workbook file names lined up with the three equipment types (CWP, CP, CT) previously mentioned. Another workbook contained the aggregated results from the four equipment-level workbooks, some miscellaneous notes, screen captures of the CP/CT and CWP loops from a building automation system (BAS), and partial trend data. No narrative was provided to explain how this data was used for the ex ante savings estimation, but we were able to identify one table in the aggregated workbook with a total that matched the ex ante claimed savings for this project. A few pages from the full building plans were provided in the project documentation which included the Mechanical Schedule that identified all the equipment for this measure. The invoice that was provided did not detail any equipment and was only a lump-sum fee for services, but it did reference this facility's address. We also reached out to the customer to try to obtain additional information but never received a response.

ANALYSIS

The primary measure in the equipment-level workbooks was reducing a baseline 24/7/365 operation schedule to reflect actual school operating hours of Monday through Friday and occupied business hours. The primary schedule for both loops was 5 to 22 (10 pm), which, as expected, spans the hours of operation for the air distribution units served by this plant in the Site 2018 project.

We reviewed the aggregated results workbook and each of the four underlying equipment-level bin analysis workbooks. We located a table in the aggregated results workbook where the total savings matched the ex ante claimed savings. Key elements from the workbook table are summarized in Table 75. We also verified that the equipment-level savings values in this table matched the bin analysis workbooks, and they did with one exception: There was no workbook for the “CH-1 & 2” equipment group.

Table 81. Site 2018 Summary of Ex Ante Savings by Equipment Groups from Bin Analysis

Equipment Group	Equipment Type	Bin Analysis Workbook Filename	kWh Savings	Percent of Savings
CP-1 & 2	Condenser water pumps	CP-1 & 2 Pump Calc w-VFD v2	182,466	67%
CWP-1 & 2	Chilled water pumps	CWP-1 & 2 Pump Calc w-VFD v2	2,442	1%
CWP-3 & 4	Chilled water pumps	CWP-3 & 4 Pump Calc w-VFD v2	39,534	15%
CT-1 & 2	Cooling tower fans	CT-1 & 2 Fan Calc w-VFD v2	2,832	1%
CH-1 & 2	Efficient chillers	Missing/None	44,866	16%
		Ex Ante Total	272,140	100%
		Revised Total minus chiller	227,274	NA

We found a calculated savings value within the aggregated workbook that matched the CH savings value in Table 75. There was a short narrative and the calculation used chiller efficiencies of 0.77 kW/ton for the baseline and 0.338 kW/ton for the new chillers and assumed an equivalent full load hours (EFLH) value. The Standard efficiency split-project was also for higher-efficiency chillers, but the tracking data indicated 0.55 kW/ton for the baseline and 0.34 kW/ton for the new chillers. We concluded that the chiller savings were double-counted, and furthermore, the analysis from the aggregated workbook used a higher baseline efficiency than was used for the Standard project.

The only change made to ex ante savings was to subtract the savings for the high-efficiency chillers that were already claimed by the Standard project, as reflected in Table 82. The ex ante claim correctly applied the “Cooling” enduse.

Table 82. Site 2018 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	New High-Efficiency Chiller Savings	44,866 kWh	0 kWh	Review of multiple split-projects
EEM-1	System Operating Hours	7/24/365 to M-F 5-22 (typical)	NA	No change to ex ante

RESULTS

Table 83 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 83. Site 2018 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Chiller Plant EMS/VFD	272,140	227,274	84%	247.83	206.97	84%
Total	**272,140**	**227,274**	**84%**	**247.83**	**206.97**	**84%**

Reasons for discrepancies

- The ex ante analysis for this project included savings for new, high-efficiency chillers that are already covered by the Standard project for this facility. There are two Custom projects and one Standard project for this facility.

Other Findings and Recommendations

- Building energy modeling should be required for any project with significant savings and an HVAC system analysis as complex as this one. This project could perhaps have been claimed as a single project instead of three split-projects (two Custom and one Standard) and would be much simpler to create and review versus the three projects, twelve separate bin analysis workbooks, and two aggregate analysis workbooks that pulled the bin analysis results together for ex ante claims.
- All facilities with split-projects should be double-checked for double-counted savings. Furthermore, if one of them is a Custom project, then a summary table of the savings for all projects at the facility should be included as part of the project documentation for all projects.

SITE 2019 (CUSTOM HVAC)

This project involved installing a new building automation system (BAS) and implementing energy-saving HVAC control measures in an elementary school. Variable frequency drives (VFDs) were installed on two air-handling unit (AHU) supply fans, allowing the AHUs to be converted from constant air volume (CAV) to variable air volume (VAV) operation. Additional control measures included reducing occupied hours, lowering minimum supply fan speed, increasing economizer switchover temperatures, implementing static pressure reset, and enabling an energy recovery wheel. The boiler hot water pumps were also included in the project, with the implementation of occupied schedules and conversion of the primary hot water pumps to variable speed operation.

Based on the implementer's calculations, none of the air-handlers or rooftop units include electric heating; all electric savings are from cooling, fan, or pump energy.

Table 84. Site 2019 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Education	76,760	2015 IECC	HVAC	Equipment Replace/ Mod/Add/Remove

Table 85. Site 2019 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls - HVAC Loadshape	HVAC	147,291	65.39
EEM-2 HVAC Controls - Cooling Loadshape	Cooling	94,301	85.88
	Total	**241,592**	**151.27**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for the estimated energy savings. The invoice, trend data, and BAS screenshots provided evidence that the measures were installed. Submittals for the VFDs provided further evidence of the CAV to VAV conversion.

ANALYSIS

The evaluation team carefully reviewed the provided trend data and BAS screenshots to verify the installation of the control measure. We identified several discrepancies between the modeled input parameters and the actual input parameters, which are listed in Table 86. We reviewed the trade ally's calculation models, which are spreadsheet-based bin analyses, and found them generally reasonable. Where we found discrepancies with input parameters, we recalculated the savings with the corrected inputs using the Trade Ally's calculator.

Table 86. Site 2019 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1, EEM-2	AHU-1, AHU-2 Existing / Efficient Operation	CAV / VAV	CAV / VAV	Ex ante calculations and trend data, VFD submittals
EEM-1	Primary hot water pumps Existing / Efficient Operation	24/7 constant speed / Scheduled variable speed	24/7 constant speed / Scheduled variable speed	Ex ante calculations and trend data
EEM-1, EEM-2	AHU and Rooftop Unit Existing Occupied Hours	3:00 a.m.–9:00 p.m. Sun–Sat or 24/7	Varies	Ex ante calculations and trend data
EEM-1, EEM-2	Zone Temperature Occupied / Unoccupied Temperature, Existing	75°F / 85°F	75°F / 85°F	Ex ante calculations
EEM-1, EEM-2	Zone Temperature Occupied / Unoccupied Temperature, Efficient	75°F / 85°F	75°F / 85°F or 70°F / 80°F	Ex ante calculations and BAS screenshots
EEM-2	Economizer switchover temperature, Existing / Efficient	55°F / 65°F	Varies / 65°F	Ex ante calculations and BAS screenshots
EEM-1	Minimum VFD Speed, Existing	Varies, 50%–93%	Varies, 50%–93%	Ex ante calculations and BAS screenshots
EEM-1	Minimum VFD Speed, Efficient	50%	Varies, 30% or 50%	Ex ante calculations and trend data
EEM-1	Static pressure reset, Existing / Efficient	None / Installed on some systems	None / Installed on some systems	Ex ante calculations and trend data
EEM-2	Energy recovery wheel, Existing	None	Already installed on RTU-6, 7, 8	BAS screenshots
EEM-2	Energy recovery wheel, Efficient	Installed on RTU-5	Installed on RTU-5	BAS screenshots

RESULTS

Table 87 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 87. Site 2019 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Controls - HVAC Loadshape	147,291	147,291	100%	65.39	65.39	100%
EEM-2 HVAC Controls - Cooling Loadshape	94,301	79,293	84%	85.88	72.21	84%
Total	**241,592**	**226,584**	**94%**	**151.27**	**137.61**	**91%**

Reasons for discrepancies

- The largest driver of the discrepancy in Cooling savings pertains to energy recovery wheels (ERW) for RTU-6, 7, and 8: we removed the savings for ERW from these units because the BAS screenshots provided by the Trade Ally indicate that these units already had wheels installed. ERW savings were accepted for RTU-5 because the BAS screenshot for the pre-condition showed that the ERW was not installed.

- We identified several other discrepancies in pre- and post-control conditions from the BAS screenshots or trend data provided by the Trade Ally and are factored in the ex post savings; however, these discrepancies were less impactful than the ERW discrepancies.

Other Findings and Recommendations

- We reran the Trade Ally's calculation workbooks with modified inputs where the BAS screenshots and trend data indicated the ex ante inputs were erroneous. This resulted in realization rates of 106% for the HVAC loadshape and 84% for the cooling loadshape. However, because not all inputs were verifiable, and no mechanical schedules or inspection photos were provided to allow verification of fan and pump parameters, we reduced the HVAC loadshape realization rate to 100%.

SITE 2020 (CUSTOM HVAC)

This project involved the replacement of two working 400-ton air-cooled chillers with more efficient chillers with 100% water-side economizers. The two chillers plus a third 400-ton existing chiller serve three data centers totaling 15,000 square feet. The data centers are primarily used for testing and integration of IT equipment, so the cooling load varies throughout the year. The customer estimated that the average cooling load is 800 tons, such that two chillers are normally operating. The old chillers were replaced because they were not able to operate at cold ambient temperatures without supplemental heat. Currently, all three chillers--the two new chillers, plus one existing chiller--are cycled weekly in a regular rotation to reduce wear and tear and operated in lead-lag fashion.

Table 88. Site 2020 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
IT/Data Center	15,000	2015 IECC	Process	Equipment Replace/Mod/Add/Remove

Table 89. Site 2020 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Efficient Chillers with Water-side Economizer	HVAC	1,214,400	539.1730
	Total	**1,214,400**	**539.1730**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for the estimated energy savings. The invoice confirms that efficient chillers were purchased and installed at the site location. Onsite review also confirmed the installation.

ANALYSIS

The ex ante savings were derived through a bin analysis and assumed the existing chiller is for backup and not normally used. However, the evaluation team learned during the site visit that all three chillers are in a regular cycling rotation. This results in the two new chillers being used together only one-third of the time; over the other two-thirds of the year, only one of the new chillers is running as the lead unit with the existing chiller as the lag unit. The evaluation created a new bin analysis reflecting this staging scheme; the baseline scenario differs from the proposed only in that the old chillers are substituted for the new chillers. Equipment submittals were referenced for the old and new chiller efficiencies.

Table 90. Site 2020 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline Chiller Efficiency (FLV/IPLV) @ AHRI conditions	Not specified / 16.10 EER	11.20 / 15.90 EER	Submittal
EEM-1	Efficient Chiller Efficiency (FLV/IPLV) @ AHRI conditions	9.08 / 18.32 EER	9.08 / 18.32 EER	Submittal
EEM-1	Efficient Chiller Water-Side Economizer Switchover Temperature	40°F	40°F	Verified with customer

RESULTS

Table 91 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 91. Site 2020 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Efficient Chiller with Water-side Economizer	1,214,400	844,347	70%	539.17	374.88	70%
Total	**1,214,400**	**844,347**	**70%**	**539.17**	**374.88**	**70%**

Reasons for discrepancies

- The ex ante calculations did not include the existing chiller, which is expected to run two-thirds of the time over the course of a year based on the cycling rotation.
- The ex ante calculations did not account for the energy consumed by the water-side economizer when operating. The ex-post calculations used the parameters from the new chiller cut sheets to derive this load, which reduced the savings.
- The ex ante calculations also assumed a 32-ton HVAC cooling load; however, the evaluation team learned during the site visit that the chillers only serve the data center; other equipment serves the office and other ancillary space at the facility.
- The ex ante calculations used the integrated part load value (IPLV) efficiency for the baseline and efficient chillers, which is significantly higher than the full-load value (FLV) efficiency. However, with an average load of close to 800 tons, two chillers would be running at full load; therefore, FLV is a better predictor of average operating efficiency. The ex post calculations, therefore, used the FLV efficiencies. This resulted in negative savings over ambient temperatures when the WSE was not running because the new chiller FLV is lower than the baseline chiller FLV; however, savings were increased at cold temperatures when the WSE was running. The overall positive ex post savings for this project were driven by the water-side economizer.

Other Findings and Recommendations

- The ex ante and ex post savings are premised on the customer's assertion that the average data center load is 800 tons. The customer may assume that it is 800 tons because two chillers are normally running but the actual load could be between 400 and 800 tons. The evaluation team requested trend data to verify the average load, but the BAS was not set up to save trends. For a project of this magnitude, the implementation team should arrange to install metering devices and measure loading over a period of time sufficient to capture normal operating conditions in order to better estimate the average load.

SITE 2021 (CUSTOM HVAC)

This facility is a multi-building medical complex comprised of almost one million square feet and served by a central plant. The project involved implementing a vendor's proprietary chilled water plant control system and additional equipment and instrumentation at the central chiller plant and outlying buildings. The efficiency measures include installing variable frequency drives (VFDs), eliminating chilled water (CHW) bypass on air handling units (AHUs), maximizing free cooling in the shoulder season, and installing differential pressure (DP) sensors across the CHW supply/return.

Table 92. Site 2021 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Healthcare	999,230	2015 IECC	Cooling	New Construction/Major Renovation

Table 93. Site 2021 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Chiller Plant Optimization	Cooling	1,201,882	1094.53
	Total	**1,201,882**	**1094.53**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The invoice confirms that a VFD and controls package was purchased and installed at the site location. Onsite verification review also confirmed the installation.

ANALYSIS

A project summary narrative was not provided in the limited project documentation, but we were able to piece together a project overview from the available documents, information collected by our onsite verification, and a review of the annual consumption data. The original estimate of project savings was provided by the chiller system optimization services vendor using their proprietary engineering estimation tool, which leveraged existing trend data (temperatures, flows, power, etc.) and facility consumption data. However, due to the poor quality of the trend data from the pre-existing building automation system (BAS) system, the vendor's project narrative described many issues with the trend data and resulting approximations and adjustments needed for the engineering estimate of annual energy use and measure savings. In recognition of the significant uncertainty in the estimated savings, the vendor applied a final savings derating of 15%. However, the ex ante savings claim changed this value to 5% as noted on the project application: "*Derate savings by 5% not the 15% described.*" The basis for this revised adjustment of the vendor's estimate was not provided anywhere in the project documentation.

Due to the uncertainty of the project details and savings, we performed an onsite verification to gather additional details about the implementation elements. The onsite verification confirmed the installation of the new BAS system and devices, obtained an overview and detailed description of the central plant, the facility, and its operation, and also provided extensive photos. We were also able to obtain a copy of the vendor's Statement of Work (SOW) which provided essential details of the equipment and building-specific improvements. The onsite verification confirmed the reported upgrades.

Given the uncertainty of the ex ante savings estimate, we also comapred the savings against the facility's total consumption data available from the implementer's project tracking system. Based on average annual energy use for four years (2020 through 2023), the ex ante project savings was about 7%, which would be difficult to validate without a more formal, advanced consumption data analysis. We did note, however, that annual energy use was extremely consistent across all four years with a very high baseload, although some elements of this project appear to have been implemented early to mid-2022. A high 7/24/365 base cooling load might also minimize the effectiveness and use of some of the controls, even if the trend measurement devices were deficient.

To ensure we had all the facilities' consumption data, we also compared the site-specific electricity energy use intensity (EUI=Annual kWh/Total floor area) to the 2018 Commercial Buildings Energy Consumption Survey (CBECS) data for this building type: The facility EUI average was 17.8 kWh/sq ft versus 17.4 kWh/sq ft for CBECS (national average for Health Care/Outpatient). We also performed a high-level check of expected chiller optimization savings via an internet search. Two general references suggested that: (1) chiller optimization can save 20% of chiller energy use, and (2) cooling is typically 15-25% for large buildings. Using 25% due to the high base load observed in the consumption data, applying these percentages to the average annual facility energy produced a savings estimate that was 20% higher than the ex ante claimed value. However, the only point this illustrates is that there is a large amount of uncertainty in performance.

Based on our analysis and the observations from the onsite verification, the vendor's savings estimates seemed reasonable, and their assumptions are documented. As a result of the lack of explanation for changing the vendor's reduction of their engineering estimate from 15% to 5% (which increased the ex ante claimed savings), and to provide direct traceability to the vendor's original savings estimate, we restored the 15% adjustment.

Table 94. Site 2021 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Vendor's engineering estimate of savings	5% reduction	15% reduction	Restored vendor original estimate

RESULTS

Table 95 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 95. Site 2021 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Chiller Plant Optimization	1,201,882	1,075,368	89%	1,094.53	979.32	89%
Total	**1,201,882**	**1,075,368**	**89%**	**1,094.53**	**979.32**	**89%**

Reasons for discrepancies

- The BAS vendor reduced their engineering estimate of project savings from 15% to 5% for the ex ante claim, as noted on the application. However, the basis for this revision was not provided nor available in the project documentation. The vendor made this adjustment because there was significant uncertainty in the savings due to issues with the trend data from the existing BAS system, which was likely the reason for replacing that system. Relying on the vendor's experience with their optimization approach and savings estimation tool, including their own derating of the savings based on independent checks for reasonableness of the savings and for direct traceability to the original calculations, the original 15% reduction was restored, and used for ex post savings.

Other Findings and Recommendations

- Energy savings calculations should be transparent and reviewable rather than in a proprietary tool. This ensures the inputs and calculations can be independently reviewed and vetted. A comparison to four years of billing data (2020-2023) showed the project energy savings were only about 6-7% of total energy use, which is reasonable. Electricity use energy intensity (kWh/sq ft) for the facility was consistent with CBECS EUI for this building type (about 17.4 versus 17.8 for this facility), which indicates we have consumption data for the entire facility. Consumption data also showed impressively consistent annual energy use across all years and a significant baseload (roughly 85%), as might be expected for a chiller plant and medical facility this large. There is little indication of energy reduction in the 2023 consumption data (some phases of this project appear to have been implemented mid-year or earlier), but it may be too soon to observe any change.

SITE 2022 (CUSTOM HVAC)

This project consists of constructing a new public high school totaling over 210,000 square feet. Over 75 staff members serve a student population of approximately 680 in grades 9–12. Heating and cooling are primarily provided by hydronic systems, including gas boilers and water-cooled centrifugal chillers, with some limited air-cooled direct expansion (DX) air-conditioners. The custom HVAC measures include high-efficiency chillers and low minimum fan speed compared to ASHRAE 90.1-2013 minimum requirements. Energy modeling was used as the basis of the savings claims, with all systems modeled as air-cooled DX equipment with hydronic heating in the baseline model. The Trade Ally stated that ASHRAE 90.1-2013 was used for the baseline requirements, which aligns closely with IECC 2015, the energy code adopted by the local jurisdiction.

Table 96. Site 2022 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Education	210,466	2015 IECC	HVAC	New Construction/Major Renovation

Table 97. Site 2022 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Design: Cooling Enduse	Cooling	1,669,940	1520.79
EEM-2 HVAC Design: HVAC Enduse	HVAC	442,447	196.44
	Total	**2,112,387**	**1717.23**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for the estimated energy savings. We also conducted an onsite review, which verified the as-built equipment and controls.

ANALYSIS

Energy modeling using TRACE® 3D Plus (TRACE) was the basis for the ex ante savings claims. The evaluation team viewed the baseline and proposed energy models in TRACE and observed that all baseline HVAC systems were air-cooled DX with hydronic heating. In addition, there were only seven systems in the baseline model, compared to 20 in the proposed model. The proposed model aligned with the as-built design of hydronic heating and cooling systems with a water-cooled centrifugal chiller plant.

Air-cooled DX equipment is much less efficient than water-cooled chillers. The evaluation team contacted the engineering firm that did the modeling and asked if they had any documentation demonstrating that an all-DX design was considered as an alternate option. Their response was, “[DX units] are the required baseline for the size and type of unit per ASHRAE 90.1-2013.” This statement is incorrect: in general, 90.1 does not prescribe the type of equipment that should be assumed for baseline modeling, except under Chapter 11: Energy Cost Budget Method and Normative

Appendix G: Performance Rating Method, and both sections point to VAV with reheat and chilled water as the predominant baseline system for this building, which is the type scheduled and installed.[7]

Because there is no evidence that an all-DX design was considered for this facility, and in accordance with general modeling principles as well as the energy modeling-related sections in 90.1-2013, the evaluation team concluded that the appropriate baseline systems for EEM-1 are an ASHRAE 90.1-2013 Path A minimum efficiency water-cooled centrifugal chiller serving core areas of the building and air-cooled DX equipment in non-core areas of the building. The trade ally produced a new baseline energy model with these changes. The evaluation team reran the models to produce the ex post savings.

Table 98. Site 2022 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline Cooling System Type: Core Spaces	Air-Cooled DX	Water-Cooled Centrifugal Chiller	ASHRAE 90.1-2013 G3.1.1
EEM-1	Proposed HVAC System Type: Core Spaces	Water-cooled centrifugal with VFD	Water-cooled centrifugal with VFD	Mechanical plans
EEM-1	Baseline HVAC System Type: Non-Core Spaces (gym, auditorium, etc.)	Air-Cooled DX	Air-Cooled DX	ASHRAE 90.1-2013 G3.1.1
EEM-1	Proposed HVAC System Type: Non-Core Spaces (gym, auditorium, etc.)	Water-cooled centrifugal with VFD	Water-cooled centrifugal with VFD	Mechanical plans
EEM-1	Baseline chiller model	N/A	90.1-2013 water-cooled centrifugal Path A	ASHRAE 90.1-2013 G3.1.3.7
EEM-1	Proposed chiller model	Water-cooled centrifugal with VFD	Water-cooled centrifugal with VFD	Mechanical plans
EEM-2	Baseline Chilled Water Loop Configuration	N/A	Primary-Secondary	ASHRAE 90.1-2013 G3.1.3.10
EEM-2	Proposed Chilled Water Loop Configuration	Primary-Variable	Primary-Variable	Mechanical plans

RESULTS

Table 99 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 99. Site 2022 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Design: Cooling End Use	1,669,940	1,227,419	74%	1,520.79	1,117.79	74%
EEM-2 HVAC Design: HVAC End Use	442,447	648,949	147%	196.44	288.12	147%

[7] According to ASHRAE 90.1-2013 Figure 11.5.2 and Table 11.5.2-1, water-cooled sources with fossil fuel heating in non-residential single zone and all other systems are to use System 7 or System 2 for the "Budget" (baseline) system, both of which have chilled water cooling. According to Table G3.1.1-3 and G3.1.1-4, nonresidential buildings greater than 150,000 square feet in climate zone 4 are to use System 7 for the baseline, which is VAV with reheat with chilled water cooling.

Total	2,112,387	1,876,368	89%	1,717.23	1,405.91	82%

Reasons for discrepancies

- For the Cooling end use savings, the primary discrepancy is the baseline model assumed all systems are System 3 - Packaged/Single Zone AC (PSZ-AC) equipment, which is constant volume DX cooling equipment with gas heating. This system type has much lower cooling efficiency than the as-built variable air volume equipment which is served by a water-cooled chiller. Per ASHRAE 90.1-2013 G3.1.1, the baseline system type for this building is System 7 - VAV with reheat, which is variable air volume equipment with chilled water coils. Therefore, the baseline system type was changed to System 7 for the core areas of the building. However, System 3 was retained for the non-core areas of the building such as the gymnasium and auditorium, which appear to qualify for Exception 2 under G3.1.1, having schedules that "differ significantly from the rest of the buildling".
- The discrepancy in the HVAC end use savings is primarily driven by the change from all DX-cooling to majority hydronic-cooling in the ex post baseline model. Consistent with ASHRAE 90.1-2013 G3.1.3.10, the ex post baseline chilled water system was modeled as a primary-secondary system, with constant speed primary pumps and variable speed secondary pumps. The proposed chilled water system is a primary-variable system which eliminates the secondary pumps and has variable speed primary pumps, resulting in significant pump energy savings. The increase in pump energy savings offset the reduction in fan energy savings resulting from conversion of some systems in the baseline model from constant volume to variable volume.

Other Findings and Recommendations

- The issue of establishing baseline assumptions for Custom new construction projects warrants stakeholder discussions so that consistent baseline assumptions are applied going forward. Broadly speaking, newly constructed buildings can achieve compliance with either IECC or ASHRAE 90.1 under a prescriptive-based approach or a performance-based approach. The latter involves the use of energy modeling to compare the energy use of the as-designed building to a hypothetical baseline design. The specific compliance pathway taken by this project's building is unknown. The trade ally referred to the use of baseline assumptions from ASHRAE 90.1 Appendix G, which is intended for use in rating the energy efficiency of building designs rather than determining performance-based compliance. The evaluation team accepted the use of Appendix G for this project in the absence of specific rules on baseline model assumptions for new construction projects but recommends future discussions to clarify the appropriate use of prescriptive and performance-based approaches in IECC and ASHRAE 90.1.

SITE 2023 (CUSTOM HVAC)

This project involved retrofitting HVAC controls and related equipment to control supply and exhaust airflow to various lab rooms in a biotech facility. The project scope included new supply and exhaust flow control boxes and the conversion of fume hoods from constant volume to variable volume. The lab rooms are served by four air handlers supplying 100% outside air with chilled and hot water coils. Variable frequency drives (VFDs) modulate the speed of the fans. Three 500-ton water-cooled centrifugal chillers provide chilled water to the facility.

The savings measures for this project, phase one of a multiphase project, encompass adding an occupied schedule and reducing the air changes per hour from the existing average of 39.9 ACH to 6.0 ACH in occupied mode and 4.0 ACH in unoccupied mode. Reducing the airflow reduces the volume of outside air that must be cooled to the discharge air temperature setpoint to maintain space conditions and is achieved by reducing the fan speed, which reduces fan energy.

The facility was designed as a constant volume laboratory design, with switches to allow operators to reduce to half-flow. However, the vendor stated that based on discussions with occupants and the vendor's observations, the switches were not being used.

Table 100. Site 2023 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Industrial	200,000	2018 IECC	HVAC	Equipment Replace/ Mod/Add/Remove

Table 101. Site 2023 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Lab HVAC Controls - Cooling Loadshape	Cooling	262,378	238.94
EEM-2 Lab HVAC Controls - HVAC Loadshape	HVAC	135,631	60.22
	Total	**398,009**	**299.16**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, to understand the project scope and the basis for estimated energy savings. The invoice, scope of work document, and BAS screenshots provide evidence that the proposed control equipment and control settings were installed. The evaluation team confirmed that the air-handling units serving the affected lab equipment have variable frequency drives (VFDs) and that the post-project occupied hours are 40 hours per week.

We also requested trend data to verify the pre- and post-airflows. The vendor explained that trend data were not saved before the project but that they would be able to provide post-project trend data. However, the vendor was unable to provide the trend data by our deadline because a problem was discovered with the exhaust dampers, requiring repairs and rebalancing. Ultimately, we accepted the airflow assumptions based on preponderance of evidence.

ANALYSIS

The ex ante savings calculations were presented as a bin analysis; however, not all input assumptions and formulas were visible. The evaluation team recreated the bin analysis and confirmed the ex ante savings; however, we found and corrected a discrepancy in the chiller plant efficiency: the ex ante calculations assumed 1.000 kW/ton, but according to an analysis by the vendor, it is 0.826 kW/ton. This change resulted in a 91% realization rate for the Cooling enduse.

For the HVAC enduse, which is associated with fan energy savings, the evaluation team used engineering calculations to evaluate the ex ante savings claim. We calibrated the supply fan load factor so that the calculated baseline energy equaled the ex ante value with the fan horsepowers listed on the mechanical schedule. For the energy-efficient scenario, the evaluation team determined the reduced flow fractions during occupied and unoccupied hours and calculated the fan power using standard part-load curves for VAV systems. This resulted in a 114% realization rate for the HVAC enduse. The reasons for the discrepancy are unclear because the ex ante fan savings are hard-coded values.

Table 102. Site 2023 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Chiller plant efficiency	1.000 kW/ton	0.826 kW/ton	Project vendor; figure used for discontinued project at same facility
EEM-1, EEM-2	Existing / Efficient Occupied Schedule	168 / 40 hours/week	168 / 40 hours/week	Ex ante calculations, verified with vendor
EEM-1, EEM-2	Existing / Efficient Air Changes per Hour (ACH), Occupied Hours	39.9 / 6.0	39.9 / 6.0	Ex ante calculations
EEM-1, EEM-2	Existing / Efficient Air Changes per Hour (ACH), Unoccupied Hours	39.9 / 4.0	39.9 / 4.0	Ex ante calculations

RESULTS

Table 103 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 103. Site 2023 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Lab HVAC Controls - Cooling Loadshape	262,378	238,123	91%	238.94	216.85	91%
EEM-2 Lab HVAC Controls - HVAC Loadshape	135,631	154,138	114%	60.22	68.43	114%
Total	**398,009**	**392,261**	**99%**	**299.16**	**285.29**	**95%**

Reasons for discrepancies

- The ex ante calculations assumed a chiller plant efficiency of 1.0 kW/ton. According to the mechanical schedules for the existing lab equipment list, the full load chiller efficiency is 0.664 kW/ton. The ex post analysis used an estimated chiller plant efficiency of 0.826 kW/ton, a figure used by the project vendor for a discontinued project at the same facility. The evaluation team estimated a chiller plant efficiency of 0.805 kW/ton, determined from adding the chiller demand plus pumps and cooling towers, which suggests that 0.826 kW/ton is reasonable. Using the latter figure reduced the Cooling end use savings by 9% (i.e., a realization rate of 91%).
- The reason for the discrepancy for the HVAC enduse (EEM-2) is unclear, as the ex ante fan energy values are hard-coded.

Other Findings and Recommendations

- N/A

SITE 2024 (CUSTOM HVAC)

This project involved a major renovation of and additions to a public high school with approximately 2,300 students and 200 staff members. The high school formerly consisted of several individual buildings, but for security reasons, the school was rebuilt as a single structure oriented around a single front entrance. The new structure is mostly new construction, though some of the existing buildings were gut-renovated and integrated into the new structure.

This project included the new construction portion of the overall project, with Site 2009 as the renovation portion. The custom HVAC measures herein include a variable-primary chilled water pumping system (variable speed primary loop) compared to a baseline of a primary-secondary (constant speed primary loop with a variable speed secondary loop), the baseline chilled water configuration defined in ASHRAE 90.1-2007 Appendix G. A variable-primary configuration saves pumping energy by allowing the primary chiller pump speed to modulate according to chilled water demand; in contrast, the primary chiller pumps run continuously in a primary-secondary system during the cooling season.

The project was accepted into the Custom program in 2019 before Saint Louis County adopted IECC 2015, so the applicable baseline energy code is IECC 2009—the prior code in effect at the time. Construction was completed, and Custom incentives were awarded in 2023. The trade ally stated that ASHRAE 90.1-2007 was used for the baseline requirements, which aligns closely with IECC 2009.

Table 104. Site 2024 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Education	484,500	2009 IECC	HVAC	New Construction/Major Renovation

Table 105. Site 2024 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Variable-Primary Chilled Water Pumping	HVAC	1,006,713	446.96
	Total	**1,006,713**	**446.96**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for the estimated energy savings. An onsite review confirmed the installation of the variable-primary chilled water system and primary pump sizes.

ANALYSIS

The basis for the ex ante savings was derived from energy modeling results using IES software. No project narrative was initially provided in the project documentation. The trade ally later provided a narrative outlining the baseline model configuration and energy efficiency measures. The baseline model was designed in accordance with ASHRAE 90.1-2007 Appendix G directives.

The evaluation team used engineering calculations to estimate the savings of the as-built design, based on the energy efficiency measures outlined in the narrative. These measures included:

- Chiller efficiency exceeding code minimum requirements
- Higher chilled water temperature

- Air side economizers
- Variable-primary chilled water pumping
- Variable speed cooling tower fans
- Condenser water temperature reset

Table 106. Site 2024 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline Pumping Configuration	Primary-Secondary	Primary-Secondary	Project narrative (90.1 G3.1.3.10)
EEM-1	Efficient Pumping Configuration	Variable-Primary	Variable-Primary	Mechanical plans, project narrative
EEM-1	Baseline Primary-Secondary Chilled Water Pumps Power (total)	137.28 kW	137.28 kW	Project narrative (22 W/GPM per 90.1 G3.1.3.10), eng. estimate (secondary pumps)
EEM-1	Efficient Primary Chilled Water Pumps Power (total)	83.44 kW	83.44 kW	Mechanical plans, calculated from BHP
EEM-1	VFD Savings Factor	N/A	0.3389	PY2022 AMO TRM
EEM-1	Annual Cooling Hours	N/A	5279	PY2022 AMO TRM

RESULTS

Table 107 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 107. Site 2024 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Variable-Primary Chilled Water Pumping	1,006,713	301,605	30%	446.96	274.67	61%
Total	**1,006,713**	**301,605**	**30%**	**446.96**	**274.67**	**61%**

Reasons for discrepancies

- Because the evaluation team did not have access to the energy models for this project, we used engineering calculations to attempt to verify the ex ante savings. We evaluated each measure identified in the project narrative as implemented in the proposed model. Even with the explanations provided in the narrative, our estimated savings were not close to the ex ante savings. The reasons for the discrepancy are not clear.

Other Findings and Recommendations

- The project calculations in Excel were partially locked, allowing the cell values and formulas to be viewed but preventing the use of formula tracing in Excel. This made it difficult to understand the calculations. The implementation team should require that project calculation workbooks submitted for Custom incentive applications be fully unlocked.

SITE 3000 (CUSTOM INDOOR AGRICULTURE)

This project involved a new single-story 32,800, 32,800-square-foot foot indoor agriculture facility. The measures include high-efficiency heating, ventilation, air conditioning, and dehumidification (HVACD) units, interactive HVAC effects for a lighting split-project from 2022, and high-efficiency standalone dehumidifiers. The HVACD equipment serves the grow rooms (Flower Rooms and Veg Rooms), which occupy 30% of the facility. The HVACD units are water-cooled rather than the more typical air-cooled units. Minimum efficiency for the HVACD units was defaulted to IECC 2015 since this facility is in a jurisdiction that does not have a local energy code. Dehumidifier efficiency is not covered by IECC but a baseline efficiency value was stipulated by the implementer. This is also a split-project facility: Lighting savings were claimed under a Custom lighting project in the previous year (2022). The project summary and ex ante savings are provided in Table 108 and Table 109, respectively.

Table 108. Site 3000 Project Information

Facility Type	Facility Sq Ft	Local Energy Code	Enduse Description	Project Type
Indoor Agriculture	32,800	N/A	HVAC	New Construction/Major Renovation

Table 109. Site 3000 Ex Ante Savings Summary

Measure Name	Loadshape	Ex Ante Gross	
		kWh	kW
EEM-1 Efficient HVACD System	Process	1,145,524	158.02
	Total	**1,145,524**	**158.02**

PROJECT DOCUMENTATION REVIEW AND VALIDATION

The evaluation team reviewed all available project data and documents to understand the project scope and determine the measures and basis for estimated energy savings. We reviewed the program application, invoices, equipment specification sheets, building plans, and post-inspection photos. In lieu of a project overview narrative, we were only able to determine the actual energy savings measures and basis for savings from an interactive review of the Trane TRACE® 3D Plus (TRACE3D) building energy model (BEM). Only the TRACE3D input model was provided with the project documentation. Typically, the TRACE3D Project Summary output report is also provided since it is the primary source of ex ante claimed savings estimates for TRACE3D models. When we requested the TRACE3D output reports, we were informed they were not available and instructed to rerun the model and recreate them ourselves. We complied but with a newer version of TRACE3D and with slightly different results.

ANALYSIS

The evaluation team reviewed an Excel workbook containing a screen capture of TRACE3D Project Summary report results, which showed the enduse annual energy use and savings that matched the claimed savings. The tab name was "8.2.23," so assuming this label is a date, the report had been generated recently. We also reviewed the Mechanical Schedules on the building plans and made note of the HVACD systems and separate dehumidifier systems serving the grow rooms. We focused on the grow rooms because the grow rooms typically consume the majority of energy for this facility type. The building plans showed the facility has six Flower Rooms and four Veg Rooms, but some of these were labeled "for future use." Each grow room type uses a different HVACD model, but the same dehumidifiers are used for both rooms.

We verified installation of the HVACD systems from the post-installation photos. We verified their performance from the manufacturer's specification sheets, which clearly showed these were unusual and atypical water-cooled HVACD units. Lacking any other description of the project and measures, we also interactively reviewed the model in TRACE3D and observed any differences between the baseline and as-built models. We took screen captures at every step so that we could compare and summarize the differences between the baseline (IECC2015) and as-built (efficiency measures case) scenarios. Key characteristics of the HVACD systems serving the Flower and Veg Rooms are summarized in Table 110. This table contains values from the manufacturer's specification sheets, from IECC 2015 for the applicable unit size and equipment type (water-cooled, electric heating), and from our TRACE3D model review.

Table 110. Site 3000 Grow Room HVACD System Characteristics Summary

Room Served	Model	TRACE 3D Quantity	Spec. Sheet Total Cap. (MBH)	Spec. Sheet FL EER	IECC 2015 Min. EER	TRACE 3D EER	TRACE 3D Total Cap. (MBH)
Flower Room	AG-055	6	759.0	13.5	12.4	10	717.2
Veg Room	AG-024	3	337.4	14.1	12.4	11	344.1

The most significant discrepancy we found was the ex ante assumption of air-cooled units instead of water-cooled units, which resulted in an incorrect IECC baseline efficiency value and an overestimate of energy savings. For example, for the AG-055 HVACD unit, instead of using 12.4 EER (water-cooled), the ex ante baseline scenario used 10 EER (air-cooled). Our review of the TRACE3D model revealed the incorrect baseline efficiencies appear to be due to the incorrect ex ante selection of heat rejection type set to "Air-Cooled" instead of "Water-Cooled," and the resulting auto-selection of IECC 2015 from the TRACE3D library of the air-cooled minimum efficiency. The IECC 2015 air-cooled versus water-cooled efficiency differences are illustrated more clearly in Table 111.

Table 111. Site 3000 Comparison of IECC 2015 Requirements for Water-Cooled versus Air-Cooled Equipment

Size Category	Equipment Type	Heating Section Type	Minimum FL EER	Minimum IEER
≥ 240 MBH and ≤ 760 MBH	Air conditioners, air-cooled	Elec. Resistance	10	11.6
	Air conditioners, water-cooled	Elec. Resistance	12.4	13.6

In addition, we also observed significant indoor lighting savings in the TRACE 3D model even though this project was an HVACD project. The difference in baseline versus as-built lighting was unexpected for this HVAC-only measure and is a significant issue due to the interaction between the lighting and cooling systems (e.g. interactive HVAC effects). There was no mention of this facility having split-projects in the project documentation, but we checked the 2023 program tracking data for additional claims and found none. On further investigation, we discovered that a Custom lighting project had been claimed in the program year 2022 and that the savings for that project were roughly the same as that observed in the TRACE3D model (about 1M kWh). Validation of the observed lighting difference in the model was critical due to the simulation of interactive HVAC effects. Significant interactive HVAC energy savings can result from auto-sizing the baseline HVACD system to meet the larger baseline lighting load, which requires a larger cooling system versus the actual size of the as-built cooling system. The modeling of interactive HVACD effects and the use of auto-sizing are typical standard practice modeling approaches for lighting projects. Because the interactive HVAC savings were not claimed for the lighting project in 2022, we used the model as-is and noted in our project narrative that this project includes interactive HVAC savings for the lighting split-project.

Our review of the TRACE3D models also showed the inclusion of standalone dehumidifiers in each of the grow rooms, which was confirmed by the building plans and post-installation photos. The model included the quantity of units in each room type and the as-built and baseline efficiency values. We confirmed that the as-built unit efficiency matched the value on the manufacturer's specification sheet (1.063 gal/kWh). For the baseline efficiency, the TRACE3D model dehumidifier description references a value of “1.7 liters per kWh,” but values in the model are specified as gallons per kWh (1.7 l/kWh=0.449 gal/kWh). A reference source for this value was not provided, and dehumidifiers for indoor agriculture applications are not regulated by IECC 2015 nor in Missouri, but the 1.7 l/kWh value is consistent with values we have observed in other jurisdictions that do regulate indoor agriculture dehumidifier efficiency. The efficiency of the as-built unit is 2.5 times that of the baseline assumption, and we did not change the ex ante assumptions.

Key energy savings estimation parameters and ex post changes we made to the TRACE3D model are summarized in Table 112. For the HVACD systems, we changed the baseline scenario efficiency values to reflect IECC 2015 values for a water-cooled unit. Ideally the heat rejection type would be changed from air-cooled to water-cooled for both scenarios, but this would have required a significant level of effort to add the associated auxiliary equipment and the baseline efficiency change uses a consistent basis for the efficiency values. We also updated the total cooling capacities since there were very slight differences between the TRACE3D model and the manufacturer’s specification sheet.

Table 112. Site 3000 Key Parameters

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	HVACD System Type	Air-cooled	Water-cooled	Manuf. specification sheet
EEM-1	Baseline HVACD Efficiency	10 EER/11 EER	12.4 EER	IECC 2015 Water-cooled DX/ER
EEM-1	HVACD AQ-24 Total Cooling Capacity	344.1 kBtuh	337.4 kBtuh	Manuf. specification sheet
EEM-1	HVACD AQ-55 Total Cooling Capacity	717.2 kBtuh	759.0 kBtuh	Manuf. specification sheet
EEM-1	Dehumidifier Efficiency: Efficient/Baseline	1.063 / 0.449 gal/kWh	NA	Same as ex ante (TRACE3D)

RESULTS

Table 113 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 113. Site 3000 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Efficient HVACD System	1,145,524	815,954	71%	158.02	112.56	71%
Total	**1,145,524**	**815,954**	**71%**	**158.02**	**112.56**	**71%**

Reasons for discrepancies

- The ex ante analysis incorrectly used IECC 2015 minimum efficiency values for air-cooled units instead of water-cooled units.
- There were slight differences in the total cooling capacity used in the TRACE3D model versus the manufacturer’s specification sheet.

Other Findings and Recommendations

- If an atypical, unique HVACD system type is used for an indoor agriculture facility, that same system-type and the applicable IECC 2015 minimum efficiency values should be used for the baseline scenario.
- All facilities with split-projects should include a summary table of the savings for all projects implemented at that facility as part of the project narrative and project documentation.

- For TRACE3D modeled projects, the project narrative should also include screen captures from the models that show how and where the key parameters were incorporated into the model. In addition, as the primary source of ex ante claimed savings and for traceability, the TRACE3D output Project Summary output report should always be provided in the project documentation and not just the input file.
- The project documentation did not include a project narrative/overview that clearly describes the measures and summarizes the key parameters and assumptions. This primary project information had to be instead pieced together from an interactive review of the TRACE3D model, the project documentation that was provided, and even the investigation of 2022 projects. A simple project narrative, similar to the information in the evaluation Site Report, should be provided with every Custom project. This would greatly facilitate both implementation and evaluation.

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