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Ameren Missouri Program Year 2021 Annual EM&V Report

Volume 3: Business Portfolio Appendices

June 10, 2022

Opinion Dynamics

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Appendix A. Additional Methodology Detail

Respondent-Level Free Ridership Methodology

This section outlines our approach for calculating respondent-level free ridership (FR) values for the BizSavers® programs, based on responses to questions in the participant online survey/interviews. The approach estimates program influence on project efficiency and applies an adjustment to reflect program influence on (1) the quantity and timing of installed equipment or (2) preventing/reducing a COVID-19 related delay/cancellation of the project.

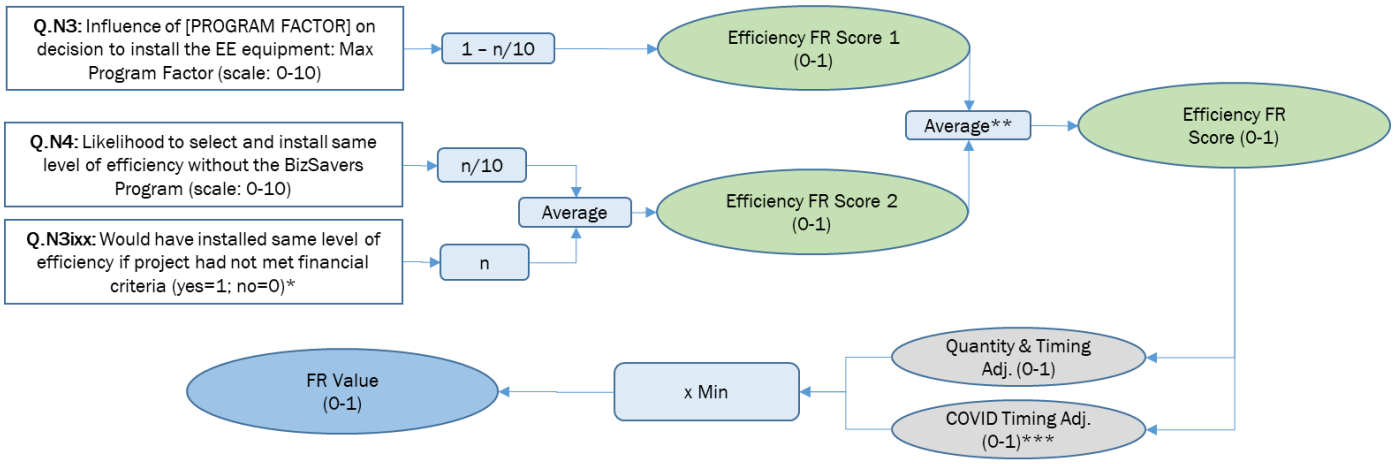
The approach is identical to that used in PY2020, except for the addition of a COVID Timing Adjustment to the Standard and Custom Programs' FR algorithm.

We used the following calculations:

- FR Value = [(Efficiency Score 1 + Efficiency Score 2) ÷ 2] x Minimum(Quantity and Timing Adjustment Factor, COVID Timing Adjustment)
- NTG Value = 1 – FR Value

Figure 1 presents a diagram of the FR algorithm used for this evaluation.

Figure 1. Overview of Respondent-Level Free-Ridership Algorithm



**Asked only of those who rated importance of financial criteria >7 and indicated that the incentive caused the project to meet their financial criteria.*
*** In cases where the two efficiency scores are inconsistent, the algorithm uses a weighted average, based on the level of program influence reported in other survey responses.*
**** Applied only in Standard and Custom evaluations.*

The following subsections describe the questions and algorithms used to estimate respondent-level FR values.

Program Influence on Project Efficiency

The participant online surveys/interviews included a series of questions to determine the influence of the program on the efficiency level of the incented project. Based on these questions, we developed two FR

efficiency scores for each respondent, which were then averaged to calculate the respondent's overall Efficiency FR Score. FR scores can range from 0 to 1, where 0 means no FR (i.e., full credit for the program) and 1 means full FR (i.e., no credit for the program).

The overall Efficiency FR Score is the average of the following two sub-scores:

- **Efficiency FR Score 1 (ES1) – Rating of program factors.** Respondents were asked to rate (on a scale of 0 to 10) the importance of several program and non-program factors on their decision to select energy-efficient equipment rather than a less efficient alternative.[1] The Efficiency FR Score 1 is based on the maximum rating given to any of the program factors and was calculated as:

  1 – (Maximum Program Factor Rating ÷ 10)

- **Efficiency FR Score 2 (ES2) – Counterfactual.** Average of ES2a and ES2b:
  - **ES2a. Likelihood to install same level of efficiency without the BizSavers Program:** Respondents were asked to rate (on a scale of 0 to 10) the likelihood that they would have installed equipment with the same level of efficiency without the program. This score was calculated as:

    Likelihood to install without the program ÷ 10

  - **ES2b. Would participant have selected the same energy-efficient equipment if it had not met their financial criteria:** This question was only asked of respondents who rated the importance of financial criteria greater than 7 and indicated that the incentive caused the project to meet or exceed their financial criteria. For all other respondents, the Efficiency FR Score 2 only uses the first measurement of the counterfactual (i.e., ES2a). This score was calculated as:

    Yes = 1; No = 0

Quantity and Timing Adjustment Factor

In addition to influencing the efficiency of a project, the program can affect the quantity and timing of the installed energy-efficient equipment. Because decisions about measure quantity and installation timing are often correlated, we calculated a combined "Quantity and Timing Adjustment Factor." This factor ranges from 0 to 1, where a lower value means a greater quantity and timing adjustment (i.e., more credit to the program). As shown in Figure 1, the Quantity and Timing Adjustment Factor is multiplied by the Efficiency FR Score to derive the FR Value.

To develop the Quantity and Timing Adjustment Factor, the survey first asked respondents how much of the installed energy-efficient equipment would have been installed at the same time without the program. Only the quantity that would not have been installed at the same time was eligible to receive the quantity and timing credit.

[1] Several factors asked about in the survey can be considered either a program factor or a non-program factor, depending on the response to a follow-up question: previous experience with this type of equipment, financial criteria, and expected energy savings.

Respondents were then asked if they would have installed the remaining quantity later and, if so, how much later. The response, expressed as the number of months the program accelerated the project, was translated into a timing adjustment, using the following formula:[2]

Timing Adjustment = 1 – (# Months Accelerated – 6) ÷ 42

Substituting the midpoint of the response for # Months Accelerated results in the following adjustments:

- Same time: 1.0
- Up to 6 months later: 1.0
- 7–12 months later: 0.93
- 1–2 years later: 0.71
- 2–3 years later: 0.43
- 3–4 years later: 0.14
- More than 4 years later: 0.0
- Don't know/Refused: Average of valid responses from other respondents

The timing adjustment can range from 0 to 1. A smaller adjustment value means a greater reduction in FR, because the program resulted in a greater acceleration of the project.

The Quantity and Timing Adjustment Factor was then calculated by multiplying the percentage of the project that would not have been installed at the same time without the program by the timing adjustment and adding this product to the percentage of the project that would have been installed at the same time without the program. We used the following formula for this calculation:

Quantity and Timing Adjustment Factor =

*(% Not Installed at Same Time * Timing Adjustment) + % Installed at Same Time*

If the respondent did not provide valid responses to the initial quantity question (i.e., an "unsure" response to the question: "*Without the incentives from Ameren Missouri's BizSavers program, would you have installed the same quantity of energy-efficient equipment in <INSTALLDATE> or would you have installed less?*"), we used the following rules to assign a Quantity and Timing Adjustment Factor:

- If the respondent indicated the availability of the BizSavers program somewhat or significantly changed either the quantity or the timing of their project, we assigned a Quantity and Timing Adjustment Factor equal to the average of valid responses from other respondents.
- If the respondent indicated the availability of the BizSavers program changed neither the quantity nor the timing of their project, we assigned a Quantity and Timing Adjustment Factor of 1.0 (i.e., no reduction in FR).

[2] The timing adjustment is capped at 1.0, i.e., if the *# Months Accelerated* is six months or less, the adjustment is equal to 1.0 and no adjustment is applied.

COVID Timing Adjustment

The COVID Timing Adjustment is a new factor designed to capture a potential impact of the program in preventing project cancelations or delays due to COVID-19 and associated containment measures or broader economic impacts. Through a series of questions, we determined if a respondent had considered delays to this project that were not, in the end, realized. We then asked respondents if the Ameren Missouri BizSavers Program had any impact on preventing/reducing the considered delay. If so, respondents were asked to rate the influence of the Ameren Missouri BizSavers Program in preventing/reducing this potential delay, and those who provided a response of 6 or greater were asked how much later the project would have occurred had it not been for the BizSavers Program.[3] The response, expressed as the number of months the program accelerated the project, was scored according to a modified version of the #Months Accelerated schedule used in the Quantity and Timing Adjustment, capped at 0.43. The revised scoring schedule is:

- Same time: 1.0
- Up to 6 months later: 1.0
- 7–12 months later: 0.93
- 1–2 years later: 0.71
- 2–3 years later: 0.43
- 3–4 years later: 0.43
- More than 4 years later: 0.43
- The project would have been canceled: 0.0
- Don't know/Refused: Average of valid responses from other respondents

Any respondents who indicated their project would have been canceled because of COVID-19 had it not been for the Ameren Missouri BizSavers Program were asked an open-ended follow up question on why the project would have been canceled. A response supporting a likely cancellation was required for a COVID Timing Adjustment of 0.0 to be applied.

Additional Response Review

To increase the confidence in the FR scores of sampled projects, we conducted an additional review of survey responses for three types of projects:

- Sampled projects with inconsistent responses about the program's influence on the efficiency of their project, defined as those with Efficiency FR Scores of (ES1<0.3 AND ES2>0.7) or (ES1>0.7 AND ES2<0.3), where ES1 is based on the maximum program factor (N3) and ES2 is based on the responses to the counterfactual questions (N4 and N3ixx). This analysis is limited to inconsistent responses for sampled projects that account for 1% or more of sampled savings (separately estimated for Standard and Custom projects).
- Sampled projects with inconsistent responses about the program's influence on the quantity and timing of their project, defined as those who (1) indicated the program had at least a moderate

[3] Respondents were asked to provide a response on a 0 to 10 scale, where 0 represents "Not at all influential" and 10 represents "Extremely Influential."

influence on quantity (i.e., a response of 2 or 3 to CF1b) or timing (i.e., a response of 2 or 3 to CF1c) but had a Q&T Adjustment of 1.0 or (2) indicated the program had no influence on quantity and timing (CF1b AND CF1c equal to 1) but had a Q&T Adjustment of less than 1.0. This analysis is limited to inconsistent responses for sampled projects that account for 1% or more of sampled savings (separately estimated for Standard and Custom projects).

- Sampled projects that account for 5% or more of sampled savings, irrespective of consistency of responses (also separately estimated for Standard and Custom projects).

Two consultants independently reviewed supplemental information collected in the survey to inform the project-level FR scores. We used a two-step process:

1. We relied on the quantitative questions about changes to plans for efficiency, quantity, and timing (CF1a-c) to develop Preliminary Attribution Ratings for both efficiency and timing/quantity.

2. The Preliminary Attribution Ratings were modified, if needed, based on responses to the additional counterfactual question (N7), as well as several open-ended questions: the consistency check question (CC1a), the introduction question (V1), and the follow-up questions about changes to plans for efficiency, quantity, and timing questions (CF2a-c).

The output of this analysis consisted of two categorical Attribution Ratings for each respondent included in this analysis: an efficiency attribution rating and a quantity/timing (Q&T) attribution rating. Each rating can take one of four values: high (H), medium (M), low (L), or inconclusive (?) program attribution. Based on these Attribution Ratings, the project-level Efficiency FR Scores (ES) and Quantity and Timing Adjustment Factors were revised as follows:

- **Efficiency Score (ES):** The Efficiency Attribution Rating determined the weights used to combine the ES1 and ES2 scores to calculate the project's overall ES. The status quo was a simple average (i.e., both scores have a weight of 0.5). For projects with a "high" efficiency attribution rating, a larger weight was applied to ES1 (always a lower level of FR), while for projects with a "low" efficiency attribution rating, a larger weight was applied to ES2. For projects where the supplemental information was inconclusive—as well as projects with a "medium" efficiency attribution rating—the status quo (i.e., weights of 0.5 each) was applied. ES Weights are provided in Table 1.

Table 1. Efficiency Score Weights

Efficiency Attribution Rating	ES1 Weight	ES2 Weight
High	0.67	0.33
Medium	0.50	0.50
Low	0.33	0.67
Inconclusive	0.50	0.50

- **Quantity & Timing Adjustment Factor:** The Q&T Attribution Rating determined how, if at all, to modify the Q&T Adjustment Factor applied to a project. This analysis differed for respondents who reported in Q. N5b that they would have installed the same quantity of efficient equipment at the same time (i.e., % Install = 100%) and those who reported a quantity of less than 100% (i.e., % Install < 100%).
  - **Respondents with % Install = 100%:** We assigned a revised Q&T Adjustment Factor based on the assigned Q&T Attribution Rating. The factors were calculated based on average Q&T Adjustments

conditioned on CF1b and CF1c responses: A respondent with a "high" Q&T Attribution Rating was assigned the average Q&T Adjustment Factor of all respondents who provided responses of "Changed significantly" to both CF1b and CF1c. A respondent with a "medium" Q&T Attribution Rating was assigned the average Q&T Adjustment Factor of all respondents who provided a response of "Changed somewhat" or "Changed significantly" to at least one of CF1b or CF1c. A respondent with a "low" or "indeterminate" Q&T Attribution Rating kept a Q&T Adjustment Factor of 1.0 (i.e., no adjustment). Q&T Adjustment Factors are provided in Table 2.

Table 2. Q&T Adjustment Factors

Q&T Attribution Rating	Q&T Adjustment Factor
High	0.40
Medium	0.59
Low	1.00
Indeterminate	1.00

- **Respondents with % Install < 100%:** We reviewed their responses to the quantity and timing battery, and the resulting Q&T Adjustment Factor, for consistency with the supplemental information. If needed, we assigned a new Q&T Adjustment Factor, using the rating methodology described above.

The two consultants compared results and discussed any instances where they assigned different attribution ratings until consensus was reached.

Appendix B. Additional Information: Standard HVAC

This section provides additional detail on our gross impact analysis method and results for Standard HVAC projects.

The evaluation of Standard HVAC projects included desk reviews and onsite visits for a sample of nine projects. Table 3 shows a summary of the number of sampled measures by measure type.

Table 3. Sampled Standard HVAC Measures by Measure Type

Measure Type	Number of Projects	Quantity of Measures	Ex Ante kWh	% of Sampled Ex Ante kWh
Learning Thermostat	3	148	131,187	28%
Packaged DX	5	34	241,021	51%
ASHP	1	1	510	<1%
Demand Control Ventilation	2	143.4*	95,361	20%
		Total	**468,079**	**100%**

* Units in 1,000 square feet of conditioned space

Table 4 summarizes the sampled projects, by measure group, including their ex ante and ex post savings and estimated realization rates.

Table 4. Summary of Standard HVAC Project Reviews

Site ID	Measure Group	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
			Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
8500	Learning Thermostat	Desk review and onsite visit	102,034	102,051	100%	92.92	92.94	100%
8501	Learning Thermostat	Desk review and onsite visit	4,106	8,446	206%	3.74	4.12	110%
8502	Learning Thermostat	Desk review and onsite visit	25,047	45,580	182%	22.81	33.25	146%
8503	Packaged DX	Desk review	50,456	55,535	110%	45.95	50.58	110%
8504	Packaged DX	Desk review	6,433	5,875	91%	5.86	5.35	91%
8505	ASHP	Desk review and phone verification	510	1,436	282%	0.23	0.46	202%
8506	Packaged DX	Desk review	6,480	6,480	100%	5.90	5.90	100%
8506	Demand Control Ventilation	Desk review	5,819	5,688	98%	5.30	5.18	98%
8507	Packaged DX	Desk review	134,176	122,956	92%	122.19	111.97	92%

Site ID	Measure Group	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
			Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
8507	Demand Control Ventilation	Desk review	89,542	120,242	134%	81.54	109.50	134%
8508	Packaged DX	Desk review	43,476	55,377	127%	39.59	50.43	127%

Data Collection

Desk Review

For each sampled Standard HVAC project, Opinion Dynamics reviewed all measure tracking data and all available project documentation (from the implementer's program tracking database).

We first reviewed the tracking data to examine the ex ante energy and demand savings and compare the ex ante savings calculations to the Ameren Missouri TRM. This tracking data review found that, in some cases, the ex ante calculations used the deemed per unit savings from the TRM Appendix F document rather than the algorithms and input parameter definitions and measure-specific input information described in the Business Program Appendix H. We also found that the calculations for ASHP measures only included the cooling savings component and did not include heating energy savings.

Then, we performed a desk review of the project documentation—including project invoices, equipment specification sheets, final application documents, and signed forms—to verify the input parameters for savings calculations. We reviewed project materials and other publicly available customer information to verify building type and building size. When necessary, we also contacted the customer to verify the installed equipment, baseline and/or existing conditions, and current operating schedules and other key parameters.

Site Visits

We also conducted three onsite visits, covering all learning thermostat projects (27% of total sampled projects). The purpose of these site visits was physical verification of key equipment and parameters, including the quantity of installed thermostats, the capacity and efficiency of the HVAC system controlled by the new thermostats, the building type, and operating hours.

We used measure-specific and building-specific data verified during the tracking data review, desk review, and onsite visits to update the calculations of ex post energy savings.

Gross Impact Analysis Method

The evaluation team calculated verified ex post gross energy and demand savings for each sampled project using methods consistent with the Ameren Missouri TRM Appendix H. The following sections describe the formulas, input parameters, and sources of the input parameters used to calculate ex post savings for each measure type.

Heat Pump System

The team used the following equations to calculate ex post electric energy and demand savings for a new high efficiency air-cooled heat pump unit providing space heating and cooling:

For equipment with cooling capacities less than 65 kBtu/hr:

$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$

$\Delta kWh_{cool} = (kBtu/hr_{cool}) * [(1/SEER_{base}) - (1/SEER_{ee})] * EFLH_{cool}$

$\Delta kWh_{heat} = (kBtu/hr_{heat}) * [(1/HSPF_{base}) - (1/HSPF_{ee})] * EFLH_{heat}$

$\Delta kW = \Delta kWh_{cool} * CF$

Table 5. Heat Pump System – Gross Savings Input Parameters and Sources

Parameter	Description	Source	Verification Method
$kBtu/hr_{cool}$	Heat pump cooling capacity in kBtu per hour	Spec Sheet/ Invoice	Desk review of project documentation
$kBtu/hr_{heat}$	Heat pump heating capacity in kBtu per hour	Spec Sheet/ Invoice	Desk review of project documentation
$SEER_{base}$	Seasonal Energy Efficiency Ratio of the baseline equipment	TRM Appendix H	N/A
$SEER_{ee}$	Seasonal Energy Efficiency Ratio of the energy efficient equipment	Spec Sheet/ Invoice	Desk review of project documentation
$EFLH_{cool}$	Equivalent Full Load Hours for Cooling	TRM Appendix H, based on Building Type	Verified Building Type with customer
$HSPF_{base}$	Heating Seasonal Performance Factor of the baseline equipment	TRM Appendix H	Desk review of project documentation
$HSPF_{ee}$	Heating Seasonal Performance Factor of the energy efficient equipment	Spec Sheet/ Invoice	Desk review of project documentation
$EFLH_{heat}$	Heating mode equivalent full load hours	TRM Appendix H, based on Building Type	N/A
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor	TRM Appendix H, based on End Use	Desk review of project documentation

Unitary Air Conditioner

The team used the following equations to calculate ex post electric energy and demand savings for installing new high-efficiency unitary air conditioning equipment:

For units with cooling capacities less than 65 kBtu/hr:

$\Delta kWh = kBtu/hr_{cool} * [(1/SEER_{base}) - (1/SEER_{ee})] * EFLH_{cool}$

$\Delta kW = \Delta kWh * CF$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

$\Delta kWh = kBtu/hr_{cool} * [(1/IEER_{base}) - (1/IEER_{ee})] * EFLH_{cool}$

$\Delta kW = \Delta kWh * CF$

Table 6. Unitary AC – Gross Savings Input Parameters and Sources

Parameter	Description	Source	Verification Method
$kBtu/hr_{cool}$	Capacity of the cooling equipment in kBtu per hour	Spec Sheet/ Invoice	Desk review of project documentation OR onsite inspection
$SEER_{base}$	Seasonal Energy Efficiency Ratio of the baseline equipment	TRM Appendix H	N/A
$SEER_{ee}$	Seasonal Energy Efficiency Ratio of the energy efficient equipment	Spec Sheet/ Invoice	Desk review of project documentation OR onsite inspection
$EFLH_{cool}$	Equivalent Full Load Hours for Cooling	TRM Appendix H, based on Building Type	Verified Building Type with customer
$IEER_{base}$	Integrated Energy Efficiency Ratio of the baseline equipment	TRM Appendix H	N/A
$IEER_{ee}$	Integrated Energy Efficiency Ratio of the energy efficient equipment (actually installed.)	Spec Sheet/ Invoice	Desk review of project documentation OR onsite inspection
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor	TRM Appendix H, based on End Use	Desk review of project documentation

Thermostats

The team used the following equations to calculate ex post electric energy and demand savings for the installation of new learning thermostats:

$$\Delta kWh = \left(\frac{1}{Eff} * EFLH_{Cool} * \frac{Btuh_{Cool}}{1000} * ESF_{Cool}\right) + \left(EFLH_{HEAT} * \frac{Btuh_{HEAT}}{\eta_{HEAT} * 3412} * ESF_{HEAT}\right)$$

$\Delta kW = \Delta kWh * CF$

Table 7. Thermostats – Gross Savings Input Parameters and Sources

Parameter	Description	Source	Verification Method
Eff	Efficiency of HVAC unit (If not available, assume 10 SEER)	Actual or TRM Appendix H	Onsite inspection
$EFLH_{cool}$	Effective Full Load Cooling Hours	TRM Appendix H, based on Building Type	N/A
$Btuh_{cool}$	Cooling System Capacity	Actual	Desk review of project documentation OR onsite inspection

Parameter	Description	Source	Verification Method
ESF_{cool}	Cooling energy savings factor (0.1625)	TRM Appendix F	N/A
$EFLH_{heat}$	Effective Full Load Cooling Hours	TRM Appendix H, based on Building Type	N/A
$Btuh_{heat}$	Heating System Capacity	Actual	Desk review of project documentation OR onsite inspection
η_{HEAT}	Heating System Efficiency	TRM Appendix F	N/A
ESF_{heat}	Heating energy savings factor (0.125)	TRM Appendix F	N/A
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor	TRM Appendix H, based on End Use	Desk review of project documentation

Demand Controlled Ventilation

The team used the following equations to calculate ex post electric energy and demand savings for the implementation of demand control ventilation (DCV) on HVAC equipment. Since the buildings in our sample had non-electric heating, the heating savings is zero, and we only calculated cooling Savings:

$\Delta kWh_{cool} = SQFT_{cond}/1000 * SF_{cooling}$

$\Delta kW = \Delta kWh_{cool} * CF$

Table 8. Demand Control Ventilation – Gross Savings Input Parameters and Sources

Parameter	Description	Source	Verification Method
$SQFT_{cond}$	Square footage of conditioned space commissioned with DCV	Actual	Desk review of project documentation
$SF_{cooling}$	Cooling Savings Factor, including cooling and fan energy savings	TRM Appendix B, based on Building Type and location	Desk review of project documentation and customer interview
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor	TRM Appendix B, based on End Use	Desk review of project documentation

Gross Impact Analysis Results

The table below presents the results of the Standard HVAC desk review analysis, including energy and demand realization rates by project and measure group. We also include a brief description of the primary drivers of realization rates.

Table 9. Summary of Standard HVAC Project Results

Site ID	Measure Group	Annual Energy (kWh) RR	Demand (kW) RR	Reason(s) for Discrepancies
8500	Learning Thermostat	100%	100%	▪ No discrepancy
8501	Learning Thermostat	206%	110%	▪ Ex post savings include heating savings; ex ante counts cooling only. ▪ The ex post calculations are based on small office EFHL; ex ante uses the C&I Average EFLH.
8502	Learning Thermostat	182%	146%	▪ Ex post savings include heating savings; ex ante counts cooling only ▪ The ex post calculations are based on lodging EFHL; ex ante uses the C&I Average EFLH ▪ Ex post used site-verified cooling and heating capacity and efficiency values, which reduce savings compared to ex ante inputs.
8503	Packaged DX	110%	110%	▪ Ex post calculations are based on small office EFHL but ex ante savings use the average cooling kWh/ton from Appendix F.
8504	Packaged DX	91%	91%	▪ Ex post calculations are based on a 22.83 ton system but ex ante savings are based on a system with 25 ton cooling capacity.
8505	ASHP	282%	202%	▪ The ex post savings include heating and cooling kwh savings; ex ante savings only include cooling savings. ▪ Ex post uses EFLH for cooling and heating based on TRM tables, based on building type and location; ex ante uses C&I Average EFLH. ▪ Ex post calculated kW as Cooling kWh * Cooling CF; ex ante calculates kW using HVAC CF
8506	Packaged DX	100%	100%	▪ No discrepancy
8506	Demand Control Ventilation	98%	98%	▪ Ex ante uses average SF_cool factor of 665 from Appendix F; ex post uses SF_cool factor of 650 from TRM table based on location and building type
8507	Packaged DX	92%	92%	▪ The ex post calculations are based on stand-alone retail EFHL but ex ante savings use the average EFHL. ▪ The verified efficiencies are slightly different from the ex post values.

Site ID	Measure Group	Annual Energy (kWh) RR	Demand (kW) RR	Reason(s) for Discrepancies
8507	Demand Control Ventilation	134%	134%	▪ Ex ante uses average SF_cool factor of 665 from Appendix F; ex post uses SF_cool factor of 893 from TRM table based on location and building type.
8508	Packaged DX	127%	127%	▪ The ex post calculations are based on Medium Office EFH; ex ante savings use the average EFHL.

Appendix C. Desk Review and Onsite Reports: Custom Incentive Program, Lighting End Use

The evaluation of Custom lighting projects included desk reviews and onsite visits for a sample of nine projects. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Summary of Custom Lighting Project Reviews

Site ID	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
		Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
9000	Desk review with e-mail verification	4,566	11,478	251%	0.87	2.18	251%
9001	Desk review	2,624	2,674	102%	0.50	0.51	102%
9002	Desk review	5,393	5,494	102%	1.02	1.04	102%
9003	Desk review with e-mail verification	44,932	49,543	110%	8.54	9.41	110%
9004	Desk review	1,991	1,712	86%	0.38	0.33	86%
9005	Desk review with e-mail verification	235,599	236,843	100%	32.67	32.82	100%
9006	Desk review with e-mail verification	230,056	260,157	113%	43.70	49.42	113%
9007	Desk review	395,112	395,112	100%	75.06	75.06	100%
9008	Desk review and onsite visit	92,906	61,537	66%	17.65	11.69	66%

Site ID: 9000 (Custom Lighting)

Project Description

This project replaced existing CFL lamps with new LED lamps for a lighting system at a recreation complex. Energy savings are achieved through the improved efficiency of the lighting equipment, and additional energy savings are achieved through interaction with the building HVAC loads.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9000 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1	Lighting	3,090	0.59
EEM-2	Lighting	963	0.18
EEM-3	Lighting	514	0.10
	Total	**4,567**	**0.87**

Data Collection

The evaluation team reviewed project documentation including the project application form, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team contacted facility personnel in December 2021 and January 2022 and collected the following verification data over e-mail: confirmation of the installed lighting systems, building type, operating schedule, annual hours of use (HOU) for the lighting equipment, primary heating and cooling equipment, and primary heating fuel source.

Analysis

The ex ante savings estimates are calculated using standard lighting savings algorithms using estimated lighting system HOU and an HVAC interaction factor of 1.07. The ex ante calculations use existing conditions as baseline and assume the annual HOU for the lighting system to be 2,500 hours per year.

$$kWh_{savings} = \left(Qty_{baseline} x\ Watts_{baseline} - Qty_{post} x Watts_{post}\right) x\ HOU\ x\ (WHF_e - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

The ex post analysis calculated energy and demand savings using the standard lighting algorithms, updated with parameter values verified through evaluation activities or based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting end use.

The table below compares the ex ante and verified ex post values for key parameters in the calculation.

Site 9000 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verification Source
EEM-2	Watt_post	48	40	Specification sheets.
All	HOU	2,500	6,000	Calculated ex post value based on e-mail communication with the facility.
All	Waste Heat Factor (WHFe)	1.07	1.09	Confirmed building type via site e-mail, TRM C&I average value.
All	IFkWh	0.0	0.0	Confirmed via e-mail that primary heating fuel is natural gas.

Results

The evaluation team estimated savings of 11,478 kWh across all the measures implemented with this project, or 251% of the ex ante estimates of annual energy savings of 4,566 kWh.

Site 9000 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1	3,090	7,554	244%	0.59	1.43	244%
EEM-2	963	2,668	277%	0.18	0.51	277%
EEM-3	514	1,256	244%	0.10	0.24	244%
Total	**4,566**	**11,478**	**251%**	**0.87**	**2.18**	**251%**

Reasons for Discrepancies

- The evaluation team increased the facility annual HOU for both baseline and EE from 2,500 hours in ex ante to 6,000 hours in ex post. This discrepancy is supported by input via e-mail from the facility, which informed the evaluation team of the facility operating hours, reasons for use, and yearly schedule.
- The evaluation team increased the WHF value from 1.07 to 1.09. Ex ante savings use the value of 1.07, based on the previous TRM "C&I Average" value. The current TRM uses 1.09 for the "C&I Average" value. The evaluation team used the current C&I Average value because the building type, a recreation complex, did not fit within the existing building type categories.
- The evaluation team reduced the EE wattage (Watt_post) for EEM-2 from 48 Watts (used in ex ante) to 40 Watts (used in ex post), based on review of the equipment specification sheet for this measure.

Other Findings and Recommendations

- N/A

Site ID: 9001 (Custom Lighting)

Project Description

This project replaced existing CFL lamps with new LED lamps for a lighting system that operates continuously (8,760 hours per year) at a gas station. Energy savings are achieved through the improved efficiency of the lighting equipment, and additional energy savings are achieved through interaction with the HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9001 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1	Lighting	2,624	0.50
	Total	**2,624**	**0.50**

Data Collection

The evaluation team reviewed project documentation including the project application, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team made multiple attempts to contact facility personnel in December 2021 and January 2022 to collect verification data but did not receive a response.

Analysis

The ex ante savings estimates are calculated using standard lighting savings algorithms using estimated lighting system hours of use (HOU) and an HVAC interaction factor of 1.07. The ex ante calculations use existing conditions as baseline and assume the annual HOU for the lighting system to be 8,760 hours per year (i.e., continuous 24/7 operation).

$$kWh_{savings} = \left(Qty_{baseline} x\ Watts_{baseline} - Qty_{post} x Watts_{post}\right) x\ HOU\ x\ (WHF_e - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

The ex post analysis calculated energy and demand savings using the standard lighting algorithms, updated with parameter values verified during our evaluation or based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting end use.

The table below compares the ex ante and verified ex post values for key parameters in the calculation.

Site 9001 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verification Source
All	Annual HOU	8,760	8,760	Unable to verify with site contact; assume ex ante value for ex post.
All	Waste Heat Factor (WHFe)	1.07	1.09	TRM C&I average value.
All	Electric Heating Interaction Factor (IFkWh)	0.0	0.0	Project application confirmed that primary heating fuel is natural gas.

Results

The evaluation team estimated savings of 2,674 kWh across all the measures implemented with this project, or 102% of the ex ante estimates of annual energy savings of 2,624 kWh.

Site 9001 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1	2,624	2,674	102%	0.50	0.51	102%
Total	**2,624**	**2,674**	**102%**	**0.50**	**0.51**	**102%**

Reasons for Discrepancies

- The evaluation team increased the WHF value from 1.07 to 1.09. Ex ante savings use an average value of 1.07 based on the previous TRM "C&I Average" value. The current TRM uses 1.09 for the "C&I Average" value. The evaluation team used the current C&I Average value because the building type, a gas station, did not fit within the existing building type categories.

Other Findings and Recommendations

- N/A

Site ID: 9002 (Custom Lighting)

Project Description

This project replaced existing CFL lamps with new LED lamps for a lighting system at a learning center. Energy savings are achieved through the improved efficiency of the lighting equipment, and additional energy savings are achieved through interaction with the HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9002 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1	Lighting	5,393	1.02
	Total	**5,393**	**1.02**

Data Collection

The evaluation team reviewed project documentation including the project application form, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team made multiple attempts to contact facility personnel in January 2022 to collect verification data but did not receive a response.

Analysis

The ex ante savings estimates are calculated using standard lighting savings algorithms using estimated lighting system hours of use (HOU) and an HVAC interaction factor of 1.07. The ex ante calculations use existing conditions as baseline and assume the annual HOU for the lighting system to be 2,500 hours per year.

$$kWh_{savings} = \left(Qty_{baseline} x\ Watts_{baseline} - Qty_{post} x Watts_{post}\right) x\ HOU\ x\ (WHF_e - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

The ex post analysis calculated energy and demand savings using the standard lighting algorithms, updated with parameter values verified during our evaluation or based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting end use.

The table below compares the ex ante and verified ex post values for key parameters in the calculation.

Results

Site 9002 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verification Source
All	Annual HOU	2,500	2,500	Unable to verify with site contact; assume ex ante value for ex post.
All	Waste Heat Factor (WHFe)	1.07	1.09	Unable to verify with site contact; used TRM C&I average value.
All	Electric Heating Interaction Factor (IFkWh)	0.0	0.0	Project application confirmed that primary heating fuel is natural gas.

The evaluation team estimated savings of 5,494 kWh across all the measures implemented with this project, or 102% of the ex ante estimates of annual energy savings of 5,393 kWh.

Site 9002 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1	5,393	5,494	102%	1.02	1.04	102%
Total	**5,393**	**5,494**	**102%**	**1.02**	**1.04**	**102%**

Reasons for Discrepancies

- The evaluation increased the WHFe value from 1.07 to 1.09. Ex ante savings use an average value of 1.07 based on the previous TRM "C&I Average" value. The current TRM uses 1.09 for the "C&I Average" value. The evaluation team used the current C&I Average value because the building type, a learning center, did not fit within the existing building type categories.

Other Findings and Recommendations

- N/A

Site ID: 9003 (Custom Lighting)

Project Description

This project replaced existing CFL lamps with new LED lamps for a lighting system at a high school. Energy savings are achieved through the improved efficiency of the lighting equipment, and additional energy savings are achieved through interaction with the HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9003 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1	Lighting	44,932	8.54
Total		**44,932**	**8.54**

Data Collection

The evaluation team reviewed project documentation including the project application, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team contacted facility personnel in January 2022 and collected the following verification data over e-mail: confirmation of the installed lighting systems, building type, operating schedule, annual hours of use (HOU) for the lighting equipment, primary heating and cooling equipment, and primary heating fuel source.

Analysis

The ex ante savings estimates are calculated using standard lighting savings algorithms using estimated lighting system HOU and an HVAC interaction factor of 1.07. The ex ante calculations use existing conditions as baseline and assume the annual HOU for the lighting system to be 3,259 hours per year.

$$kWh_{savings} = \left(Qty_{baseline} x\ Watts_{baseline} - Qty_{post} x Watts_{post}\right) x\ HOU\ x\ (WHF_e - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

The ex post analysis calculated energy and demand savings using the standard lighting algorithms, updated with parameter values verified during our evaluation based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting end use.

The table below compares the ex ante and verified ex post values for key parameters in the calculation.

Site 9003 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verification Source
All	HOU	3,259	3,259	Site communications confirmed ex ante hours.
All	HVAC Waste Heat Factor (WHFe)	1.07	1.14	Site communications confirmed space is a high school, used appropriate TRM value.
All	Electric Heating Interaction Factor (IFkWh)	0.0	0.0	Communication with site confirmed that primary heating fuel is natural gas.
EEM-3	EE Fixture Quantity (Qty_post)	59	29	Document review of spec sheets and invoices only show quantity of 29 for this measure.

Results

The evaluation team estimated savings of 49,543 kWh across all the measures implemented with this project, or 110% of the ex ante estimates of annual energy savings of 44,932 kWh.

Site 9003 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1	2,532	2,697	107%	0.48	0.51	107%
EEM-2	33,142	35,310	107%	6.30	6.71	107%
EEM-3	9,258	11,536	125%	1.76	2.19	125%
Total	**44,932**	**49,543**	**110%**	**8.54**	**9.41**	**110%**

Reasons for Discrepancies

- The evaluation team increased the WHFe value from 1.07 to 1.14. Ex ante savings use an average value of 1.07 based on the previous TRM "C&I Average" value. Ex post confirmed this site is a "secondary school" and therefore used the corresponding value of 1.14 from the TRM.
- While verifying parameters, the evaluation team noted a discrepancy in the quantity for EEM-3. The ex ante value is 59 while the invoice for this parameter only shows the ex post value of 29.

Other Findings and Recommendations

- N/A

Site ID: 9004 (Custom Lighting)

Project Description

This project replaced existing halogen lamps with new LED lamps for a lighting system at a church. Energy savings are achieved through the improved efficiency of the lighting equipment, and additional energy savings are achieved through interaction with the HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9004 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1	Lighting	1,991	0.38
	Total	1,991	0.38

Data Collection

The evaluation team reviewed project documentation including the project application, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team made multiple attempts to contact facility personnel in January 2022 to collect verification data but did not receive a response.

Analysis

The ex ante savings estimates are calculated using standard lighting savings algorithms using estimated lighting system hours of use (HOU) and an HVAC interaction factor of 1.07. The ex ante calculations use existing conditions as baseline and assume the annual HOU for the lighting system to be 2,184 hours per year.

$$kWh_{savings} = \left(Qty_{baseline} x\ Watts_{baseline} - Qty_{post} x Watts_{post}\right) x\ HOU\ x\ (WHF_e - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

The ex post analysis calculated energy and demand savings using the standard lighting algorithms, updated with parameter values verified through our evaluation or based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting end use.

The table below compares the ex ante and verified ex post values for key parameters in the calculation.

Site 9004 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verification Source
All	Annual HOU	2,184	2,184	No response from site, assume ex ante value for ex post.
All	Waste Heat Factor (WHFe)	1.07	1.09	No response from site, assume TRM C&I average value.
All	IFkWh	0.0	0.17	Project application confirmed that primary heating fuel is electric, unsure if electric resistance (ER) or heat pump (HP), assumed average from TRM.

Results

The evaluation team estimated savings of 1,712 kWh across all the measures implemented with this project, or 86% of the ex ante estimates of annual energy savings of 1,991 kWh.

Site 9004 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1	1,991	1,712	86%	0.38	0.33	86%
Total	**1,991**	**1,712**	**86%**	**0.38**	**0.33**	**86%**

Reasons for Discrepancies

- The evaluation team increased the WHF value from 1.07 to 1.09. Ex ante savings use an average value of 1.07 based on the previous TRM "C&I Average" value. The current TRM uses 1.09 for the current "C&I Average" value. The evaluation team used the current C&I Average value because the building type, a church, did not fit within the existing building type categories.
- Ex ante savings did not include a heating penalty. The evaluation team confirmed based on the project application that primary heating fuel is electric. Whether the heating system is electric resistance (0.24) or heat pump (0.1) could not be confirmed, so an average of (0.17) from TRM was used.

Other Findings and Recommendations

- N/A

Site ID: 9005 (Custom Lighting)

Project Description

This project replaced existing incandescent and halogen lamps with new LED lamps for a train lighting system. Energy savings are achieved through the improved efficiency of the lighting equipment, and additional energy savings are achieved through interaction with the HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9005 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 - Exterior	Lighting	99,952	13.79
EEM-2 - Exterior	Lighting	118,617	16.36
EEM-3 - Interior	Lighting	522	0.10
EEM-4 - Interior	Lighting	2,952	0.56
EEM-5 - Exterior	Lighting	14,936	2.06
Total (calculated ex ante)		**236,978**	**32.87**
Total (claimed ex ante, value used for comparisons)		**235,599**	**32.67**

Data Collection

The evaluation team reviewed project documentation including the project application form, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team contacted facility personnel in January 2022 and collected the following verification data over e-mail: confirmation of the installed lighting systems, building type, operating schedule, annual hours of use (HOU) for the lighting equipment, primary heating and cooling equipment, and primary heating fuel source.

Analysis

The ex ante savings calculations were partly unclear. The evaluation team could not exactly replicate the claimed ex ante savings value but was able to create a similar total savings value. The claimed ex ante value of 235,599 kWh is used in this report for comparisons to ex post.

The ex ante savings estimates are calculated using standard lighting savings algorithms using estimated lighting system HOU and an average HVAC interaction factor of 1. The ex ante calculations use existing conditions as baseline and assume an annual HOU for the lighting system to be 8,760 hours per year.

$$kWh_{savings} = \left(Qty_{baseline} x\ Watts_{baseline} - Qty_{post} x Watts_{post}\right) x\ HOU\ x\ (WHF_e - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

The ex post analysis calculated energy and demand savings using the standard lighting algorithms, updated with parameter values verified through our evaluation or based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting enduse (for interior lighting) and the miscellaneous enduse (for exterior EEMs).

The table below compares the ex ante and verified ex post values for key parameters in the calculation.

Site 9005 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verification Source
Interior EEM 3, 4	Waste Heat Factor (WHFe)	1.00	1.09	Confirmation with site contact; interior location with air conditioner. Use TRM C&I average.
Exterior EEM 1, 2, 5	Waste Heat Factor (WHFe)	1.00	1.00	Confirmation with site contact; exterior location.
Interior EEM 3, 4	IFkWh	0.0	0.24	Confirmation with site contact; interior location with electric heating.
Exterior EEM 1, 2, 5	IFkWh	0.0	0.0	Confirmation with site contact; exterior location.
Exterior EEM 1, 2 ,5	Annual HOU	8,760	8,760	Confirmation with site contact confirmed ex ante hours.
EEM-3	Annual HOU	1,000	1,000	Confirmation with site contact confirmed ex ante hours.
EEM-4	Annual HOU	4,300	4,300	Confirmation with site contact confirmed ex ante hours.
EEM-5	Watts_post	1.5	1.1	Document review of spec sheets and invoices.

Results

The evaluation team estimated savings of 236,843 kWh across all the measures implemented with this project, or effectively 100% of the ex ante estimates of annual energy savings of 235,599 kWh. Individually, ex post measure values for EEM 3, 4, and 5 differ from ex ante but average to the total realization rate of effectively 100%.

Site 9005 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1 - Exterior	99,952	99,952	100%	13.79	13.79	100%
EEM-2 - Exterior	118,617	118,617	100%	16.36	16.36	100%
EEM-3 - Interior	444	522	85%	0.10	0.08	85%
EEM-4 - Interior	2,509	2,952	85%	0.56	0.48	85%
EEM-5 - Exterior	15,321	14,936	103%	2.06	2.11	103%
Total (calculated)	**236,978**	N/A	N/A	**32.87**	N/A	N/A

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Total (claimed ex ante)	235,599	236,843	100%	32.67	32.82	100%

Reasons for Discrepancies

- The evaluation team increased the WHFe value from 1.00 to 1.09 for interior EEMs. Ex ante savings did not include the WHFe in their calculations. Ex post included the current TRM value of 1.09, the "C&I Average" value, building type (train cars) did not fit within the existing building type categories.
- The evaluation team increased the IFkWh value from 0.0 to 0.24 for interior EEMs. Ex ante savings did not include a heating penalty. The evaluation team confirmed in the project application that primary heating fuel is electric. Whether the heating system is electric resistance (0.24) or heat pump (0.1) could not be confirmed, so an ex post use an average of TRM values for the two electric heating types (0.17).
- While verifying parameters, the evaluation team noted a discrepancy in the EE input watt value for EEM-5. The ex ante value is 1.5W while the spec sheet for this parameter only shows the ex post value of 1.1W.

Other Findings and Recommendations

- N/A

Site ID: 9006 (Custom Lighting)

Project Description

This project replaced existing CFL lamps with new LED lamps for a lighting system that operates continuously (8,760 hours per year) at a healthcare building housing a continuing care retirement community. Energy savings are achieved through the improved efficiency of the lighting equipment, and additional energy savings are achieved through interaction with the HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9006 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1	Lighting	228,472	43.40
EEM-2	Lighting	1,584	0.30
	Total	**230,056**	**43.70**

Data Collection

The evaluation team reviewed project documentation including the project application form, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team contacted facility personnel in December 2021 and January 2022 and collected the following verification data over e-mail: confirmation of the installed lighting systems, building type, operating schedule, annual hours of use (HOU) for the lighting equipment, primary heating and cooling equipment, and primary heating fuel source.

Analysis

The ex ante savings estimates are calculated using standard lighting savings algorithms using estimated lighting system HOU and an HVAC interaction factor of 1.07. The ex ante calculations use existing conditions as baseline and assume the annual HOU for the lighting system to be 8,760 hours per year.

$$kWh_{savings} = \left(Qty_{baseline} x\ Watts_{baseline} - Qty_{post} x Watts_{post}\right) x\ HOU\ x\ (WHF_e - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

The ex post analysis calculated energy and demand savings using the standard lighting algorithms, updated with parameter values verified through our evaluation or based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting enduse.

The table below compares the ex ante and verified ex post values for key parameters in the calculation.

Site 9006 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verification Source
All	Annual HOU	8,760	8,760	Confirmed via e-mail communication with the facility.
All	Waste Heat Factor (WHFe)	1.07	1.21	Confirmed building type via site e-mail, TRM category 'outpatient healthcare.'
All	Electric Heating Interaction Factor (IFkWh)	0.0	0.0	Facility personnel confirmed via e-mail that primary heating fuel is natural gas.

Results

The evaluation team estimated savings of 260,157 kWh across all the measures implemented with this project, or 113% of the ex ante estimates of annual energy savings of 230,056 kWh.

Site 9006 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1	228,472	258,365	113%	43.40	49.08	113%
EEM-2	1,584	1,791	113%	0.30	0.34	113%
Total	**230,056**	**260,157**	**113%**	**43.70**	**49.42**	**113%**

Reasons for Discrepancies

- Ex post adjusted the HVAC interaction factor to 1.21 based on building type (Outpatient Health Care). Ex ante used the C&I average value of 1.07. The evaluation team confirmed the building type with site personnel via email.

Other Findings and Recommendations

- N/A

Site ID: 9007 (Custom Lighting)

Project Description

This project replaced existing high pressure sodium (HPS) lamps with new LED lamps for a lighting system at an airport. Energy savings are achieved through the improved efficiency of the lighting equipment. Since the fixtures being replaced are in exterior locations, there are no additional energy savings achieved through interaction with an HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9007 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1	Lighting	375,600	71.35
EEM-2	Lighting	2,352	0.45
EEM-3	Lighting	17,160	3.26
	Total	**395,112**	**75.06**

Data Collection

The evaluation team reviewed project documentation including the project application form, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team made multiple attempts to contact facility personnel in December 2021 and January 2022 to collect verification data but did not receive a response.

Analysis

The ex ante savings estimates are calculated using standard lighting savings algorithms using estimated lighting system hours of use (HOU) and an HVAC interaction factor of 1. The ex ante calculations use existing conditions as baseline and assume the annual HOU for the lighting system to be 3,000 hours per year.

$$kWh_{savings} = \left(Qty_{baseline} x\ Watts_{baseline} - Qty_{post} x Watts_{post}\right) x\ HOU\ x\ (WHF_e - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

The ex post analysis calculated energy and demand savings using the standard lighting algorithms, updated with parameter values verified through evaluation activities or based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting enduse.[4]

The table below compares the ex ante and verified ex post values for key parameters in the calculation.

[4] Although this lighting is in an exterior location, this lighting system does not operate like exterior lighting (which typical only operates when there is low or no daylight).

Site 9007 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verification Source
All	Annual HOU	3,000	3,000	Unable to verify with site contact; assume ex ante value for ex post.
All	Waste Heat Factor (WHFe)	1.00	1.00	Project documentation indicates fixtures are exterior. Assume unconditioned area consistent with ex ante.
All	IFkWh	0.0	0.0	No heating penalty since space is exterior. Consistent with ex ante.

Results

The evaluation team estimated savings of 395,112 kWh across all the measures implemented with this project, or 100% of the ex ante estimates of annual energy savings of 395,112 kWh.

Site 9007 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rates	Ex Ante Gross	Ex Post Gross	Realization Rates
EEM-1	375,600	375,600	100%	71.35	71.35	100%
EEM-2	2,352	2,352	100%	0.45	0.45	100%
EEM-3	17,160	17,160	100%	3.26	3.26	100%
Total	**395,112**	**395,112**	**100%**	**75.06**	**75.06**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- N/A

Site ID: 9008 (Custom)

Project Description

This project installed on/off occupancy sensors to existing lighting equipment in the office spaces of a 24/7 healthcare facility with natural gas heating. Energy savings are achieved through the reduced operation of the lighting equipment and additional energy savings are achieved through interaction with the HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9008 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1. On/Off Occupancy Sensors in Offices	Lighting	92,906	17.65
	Total	**92,906**	**17.65**

Data Collection

The evaluation team reviewed project documentation including the project application form, invoices, equipment specification sheets, and savings calculation workbooks to understand the project scope and details and to verify the equipment purchased and installed.

The evaluation team contacted facility personnel in December 2021 and January 2022 and collected the following verification data over e-mail: confirmation of the installed lighting systems, building type, operating schedule, annual hours of use (HOU) for the lighting equipment, primary heating and cooling equipment, and primary heating fuel source.

The evaluation team conducted a site visit on February 2, 2022, to verify the installed occupancy sensors and collect information about the connected lighting equipment. During the site visit, the field engineer confirmed that most lighting throughout the building was controlled by occupancy sensors. The site contact confirm that occupancy rates have been lower due to COVID-19.

Analysis

The ex ante savings calculations are unclear. The project application form provides the project savings as the difference between a baseline case (without occupancy sensors) and proposed base (with occupancy sensors) and describes other occupancy sensor measures that were not cost-effective. The project application form also provides a project description with some additional information about the project. However, the project documentation does not include any calculations showing how the baseline case and proposed case consumption were calculated, and the details in the application project description are not consistent with the reported ex ante savings.

Upon request, the implementer provided additional information about multiple lighting equipment and sensor projects at this facility, from which the evaluation team could calculate the total lighting connected kW

controlled by the new lighting controls for the office spaces. The table below compares the key parameters used in the ex ante calculations. The sampled project includes only the occupancy sensors in the facility's office spaces.

Site 9008 Key Parameters in Ex Ante Savings Calculation

Location	Baseline kWh	Installed kWh	Savings kWh	Baseline HOU	HOU w/ Occupancy Sensors	Ex Ante % HOU Reduction	Lighting Connected kW
Source	1	1	1	2	2	3	3
Office	235,232	142,326	92,906	3,120	1,888	39%	75.4

Sources: 1. Project Application Form, 2. Additional information provided by implementer, 3. Calculated based on project information

The ex post analysis calculated energy and demand savings using the standard algorithms for lighting controls with verified project-specific information as well as standard assumptions from the Ameren Missouri TRM.

$$kWh_{savings} = kW_{controlled} x\ HOU\ x\ ESF\ x\ (WHF_e - IF_{kWh})$$

The table below compares the key parameters used in the ex ante and ex post calculations, with information on the source for the ex post values.

Site 9008 Verification of Key Parameters

Parameter	Ex Ante	Ex Post	Verification Source
Connected kW in office spaces	75.4	75.4	Calculated based on project information
Annual HOU	3,120	3,120	Site contract information about building occupancy schedules and previous lighting controls
HOU Reduction with Occ Sensors	39%	24%	TRM Energy Savings Factor (ESF) for Occupancy Sensors
HOU with Occupancy Sensors	1,888	2,371	Ex ante based on project application files; ex post based on TRM ESF value.
WHFe	1.00	1.09	TRM value for C&I Average Building
IFkWh	0.0	0.0	No heating penalty since space is exterior. Consistent with ex ante.

Results

The evaluation team estimated savings of 61,537 kWh through this project, 66% of the ex ante annual energy savings of 92,906 kWh.

Site 9008 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1	92,906	61,537	66%	17.65	11.69	66%
Total	**92,906**	**61,537**	**66%**	**17.65**	**11.69**	**66%**

Reasons for Discrepancies

- Ex ante savings assume an HOU reduction of 39% for office spaces, though the project description states 20% reduction. Ex post calculations use the prescriptive TRM value 24% HOU reduction for occupancy controls.
- Ex post used updated C&I Average WHF of 1.09; based on our review of the project documentation, it appears the ex ante analysis used a WHF value of 1.00.

Other Findings and Recommendations

- N/A

Appendix D. Desk Review and Onsite Reports: Custom Incentive Program, HVAC End Use

The evaluation of Custom HVAC projects included desk reviews and onsite visits for a sample of 14 projects. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Summary of Custom HVAC Project Reviews

Site ID	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
		Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
9009	Desk review and onsite visit	301,668	318,413	106%	133.94	141.37	106%
9010	Desk review	570,350	383,740	67%	253.23	170.37	67%
9011	Desk review with phone verification	300,663	300,663	100%	133.49	133.49	100%
9012	Desk review	225,917	225,917	100%	100.30	100.30	100%
9013	Desk review with phone verification	60,606	64,550	107%	55.19	58.78	107%
9014	Desk review	2,006	599	30%	0.89	0.27	30%
9015	Desk review with phone verification	46,239	22,439	49%	42.11	20.43	49%
9016	Desk review and onsite visit	3,268,489	3,268,489	100%	1,451.15	1,451.15	100%
9017	Desk review with phone verification	2,173,141	2,173,141	100%	964.84	964.84	100%
9018	Desk review with phone verification	35,854	35,854	100%	15.92	20.64	130%
9019	Desk review with phone verification	52,879	52,879	100%	48.16	48.16	100%
9020	Desk review and onsite visit	219,109	209,414	96%	102.18	92.98	91%
9021	Desk review and onsite visit	398,632	326,998	82%	176.99	145.18	82%
9022	Desk review with phone verification	71,036	71,036	100%	61.31	61.31	100%

Site ID: 9009 (Custom HVAC)

Project Description

This project installed multiple HVAC system improvements at a 24/7 municipal building with natural gas heat, following a retro-commissioning study and optimization project. The energy efficiency measures (EEMs) installed include variable speed drives (VSDs) on chilled water and condenser water pumps (including new chilled water pumps), optimization of the air handling unit (AHU) economizer controls, and implementation of schedules for interior and garage exhaust fans. Energy savings are achieved through reduced pump and fan energy due to the VSDs and scheduling, and reduced cooling load due to the economizer operation and reduced equipment waste heat.

The table below describes the EEMs and ex ante gross savings claimed for this project.

Site 9009 Ex Ante Savings Summary

Measure Name	End use Category	Ex Ante Gross	
		kWh	kW
EEM-1 Chilled Water System Improvements (VSD on Pumps)	HVAC	150,900	67.00
EEM-2 Optimize AHU Economizer Controls	HVAC	91,061	40.43
EEM-3 Exhaust Fan Schedules	HVAC	59,707	26.51
	Total	**301,668**	**133.94**

Data Collection

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

The evaluation team conducted a site visit in February 2022 to collect information on installed equipment, verify the installation of the VSDs, and review operating schedules and setpoints. During the site visit, the facility was in heating mode, so the chiller plant was not operating. The onsite engineer collected photos of equipment and screenshots from the facility building automation system (BAS). During the site visit, the site contact confirmed that facility operations have not been impacted by COVID-19 and that there have been no substantive changes to the facility operations since the project was implemented.

The evaluation team also collected and reviewed billing data from January 2019 through December 2021. The project completion form was signed in November 2021, so there is limited post-implementation consumption data.

Analysis

The ex ante project savings were estimated through spreadsheet analysis, comparing baseline and proposed equipment operation and energy consumption. Savings for all measures were estimating using standard engineering assumptions to estimate equipment power at various temperature and/or load bins and operating hours to determine baseline and efficient-case energy consumption.

The ex post analysis reviewed and adopted the ex ante savings calculation methods, updating equipment and operating parameter values verified through evaluation activities or based on current TRM specifications. The

table below compares the ex ante and ex post values for key parameters in the savings calculation and shows the source of ex post values.

Site 9009 Key Parameters for Ex Ante and Ex Post Savings

Key Parameter	Ex Ante	Ex Post	Source
CHWP HP and Efficiency	20HP, UNK	20HP, 92.4% Efficiency	Onsite inspection
CWP HP and Efficiency	30HP, UNK	30HP, 92.4% Efficiency	Onsite inspection
CHWP VFD	VFD Installed, operate when OAT > 55 at reduced speed	VFD Installed, not operating at time of site visit due to winter season	Onsite inspection
CWP VFD	VFD Installed, operate when OAT > 55 at reduced speed	VFD Installed, not operating at time of site visit due to winter season	Onsite inspection
Exhaust Fan Schedules	Reduced 50% from baseline	Verified scheduling for a sample of fans	Onsite inspection

The evaluation team updated the savings calculations based on verified parameters and re-calculated savings for each measure. Since, in most cases, the evaluation findings verified the proposed energy efficiency measures, the evaluation adjustments resulted in only a small increase in savings.

Results

The table below shows the evaluated energy and demand savings for this project. The evaluation findings verified that the project was implemented as proposed but was not able to validate cooling season performance data. Based on the project document review and available data collection, the evaluation team made minor adjustments to the ex ante savings estimate, resulting in a 106% realization rate.

Site 9009 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Chilled Water System Improvements (VSD on Pumps)	150,900	167,644	111%	67.00	74.43	111%
Optimize AHU Economizer Controls	91,061	91,061	100%	40.43	40.43	100%
Exhaust Fan Schedules	59,707	59,707	100%	26.51	26.51	100%
Total	**301,668**	**318,413**	**106%**	**133.94**	**141.37**	**106%**

Reasons for Discrepancies

- The ex ante calculation did not include pump efficiency in the savings calculations. The evaluation team verified the rate efficiency of the installed chilled water (CHW) pumps, estimated efficiency of the baseline pump, and included efficiency in the savings calculation, which resulted in a small increase in savings.

Other Findings and Recommendations

- Due to the timing of the project completion (November 2021) and evaluation analysis (Winter 21/22), the evaluation team was not able to observe the cooling equipment in operation or collect key operating and performance data to validate the actual savings achieved by the project. Ameren Missouri should consider the timing of evaluation activities for seasonal projects to ensure evaluations can assess savings during the season(s) those savings occur.

Site ID: 9010 (Custom HVAC)

Project Description

This project implemented five HVAC controls measures at a 163,000 square-foot, faith-based facility with natural gas heating. The controls measures include reducing the equipment schedule and implementing space temperature setbacks, demand control ventilation (DCV), optimum start, fan pressure optimization, and supply air (SA) reset controls. The project achieves energy savings through reduced equipment runtimes and improved overall efficiency of the HVAC system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9010 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1: Trimmed schedule and setback	HVAC	528,931	234.84
EEM-2: DCV (Cooling)	HVAC	4,952	2.20
EEM-3: DCV (Ventilation)	HVAC	9,903	4.40
EEM-4: Optimum start, fan pressure optimization, SA Reset (Cooling)	HVAC	6,641	2.95
EEM-5: Optimum start, fan pressure optimization, SA Reset (Ventilation)	HVAC	19,923	8.85
	Total	**570,350**	**253.23**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings. The project materials included the Trane TRACE simulation files (which account for the majority of project savings) but did not include the energy calculation workbook used to estimate the DCV savings.

The invoice details confirmed the contractor replaced 30 existing CO_2 sensors and programmed the facility rooftop units to control the outdoor air (OA) damper based on measured CO_2 levels and describes the installation and programming of upgraded building management systems (BMS) controls.

The project invoices indicate the project was completed in October 2021. The evaluation team reviewed facility consumption data from January 2019 through December 2021. Due to the date of project implementation (late 2021), there is limited post-implementation consumption data.

The evaluation team made multiple attempts to contact facility personnel during the evaluation period to collect verification data but did not receive a response. As a result, the evaluation relied on available project documentation, which included the energy simulation models and post-implementation building automation system (BAS) screenshots, and facility billing data.

Analysis

The ex ante savings estimates use a combination of methods to estimate energy savings achieved by the projects. The table below shows the key assumptions and savings estimation methods for each measure. The total estimated savings for all EEMs are 56% of the modeled baseline HVAC consumption.

Site 9010 Ex Ante Savings Summary

Measure Name	% Ex Ante Savings	Baseline	Proposed	Savings Estimation Method
EEM-1: Trimmed schedule and setback	92.7%	Occupancy schedule: 7 days per week 4:30 a.m. to 7:00 p.m.	Occupancy schedule: 5 days per week 4:30 a.m. to 6:00 p.m. Implement setback setpoints	Trane TRACE energy simulation
EEM-2: DCV (Cooling)	2.6%	No DCV	DCV	Estimated at 2.5% of baseline HVAC using CUS AirTest spreadsheet
EEM-3: DCV (Ventilation)		No DCV	DCV	Estimated at 2.5% of baseline HVAC using CUS AirTest spreadsheet
EEM-4: Optimum start, fan pressure optimization, SA Reset (Cooling)	4.7%	EMS controls not implemented	Optimum start, fan pressure optimization, SA reset	Estimated at 4.7% of baseline HVAC
EEM-5: Optimum start, fan pressure optimization, SA Reset (Ventilation)		EMS controls not implemented	optimum start, fan pressure optimization, SA reset	Estimated at 4.7% of baseline HVAC

EEM-1 accounts for 93% of the ex ante savings, which were estimated using Trace TRACE simulation software. The evaluation team reviewed the simulation model input and output files to confirm the modeled savings reflect the measure as proposed and implemented. The table below shows the key parameters used to model the annual energy savings for EEM-1. The modeled savings are based on adjustments to the occupancy schedules (primary to remove occupancy during the weekends) and implementation of temperature setbacks and temperature drifts. The simulations assume no DCV implemented in either the baseline or proposed case.

Site 9010 Key Parameter Inputs for Energy Modeling

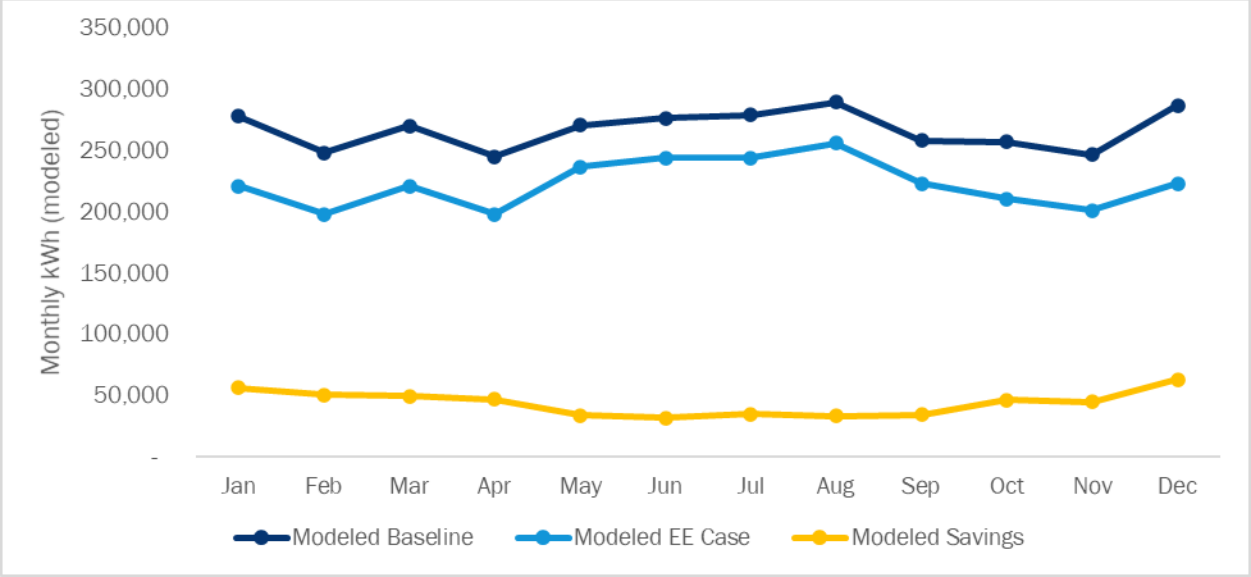
Modeling Parameter	Baseline Model (Alternative 1)	Proposed Model (Alternative 2)
Room Information, People Schedule	Scheduled 7 days per week 7:00 a.m. to 5:00 p.m. 5% unoccupied	Modified schedule for 5 days per week only 7:00 a.m. to 5:00 p.m. 5% unoccupied
Room Information, Design Cooling DB / Drift Point	73°F / 73°F	74°F / 80°F
Room Information, Design Heating DB / Drift Point	73°F / 73°F	71°F / 60°F

Modeling Parameter	Baseline Model (Alternative 1)	Proposed Model (Alternative 2)
System Information	No DCV	No DCV

According to notes in the project application, ex ante savings for the remaining EEMs rely on a case study (not provided with project materials) that showed "18% HVAC energy savings on a VAV [variable air volume] system" in the same weather zone. Ex ante savings multiple this 18% savings factor by 40% (percentage of facility served by VAV) to estimate savings as 7.2% of total HVAC energy. The implementer assigned 2.5% to the DCV measure (based on a "AirTest" spreadsheet calculation not provided with project materials) and assigned the remaining 4.7% to the remaining EMS controls measure (optimal start, fan pressure optimization, and SA temperature reset). It is unclear whether the ex ante calculations take into account interactive effects with the modeled EEM-1.

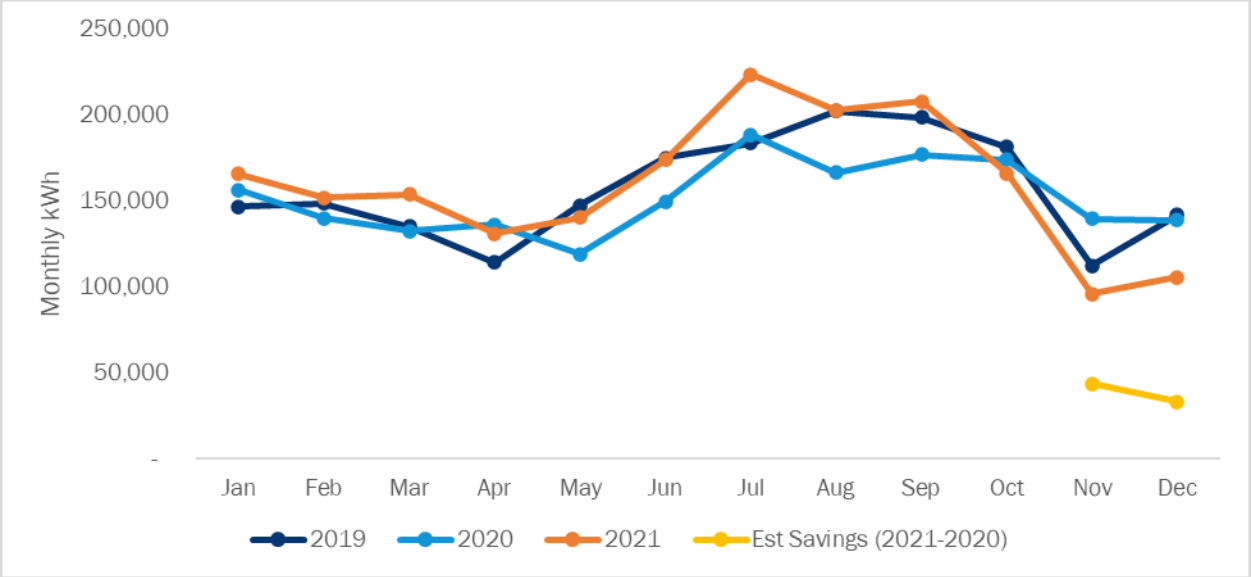
The figure below shows the modeled monthly whole building energy consumption for the baseline case (existing building), proposed case (with EEM-1 implemented), and the modeled savings. The modeling outputs show monthly savings range between 32,000 kWh and 64,000 kWh with an average monthly savings of 44,000 kWh for a normal weather year. The total modeled savings are 52% of the modeled baseline consumption for the impacted equipment.

Site 9010 Modeled Monthly Energy Consumption for Baseline and Efficient Models



The project completion form was signed in November 2021, so the evaluation team has limited post-installation consumption data to examine. The figure below shows the monthly consumption data for 2019, 2020, and 2021, including the two months (November and December 2021) of post-installation performance. The post-installation months do show an average reduction in energy consumption comparable but lower than the modeled savings for the same month.

Site 9010 Monthly Facility Consumption for 2019 through 2021



The evaluation team compared the pre- and post-implementation energy consumption for the months of November and December to assess the modeled ex ante savings for the same months. The observed reduction in building consumption is lower than estimated, so the evaluation team applied an adjustment to the ex ante savings.

Results

The table below shows the evaluated energy and demand savings for this project. The evaluation's analysis of pre- and post-implementation billing data found that actual savings are 67% percent of estimated ex ante savings.

Site 9010 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1: Trimmed schedule and setback	528,931	N/A	N/A	234.84	N/A	N/A
EEM-2: DCV	4,952	N/A	N/A	2.20	N/A	N/A
EEM-3: DCV	9,903	N/A	N/A	4.40	N/A	N/A
EEM-4: Optimum start, fan pressure optimization, SA Reset	6,641	N/A	N/A	2.95	N/A	N/A
EEM-5: Optimum start, fan pressure optimization, SA Reset	19,923	N/A	N/A	8.85	N/A	N/A
Total	**570,350**	**383,740**	**67%**	**253.23**	**170.37**	**67%**

Reasons for Discrepancies

- Ex post savings are based on analysis of two months of post-implementation consumption data, which show a significant reduction in energy consumption compared to pre-implementation operation, but a smaller reduction than estimated through the ex ante energy model and calculations.
- Ex ante savings for EEMs 2,3,4, and 5 are based on a case study for a similar project in another building and not based on project-specific analysis. It is also unclear whether the ex ante savings for these measures account for interactivity with EEM-2 and may result in overstated savings.

Other Findings and Recommendations

- The savings assumptions use case study information from other sites and rule-of-thumb assumptions to estimate energy savings. For this project that estimated energy savings exceeding 30% of baseline facility consumption and exceeding 50% of baseline HVAC consumption, Ameren Missouri should require consider validating savings with post-installation data review.

Site ID: 9011 (Custom HVAC)

Project Description

This project upgraded existing HVAC equipment and controls to improve the overall HVAC system efficiency at an 85,000 square foot office building with electric heating. Upgrades to the building energy management system (EMS) hardware and control programming included demand control ventilation (DCV), space temperature setbacks for occupied and unoccupied periods, optimum start/stop controls, supply air resets, and fan pressure optimization. Energy savings are achieved through the overall improved efficiency of the HVAC system in supplying conditioned air to the building spaces.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9011 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
HVAC Controls / EMS	HVAC	300,663	133.49
	Total	**300,663**	**133.49**

Data Collection

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

The evaluation team contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The site contact described the implemented system programming and provided photos of the installed electric boiler.

The evaluation team also collected and reviewed billing data, includes several months of post-installation consumption data. The project completion form was signed in August 2021, and the evaluation team reviewed consumption data from January 2019 through January 2022.

Analysis

Ex ante savings were estimated using Trance TRACE 700 building simulation software. The modeled annual kWh savings are 21% of the modeled whole building baseline consumption and 37% of the modeled baseline consumption for the impacted HVAC equipment. The table below shows the modeled savings by equipment. Almost two-thirds (64%) of the modeled ex ante savings are at the electric boiler, 21% of the energy savings are at the rooftop unit (RTU), and 12% are at the main cooling fan.

Site 9011 Ex Ante Savings Summary

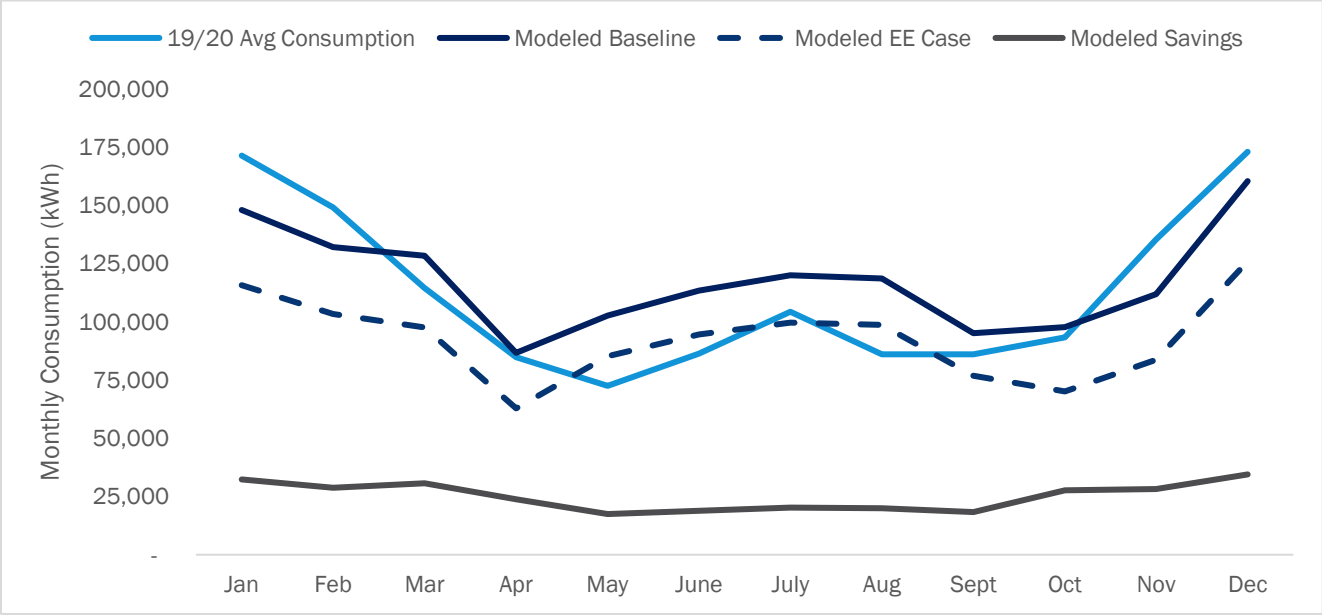
Equipment	Modeled Annual kWh Savings	% of Total kWh Savings
Direct Exchange (DX) Cooled RTU	62,271	21%
Condenser Fan for RTU	5,384	2%
Control Panel & Interlocks for RTU	123	0%

Equipment	Modeled Annual kWh Savings	% of Total kWh Savings
Electric Boiler	193,253	64%
Constant Volume (CV) Hot Water Pump	3,845	1%
Main Cooling Fan	35,788	12%

The evaluation team reviewed the energy model input and output files and compared the modeled savings to the building's actual baseline consumption. The figure below shows the actual building consumption (2019–2020 average), modeled baseline and energy-efficient case (EE case) consumption, and modeled savings by month. The modeled baseline consumption was within 5% of the 2019–2020 average actual consumption, and the modeled savings are 23% of actual baseline consumption for both 2019 and 2020.

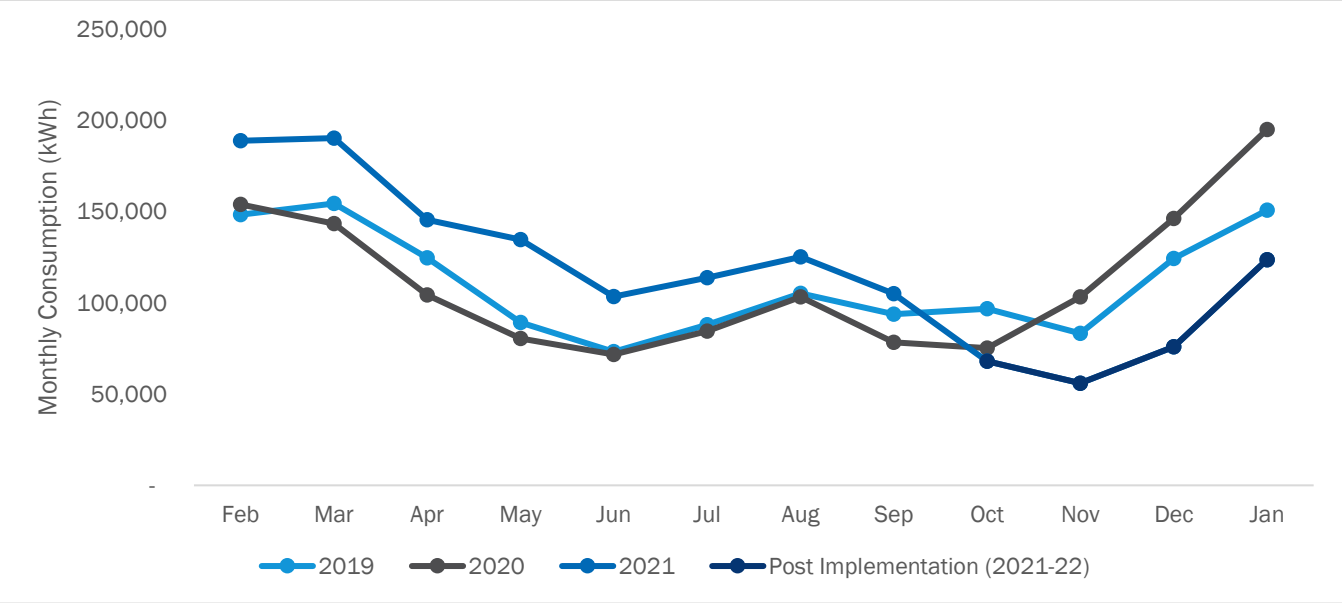
The comparison shows the modeled baseline slightly understates winter heating energy and overstates cooling energy. This suggests that the ex ante savings may be understated in the winter and overstated in the summer.

Site 9011 Comparison of Modeled and Actual Facility Consumption



The evaluation team the examined consumption data to identify savings for the post-implementation period. The figure below shows actual consumption data for the months before and after project implementation. The post-implementation consumption shows a clear reduction compared to baseline (pre-project consumption) for the same months.

Site 9011 Facility Consumption Data for 2019 through 2021



The evaluation team compared the total modeled savings to the difference between 2019 and 2021–2022 consumption for the four post-implementation months and found the actual winter season savings were about 107% of the modeled winter season savings. This finding is consistent with our expectation of understated winter season savings. Since we do not have data to assess summer season savings and whether the modeled summer savings were overstated, we do not apply the 107% winter realization rate to the total modeled savings. Rather, we use this consumption data review combined with the verification of implemented measures as a verification that the modeled savings are appropriate, resulting in 100% realization rate for the modeled annual energy savings.

Results

The table below shows the evaluated energy and demand savings for this project. Based on the project document review, data collection, and consumption data review, the evaluation team confirmed the ex ante savings estimate, resulting in a 100% realization rate.

Site 9011 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
HVAC Controls / EMS	300,663	300,663	100%	133.49	133.49	100%
Total	**300,663**	**300,663**	**100%**	**133.49**	**133.49**	**100%**

Reasons for Discrepancies

N/A

Other Findings and Recommendations

- N/A

Site ID: 9012 (Custom HVAC)

Project Description

This project installed a new chiller plant controller to optimize chiller plant efficiency for cooling at a 24/7 municipal building with electric heating. The same facility also installed new high-efficiency air-conditioning equipment through the Ameren Missouri Standard Program; those measures and savings are not included in this Custom project evaluation.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings for this project.

Site 9012 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
HVAC Controls / EMS	HVAC	225,917	100.30
	Total	**225,917**	**100.30**

Data Collection

The evaluation team reviewed all available project documents to understand the scope of the project, including the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings. The evaluation team also collected and reviewed billing data to compare whole building consumption before and after the project implementation.

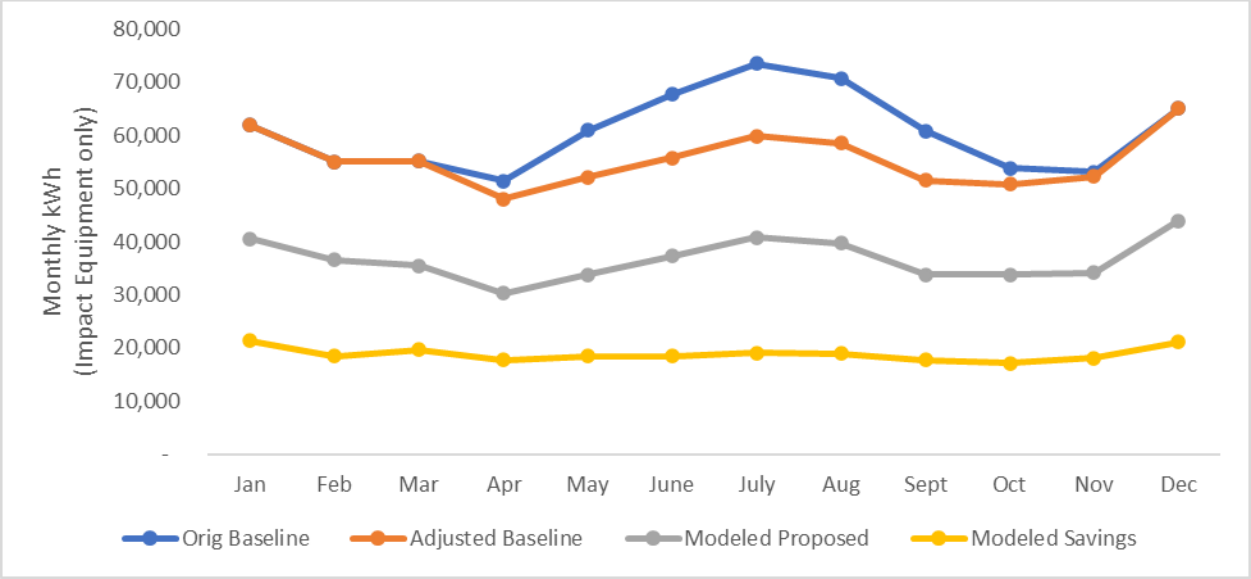
The facility assessment, developed by the manufacturer, documented that the existing building automation system (BAS) did not have occupancy schedules, temperature schedules, or floor plan graphics (to facility building energy management). The evaluation team reviewed post-installation BAS screenshots that show daily building occupancy schedules, occupied and unoccupied space temperature setpoints for variable air volume (VAV) and fan terminal unit (FTU) equipment, and facility floor plans that map HVAC equipment to building spaces.

The evaluation team made multiple attempts to contact facility personnel in December 2021 and January 2022 but did not receive and response. As a result, the evaluation relied on available project documentation, which included the energy simulation models and post-implementation BAS screenshots, and facility billing data.

Analysis

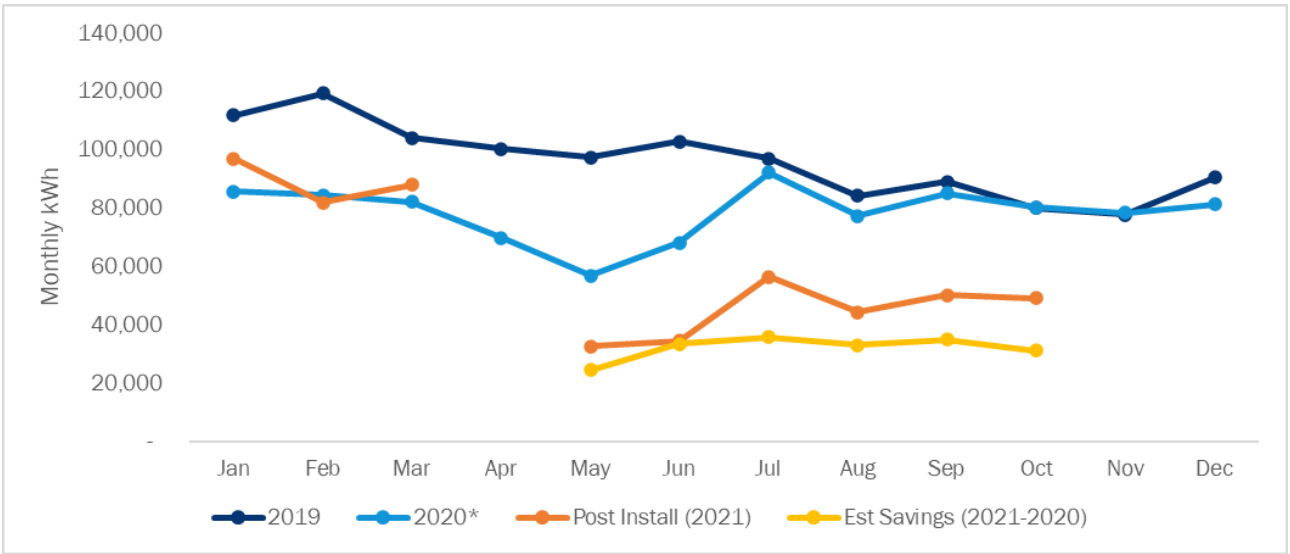
Ex ante savings were estimated using Trane TRACE simulation software. The figure below shows the modeled original baseline, adjusted baseline, proposed case (with the custom HVAC upgrade), and energy savings by month. The evaluation team confirmed that the adjusted baseline takes into account the cooling equipment upgrades supported by the standard program, so the custom project savings account for the BAS upgrades on the updated equipment. The figure shows that the modeled savings occur throughout the year in both cooling and heating seasons.

Site 9012 Modeled Electricity Consumption and Savings



The project invoice was dated July 2021, and the project completion form was signed in August 2021. The evaluation team collected and reviewing facility consumption data before and after the project implementation. The figure below compares the pre-implementation consumption data from 2019 through 2020 and the first part of 2021. The post-installation consumption data starting in May 2021 shows a significant reduction in facility consumption. Comparing the 2020 and 2021 consumption data for the months of May through October shows an average monthly savings around 30,000 kWh, higher than the estimated monthly kWh savings from the Custom HVAC project (see figure above). The actual energy savings include the Custom HVAC project savings and the Standard HVAC project savings.

Site 9012 Comparison of Pre- and Post-Installation Electricity Consumption



Based on review of the ex ante modeling inputs and outputs, verification through BAS screenshots that the measures were installed as proposed, and review of pre- and post-installation monthly billing data, the evaluation team confirmed the energy savings estimated from the ex ante modeling.

Results

The table below shows the evaluated energy and demand savings for this project. Based on the project document review and data collection, the evaluation team confirmed the ex ante savings estimate, resulting in a 100% realization rate.

Site 9012 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
HVAC Controls / EMS	225,917	225,917	100%	100.30	100.30	100%
Total	**225,917**	**225,917**	**100%**	**100.30**	**100.30**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- The facility accurately modeled the adjusted baseline to account for multiple energy efficiency interactive measures implemented at the facility.

Site ID: 9013 (Custom HVAC)

Project Description

The project involved the replacement of a 65-ton chiller with a new high-efficiency chiller and the implementation of an enthalpy economizer at a 36,000 square foot government administrative office building with natural gas heating. Energy savings are achieved by the improved efficiency of the new chiller and reduced cooling load enabled by the enthalpy economizer.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9013 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Chiller Replacement	HVAC	48,184	21.39
EEM-2 Enthalpy Economizer	HVAC	12,422	5.52
	Total	**60,606**	**26.91**

Data Collection

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

The evaluation team also collected and reviewed billing data from January 2019 through October 2021. This project was completed in September 2021 and the primary energy savings are achieved through cooling load reduction; however, the limited months of post-implementation data do not include the majority of cooling season when the project savings are achieved. Also, the ex ante savings are less than a percentage of the customer's annual electricity consumption, so any post-implementation energy impacts would not be discernable at the electric meter.

The evaluation team contacted the site contact to discuss the project details and current facility operations and had multiple conversations with the facility engineer. Through these discussions, the evaluation team collected the following information:

- The building operates primarily as an administrative building with typical office occupancy hours and operates year round.
- Building occupancy schedules are programmed into the building automation system (BAS), but were still not in use as of March 1, 2021, due to equipment challenges with winter temperatures. The facility manager intends to implement the programmed schedules when these issues are addressed. The programmed schedules to be implemented are:
  - Occupied, 7:00 a.m. to 7:00 p.m. (12 hours per day), Monday through Sunday
  - Unoccupied, 7:00 p.m. to 7:00 a.m. (12 hours per day), Monday through Sunday

- The interior space occupied temperature setpoints range is 70°F–74°F. The BAS is programmed with the following unoccupied setpoints:
  - 82°F for Unoccupied cooling
  - 60°F for Unoccupied heating
- The new chiller plant matched the make/model information described in the project documentation.
- The chiller is available year round to serve cooling loads and operates when the outside air temperature is above 60°F.
- The Sequence of Operation information for the economizer describes the following programming:
  - The enthalpy economizer is disabled (outdoor air [OA] dampers at minimum position) when the OA enthalpy exceeds the RA enthalpy
  - The enthalpy economizer is enabled when the OA enthalpy is lower than the RA enthalpy. If the OA temperature is above 55°F, the mixed air dampers are set to 100% OA. If the OA temperature is below 55°F, the mixed air dampers modulate to maintain the mixed air temperature setpoint (SAT minus 2°F).
- The OA ductwork and economizer equipment were still being installed in January 2022. This installation was completed during the evaluation period, though the cooling system overall was still being commissioned.

The site contact also provided the following data:

- Two days of trend data showing chiller operation on February 28 and March 1, when outside air temperatures were high enough to call for cooling. Trend points include chiller power, chiller load, and entering and leaving chilled water temperatures.
- BAS screenshot showing current system operations. The BAS screenshot showed the system setpoints, demonstrated that the economizer was enabled when conditions called for economizing, and showed the chiller plant load.

Analysis

Ex ante savings for both EEMs are estimated using separate weather bin analyses for each EEM, with EEM-1 (chiller replacement) modeled as part of the baseline for EEM-2 (enthalpy economizer) to account for interactive effects between the measures. The ex ante analyses use TMY3 weather data for the appropriate weather zone to estimate annual energy savings for a typical weather year.[5]

The evaluation team reviewed the bin analysis and compared the key parameter values in the ex ante analysis to verified information collecting through evaluation activities. Based on this comparison the evaluation team made two adjustments to the bin analysis:

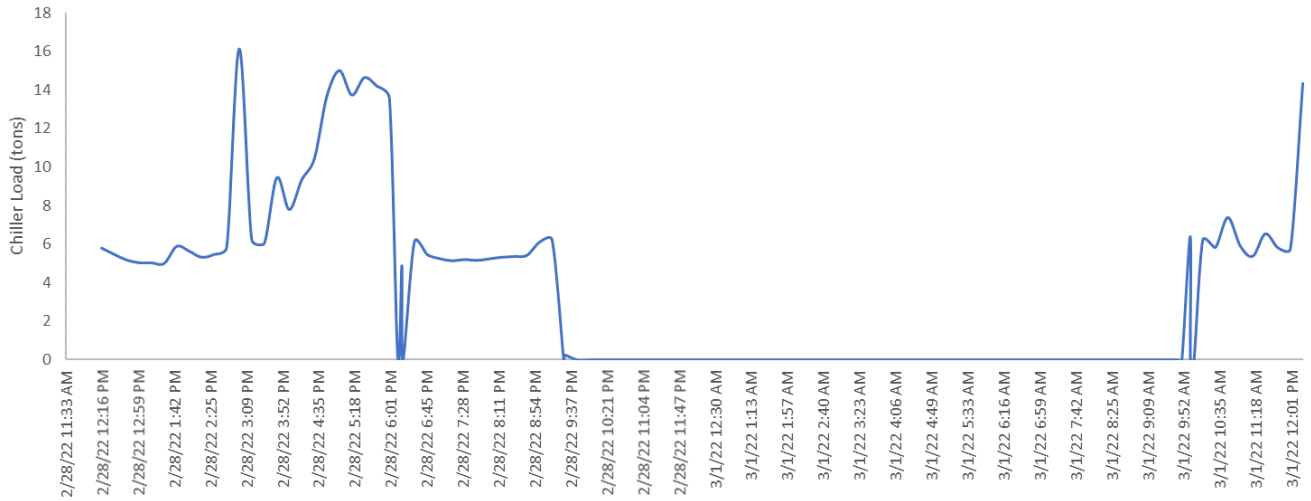
- Decreased the occupied cooling setpoint from 74°F (ex ante) to 72°F (ex post), based on the site contact confirmation of interior occupied space cooling setpoints ranging between 70°F and 74°F.

[5] Typical Meteorological Year (TMY) data sets, including TMY3 data, are available from the National Solar Radiation Database (NSRDB) here: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3.

- Decreased the unoccupied cooling setpoint from 85°F (ex ante) to 82°F (ex post), based on the site contact confirmation of unoccupied cooling setpoint.

The evaluation team also compared the cooling loads modeled in the bin analysis to the cooling load observed in the trend data. The figure below shows the building's chiller plant load for a two-day period when temperatures were warm enough to call for cooling. During this period the chiller load ranged between 5 and 16 tons with an average of 7.5 tons when operating. This range is comparable to the modeled cooling loads when outside air temperatures are below 65°F as they were on the days with trend data (February 28 and March 1).

Site 9013 Facility Chiller Load Trend Data



The evaluated team recalculated annual energy savings using the bin analysis calculators for both EEM-1 and calculation demand savings using the Cooling loadshape factor.

Results

The table below shows the evaluated energy and demand savings for this project. The evaluation findings resulted in energy and demand realization rates of 107%.

Site 9013 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1 Chiller Replacement	48,184	51,177	106%	43.88	46.61	106%
EEM-2 Enthalpy Economizer	12,422	13,372	108%	11.31	12.18	108%
Total	**60,606**	**64,550**	**107%**	**55.19**	**58.78**	**107%**

Reasons for Discrepancies

- Ex post adjusted the savings bin analysis based on verified occupied/unoccupied setpoints.

Other Findings and Recommendations

- The OA ductwork and economizer equipment were still being installed when the evaluation team first made contact with the site in January 2022, more than three months after the project completion form was signed in September 2021. The site completed the installation during the evaluation period, so the savings are included in the ex post results; however, the cooling system overall was still being commissioned. Ameren Missouri should review its practices regarding post-installation inspection and determining project completion to ensure energy efficiency measures are fully implemented and achieving the anticipated energy savings.
- The site has a robust BAS system that was able to record trend data, but the system was enabled to record data for only two days. As a result of the evaluation requests, the site contact increased the trend period to be able to record more data in the future. Such trend reports provide valuable information for facility managers to both verify and monitor energy savings and optimize operation. Ameren Missouri should establish a practice of setting up standard trend reports when implementing energy efficiency projects impacting the BAS and connected equipment. Reports should cover four or more weeks and include different parameters (depending on the project) such as cfm, temperature of water or air, air pressure, and/or other key parameters we need to verify for the particular project.

Site ID: 9014 (Custom HVAC)

Project Description

This project implemented an enthalpy economizer on two new 60-ton high-efficiency rooftop units (RTUs) replacing failed HVAC equipment at a 100,000 square foot office building with electric heating. Energy savings are achieved by the reduced ventilation requirements and associated air conditioning and fan energy. The new RTUs received incentives through the Standard HVAC program, so the savings associated with the increased efficiency of the new RTUs are not included in this Custom HVAC project.

The table below describes the energy efficiency measures and ex ante gross savings claimed for this project.

Site 9014 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
Enthalpy economizer	HVAC	2,006	0.89
	Total	**2,006**	**0.89**

Data Collection

The evaluation team reviewed all available project documents to understand the scope of the project, including the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings. We reviewed the project completion form to understanding the installation timing, the equipment specification sheets to collect equipment performance information, and project invoice to confirm the enthalpy economizer was included in the equipment purchase and installation.

The evaluation team made multiple attempts to contact facility personnel during the evaluation period to collect verification data but did not receive a response.

Analysis

Ex ante energy savings are calculated in a workbook designed for outside air ventilation analysis. Although the evaluation team could not access the backend calculations, the evaluation team reviewed the workbook and confirmed that the ex ante savings represent the estimated annual savings for an enthalpy economizer compared to no economizer.

This measure was installed as part of a project "to replace existing rooftop units that are the end of their useful life." Therefore, the baseline equipment for the project is new code-compliant equipment, not existing equipment. The applicable building code for the project location is 2018 IECC, which requires economizers on cooling units larger than 54,000 Btu/h. Since the new air conditioning equipment has a 60-ton cooling capacity, an economizer must be included in the baseline for this measure. For such unitary rooftop equipment, the Ameren Missouri TRM provides the following baseline definition: "The baseline equipment is assumed to be a standard-efficiency air-, water, or evaporatively cooled air conditioner that meets the energy efficiency requirements of local building code."

The ex post analysis recalculated savings using a dry bulb economizer baseline. Since the ex ante workbook was locked, the ex ante team calculated savings in a separate bin analysis. We matched the operating assumptions (e.g., equipment schedules and setpoints) used in the ex ante analysis and used the efficiency of the new high-efficiency RTUs for both the baseline and installed cases. We calibrated setpoints and assumptions to achieve similar savings estimated as the ex ante when comparing a baseline with no economizer to high-efficiency case with enthalpy economizing. Then we updated the baseline to dry bulb economizer to estimate ex post savings. We then calculated demand savings using the HVAC loadshape factor.

Results

The table below shows the evaluated energy and demand savings for this project. The evaluation found zero savings for the project because the economizer measure is required by code and should be part of baseline.

Site 9014 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
HVAC Controls / EMS	2,006	599	30%	0.89	0.27	30%
Total	**2,006**	**599**	**30%**	**0.89**	**0.27**	**30%**

Reasons for Discrepancies

- Ex post savings used a dry bulb economizer in the baseline; ex ante used no economizer in the baseline. This project was implemented with a new RTU replacing old units at the end of their useful life. The new RTU must comply with code, which requires economizer operation. The energy efficiency project should not claim savings compared to economizer operation since an economizer is required by code.
- Ex post used the efficiency (14.4 IEER) of the new RTU equipment for both the baseline and installed cases. It appears ex ante used a lower efficiency value (9.6) to estimate ex ante savings.

Other Findings and Recommendations

- The ex ante analysis overstated savings by using an inappropriate baseline. This is a common challenge for energy efficiency projects replacing failed equipment, for which program requirements include minimum efficiency requirements consistent with local code. To minimize potential for overstating savings, Ameren Missouri should consider opportunities (e.g., annual training) to improve awareness around baseline requirements to contractors who estimate savings for projects requesting program incentives.
- The ex ante calculation workbook was locked, making it impossible for the evaluation team to review the detailed assumptions and calculation methods used to estimate project savings. This also required the evaluation team to use an alternative calculation approach in the calculation of ex post savings, likely resulting in some savings discrepancy solely due to the calculation approach. Transparency in savings estimation methods is an important requirement for impact evaluation and validation in the program's reported savings. Ameren Missouri should require that transparent and accessible calculation methods are available for sampled evaluation projects.

Site ID: 9015 (Custom HVAC)

Project Description

This project replaced a failed rooftop cooling system serving a large office building with two 75-ton single packaged air conditioners. Energy savings are achieved by the improved efficiency of the new high-efficiency air conditioners compared to new air conditioning equipment that only meets the minimum efficiency requirements.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9015 Ex Ante Savings Summary

Measure Name	Enduse	Ex Ante Gross	
		kWh	kW
Two new 75-ton RTUs replacing failed equipment	Cooling	46,239	42.11
	Total	**46,239**	**42.11**

Data Collection

The evaluation team reviewed all available project documents to understand the scope of the project, including the baseline and proposed equipment and operating conditions.

The evaluation team also collected and reviewed billing data. The project completion form was signed in July 2021.

The evaluation team contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The site contact described the operational details and provided the following data:

- Photos of the installed air conditioner units and nameplates, confirming the make and model information for the new high-efficiency air conditioning units.
- Building automation system (BAS) screenshot showing the following equipment schedules: Occupied 5:00 a.m. to 8:00 p.m. (15 hours per day) and unoccupied 8:00 p.m. to 5:00 a.m. (9 hours per day).
- BAS screenshot showing heating (85°F) and cooling (55°F) supply air setpoints
- BAS screenshot showing occupied zone setpoints of 70°F for heating and 74°F for cooling

Analysis

The ex ante analysis estimated savings using an excel spreadsheet-based 8760 analysis that estimates cooling load and baseline and proposed case energy consumption for each hour of the year. The table below shows key parameter values and assumptions used to estimate ex ante savings.

The evaluation team reviewed the 8760 analysis and compared the key parameter values in the ex ante analysis to verified information collecting through evaluation activities. The table below compares the verified ex post key parameter values to the ex ante assumptions and provides information on the verification source.

The evaluation team recalculated annual energy savings using the 8760 analysis and verified ex post parameter values, and then the evaluation team calculated demand savings using the Cooling loadshape factor.

Site 9015 Comparison of Key Parameter Values

Key Parameter/ Assumption	Ex Ante	Ex Post	Verification Source
Quantity of equipment	2	2	Invoice, site contact interview
Cooling capacity of new equipment	75 tons	75 tons	Photos of installed equipment nameplate, equipment specification sheets
Baseline Code	IECC 2009	IECC 2015	Building codes department for local government in which facility is located
Baseline Efficiency	9.8 SEER/IEER	11 SEER/IEER	Minimum efficiency requirements for appropriate building code
New Efficiency	12.4 SEER/IEER	12.4 SEER/IEER	Photos of installed equipment nameplate, equipment specification sheets
Operating Hours	Monday–Friday 8:00 a.m.–5:00 p.m. (9 hrs) Saturday–Sunday, OFF	Monday–Friday 5:00 a.m.–8:00 p.m. (15 hrs) Saturday–Sunday, OFF	Site contact interview and BAS screenshots

Results

The table below shows the evaluated energy and demand savings for this project. The evaluation findings resulted in energy and demand realization rates of 49%.

Site 9015 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Two new 75-ton RTUs replacing failed equipment	46,239	22,439	49%	42.11	20.43	49%
Total	**46,239**	**22,439**	**49%**	**42.11**	**20.43**	**49%**

Reasons for Discrepancies

- The ex post analysis used IECC 2015 code requirements to determine the minimum efficiency of the baseline equipment; ex ante analysis used IECC 2009. The local government website where the project facility is located confirms that the jurisdiction adopted IECC 2015 in 2017, well before this energy efficiency project was developed. The Ameren Missouri TRM provides the following baseline equipment definition for unitary air conditioning equipment: "In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-, water-, or evaporatively cooled air conditioner that meets the energy efficiency requirements of local building code." This change to the baseline code reduced savings.

- The ex post analysis updated the equipment operating schedule based on verified data, increasing the Monday through Friday operating hours from 9 hours per day (used in the ex ante analysis) to 15 hours per day (used in the ex post analysis). This change increased savings.

Other Findings and Recommendations

- This Custom HVAC project involved the installation of two new 75-ton air conditioning units. The new units were installed with enthalpy economizers. A separate project completed in the Standard HVAC program counted "Demand Control Ventilation" (DCV) savings, using the prescriptive Ameren Missouri TRM approach for a DCV measure, for what appear to be the same new air conditioning units. If the Standard HVAC project addresses the same new equipment, the enthalpy economizer measure and savings should have been included in the Custom HVAC project rather than separating savings associated with the same equipment is distinct projects.
- Since the state of Missouri does not have a statewide code requirement, the appropriate baseline for time of sale/service (TOS) projects and projects replacing failed equipment (ROF) varies by jurisdiction, depending on the building code requirements of each local jurisdiction. Some jurisdictions have not adopted codes, and each jurisdiction may have different enforcement practices. The implementer also described TOS and ROF measures do not necessarily trigger code requirements, so the appropriate baseline may be an individual customer's anticipated action or may be based on an industry standard practice.. To avoid confusion and improve consistency in savings estimation methods, Ameren Missouri should clarify requirement and recommendations for defining baselines in custom project savings calculations.

Site ID: 9016 (Custom HVAC)

Project Description

This project implemented a comprehensive set of energy efficiency measures (EEMs) including equipment replacements, addition of variable frequency drives (VFDs) on HVAC equipment, and installation of controls equipment and programming upgrades for a 520,000 square foot high-rise office building undergoing major renovation. This comprehensive project achieves energy savings by reducing the facility heating, ventilation, and air conditioning loads and improving the overall efficiency of the HVAC system in serving those loads.

The table below describes the energy efficiency measures and ex ante gross savings claimed for this project.

Site 9016 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
HVAC Controls/ EMS	HVAC	3,268,489	1,451.15
	Total	**3,268,489**	**1,451.15**

Data Collection

To understand the scope of the project and the basis for estimated energy savings, the evaluation team reviewed all available project documents, including the baseline and proposed equipment and conditions. The project materials included the Trane TRACE simulation files and spreadsheets for out-of-the-model adjustments. Based on available project information, the evaluation team identified the following distinct energy efficiency measures:

- Installed isolation valves for two chillers and installed a plate-to-frame heat exchanger between the cooling towers and chillers
- Replaced two existing electric boilers with gas boilers and automated boiler operation to respond to space temperatures
- Correcting outside air damper operation to allow for economizer operation
- Replaced manual and pneumatic controls with direct digital controls
- Implemented occupied/unoccupied space temperature setback, optimum start/stop programming, chilled water reset and hot water reset programming, and airside and waterside economizer operation
- Installed VFDs for two chilled water pumps, two condenser water pumps, two hot water pumps, and the two cooling tower fans
- Installed VFDs for supply fans for both the cold and hot ducts of the eleven two-fan double-duct variable air volume (VAV) air handling units (AHUs) and removed inlet guide vanes from the cold duct supply fan of the eleven two-fan double-duct VAV AHUs
- Installed VFDs on garage ventilation fans controlled by CO detectors year-round, on a fan that supplies fresh air to the first floor AHUs, and on the two outdoor air (OA) fans that pressurize the common shaft that delivers outside air to the two-fan double-duct VAV AHU's mixing boxes

The project did not claim electricity savings for the switch from electric to gas boilers.

The project completion form was signed in July 2021. The invoice details confirmed the HVAC improvements including system programming, replacing the existing electric boilers with gas boiler, and installation of VFDs on pumps and fans, isolation valves, and plate-to-frame heat exchanger.

The evaluation team contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The site contact described the implemented system programming and provided photos of the installed gas boilers and the VFDs.

The evaluation team also conducted a site visit on February 1, 2022. The field engineer confirmed the installation of the new equipment, including all VFDs, and confirmed the HVAC equipment programming. Although all the project equipment had been installed, the building was still undergoing major renovation and was only partially occupied. Due to the limited occupancy and ongoing construction, the HVAC systems were not serving normal loads, and the evaluation team was unable to collect relevant equipment performance trends (e.g., to verify heating and cooling loads).

The evaluation team also collected and reviewed billing data from February 2020 to October 2021 to compare whole building consumption before and after the project implementation. There is drop in energy consumption which can be justified by the fact that the building is not fully occupied. As a result, we were limited in our ability to examine the effect of savings from this project on utility data.

Analysis

The ex ante savings estimates are based on Trance TRACE 700 building simulation for three distinct alternatives, measured from the baseline model:

- **Alternative 1:** Increased occupancy, models the baseline building with increased occupancy levels
- **Alternative 2:** Increased occupancy, Improved HVAC, Improved Lighting, models the baselined building with improved lighting and HVAC measures and with increased occupancy
- **Alternative 3:** Alternative 2 with baseline occupancy, models the baseline building with improved lighting and HVAC measures.

The results of Alternative 3 were used to separate the HVAC measures, and the final ex ante savings were calculated in an excel spreadsheet. The total modeled annual kWh savings are 19% of the modeled baseline consumption.

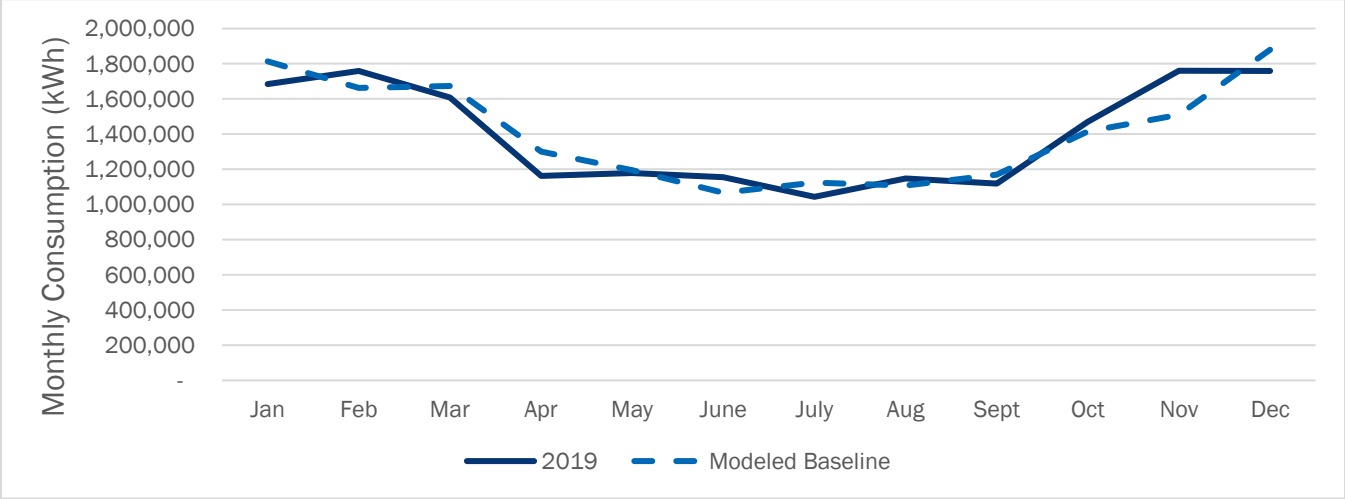
The table below shows the modeled savings by equipment. More than half (54%) of the modeled ex ante savings are the result of installing VFDs on pumps and 39% for installing VFDs on fans. 22% of the estimated savings are at the chillers and cooling tower. The model also shows increased electric consumption (–15% total negative savings) from electric reheating savings and for the boiler's forced draft fans.

Site 9016 Ex Ante Savings Summary

Equipment	Modeled Annual kWh Savings	Modeled Annual kWh Savings	
Chillers	442,136	14%	
Cooling Tower	268,425	8%	
Constant Volume Chilled Water Pump	1,187,732	36%	54%
Constant Volume Condensing Water Pump	498,517	15%	
Hot Water Pumps	74,402	2%	

Equipment	Modeled Annual kWh Savings	Modeled Annual kWh Savings	
Main Cooling Fans	701,960	21%	39%
Auxiliary and Heating Fans	588,843	18%	
Electric Reheat	(439,233)		-13%
Boiler Forced Draft Fan	(50,230)		-2%
Miscellaneous	(4,064)		0%
Total	**3,268,489**		**100%**

The evaluation team reviewed the energy model input and output files and compared the modeled savings to the building's actual baseline consumption. The figure below shows the actual building consumption (2019) and modeled baseline case consumption by month. The comparison shows that the modeled baseline annual consumption is within 0.4% of the metered baseline annual consumption.



Based on our review of the baseline model (compared to baseline consumption) and proposed model inputs, our findings on the desk review and onsite verification, and limitations associated with the ongoing building construction and limited occupancy, the evaluation team found no reason to adjust the ex ante savings. Therefore, the evaluation team accepted the ex ante savings.

Results

The table below shows the evaluated energy and demand savings for this project. Based on the project document review, data collection, and consumption data review, the evaluation team confirmed the ex ante savings estimate, resulting in a 100% realization rate.

Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
HVAC Controls / EMS	3,268,489	3268489	100%	1,451.15	1,451.15	100%
Total	**3,268,489**	**3,268,489**	**100%**	**1,451.15**	**1,451.15**	**100%**

Reasons for Discrepancies

N/A

Other Findings and Recommendations

- The evaluation team was limited in our ability to collect system performance data due to the ongoing major renovation of the project facility. The Custom project's completion form was signed in July 2021 confirming the installation of HVAC equipment; however, the facility spaces were still under major renovation and sparsely occupied during the evaluation period in January and February of 2022. Although the evaluation team was able to verify the installation of key equipment, the low occupancy levels limited the evaluation team's ability to collect equipment loading and performance data and limited the usefulness of any post-installation consumption data.

- For a project of this size, with estimated savings over three million kWh, the project documentation lacked clear information about the project scope, specific measures (including baseline and efficient case assumptions), and basis for savings. The project materials provided a one-page "Project Description," which included a summary of the baseline and proposed measures. A project of this size should have a clear description and equipment inventory for the baseline and proposed systems, a summary of the key assumptions used to model savings, and materials documenting findings from the post-installation inspection.

Site ID: 9017 (Custom HVAC)

Project Description

This project supported the following energy efficiency measures (EEMs) for a 300,00 square foot office building: (1) direct digital control (DDC) system, (2) occupied vs. unoccupied space temperature setback programming, (3) supply air reset programming, (4) Demand Control Ventilation (DCV), (5) optimal start/stop programming, and (6) fan pressure optimization. Energy savings are achieved by reducing heating, ventilation, and air conditioning (HVAC) loads and improving the overall efficiency of the HVAC system to serve those reduced loads.

The table below describes the EEMs and ex ante gross savings claimed for this project.

Site 9017 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
HVAC Controls/ EMS	HVAC	2,173,141	964.84
	Total	**2,173,141**	

Data Collection

To understand the scope of the project and the basis for estimated energy savings, the evaluation team reviewed all available project documents, including the baseline and proposed equipment and conditions. The project materials included the Trane TRACE simulation files. The invoice details confirmed the HVAC improvements including system programming and installation of VFDs on pumps and fans.

The evaluation team also collected and reviewed billing data from January 2019 through January 2022 to compare whole building consumption before and after the project implementation. The completion form was signed in June 2021, so the evaluation team had six months of post-installation performance data.

The evaluation team contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The site contact described the implemented system programming and provided photos of existing equipment and screenshots from the building automation system.

Analysis

The ex ante savings estimates are based on Trance TRACE 700 simulation of the proposed EEMs compared to baseline operations. The modeled annual kWh savings are 32% of the modeled whole building baseline consumption. The table below shows the modeled savings by equipment type. Almost two-thirds (60%) of the modeled ex ante savings are heating savings at the electric boiler, and 20% of the energy savings are at the cooling plant.

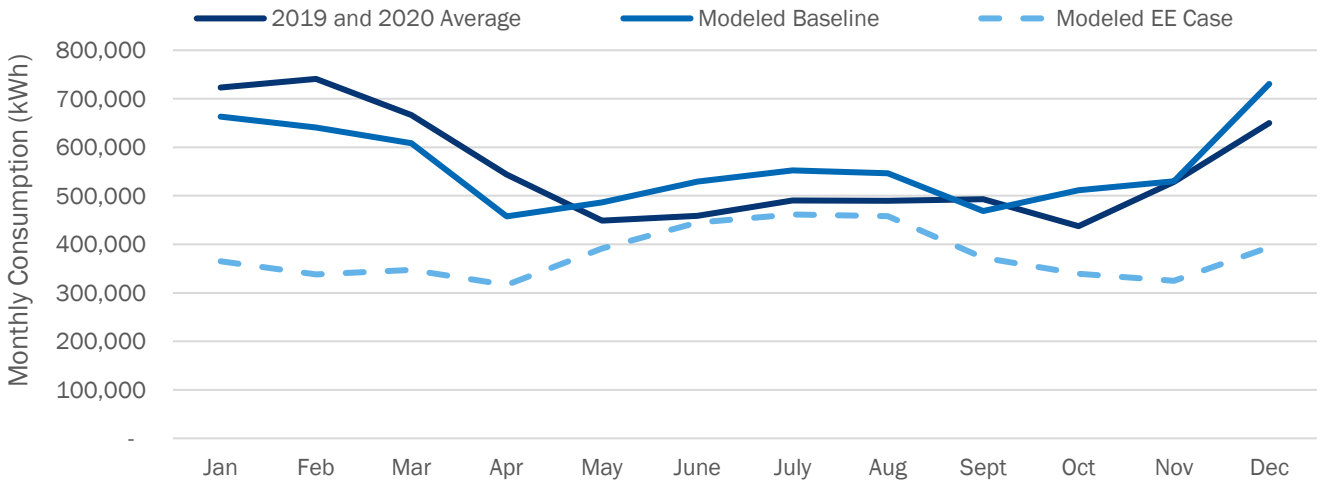
Site 9017 Modeled Ex Ante Savings by Equipment Type

Equipment	Modeled Annual kWh Savings	% of Total Ex Ante kWh Savings
Cooling Plant: Water Cooled Unitary	441,697	20%
CT for VFD Fans	77,289	4%

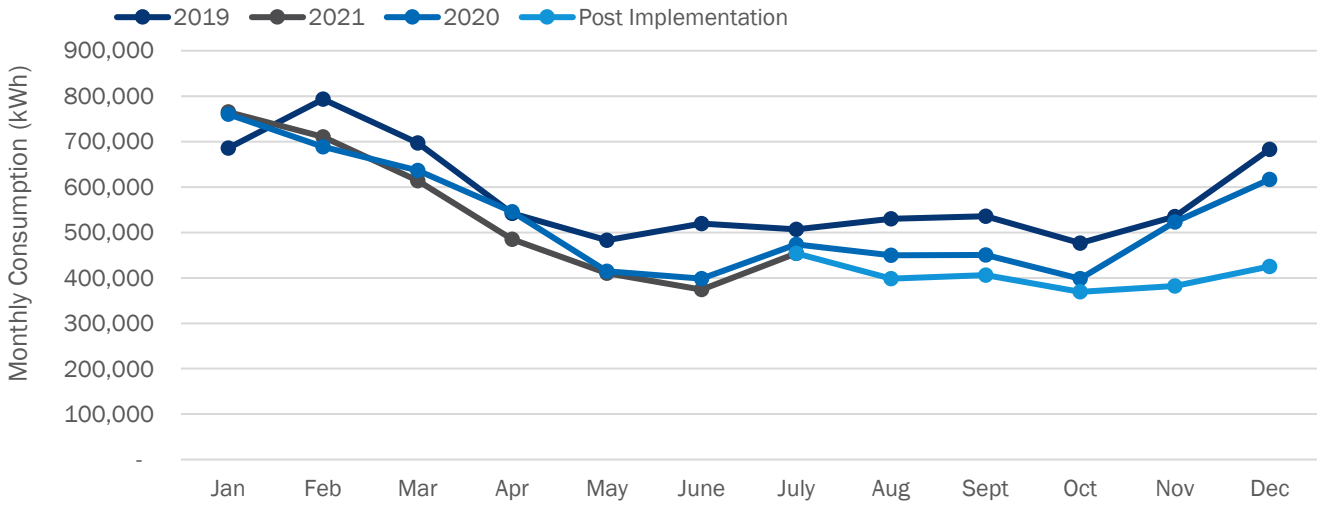
Equipment	Modeled Annual kWh Savings	% of Total Ex Ante kWh Savings
Constant Volume Condensing Water Pumps	35,102	2%
Control Panel and Interlocks	294	<1%
Electric Boiler	1,304,828	60%
CV Hot Water Pump	81,415	4%
Variable Air Volume (VAV)	232,516	11%

The evaluation team reviewed the energy model input and output files and compared the modeled kWh savings to the building's metered kWh consumption data. The figure below compares the actual building consumption (2019–2020 average) to modeled baseline and energy-efficient (EE) case consumption. The modeled baseline consumption was within 5% of the 2019–2020 average actual consumption, and the modeled savings are 23% of actual baseline consumption for both 2019 and 2020.

The comparison shows that the modeled baseline slightly understates winter heating energy and overstates cooling energy. This suggests that the ex ante savings may be understated in the winter and overstated in the summer.



The evaluation team examined the metered consumption data to identify savings for the post-implementation period. The figure below shows actual consumption data for the months before and after project implementation. The post-implementation consumption shows a clear reduction compared to baseline (pre-implementation consumption) for the same months.



The evaluation team compared the modeled savings to the difference between 2021 and 2019 consumption for the months with post-implementation data (July through December) and found the average savings to be 93% of the modeled savings.

Since we do not have data to assess savings for a full summer and winter season, we did not apply the 93% realization rate to the total annual modeled savings. Rather, we used this consumption data review combined with the verification of implemented measures as a verification that the modeled savings are appropriate, resulting in 100% realization rate for the modeled annual energy savings.

Results

The table below shows the evaluated energy and demand savings for this project. Based on the project document review, data collection, and consumption data review, the evaluation team confirmed the ex ante savings estimate, resulting in a 100% realization rate.

Site 9017 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
HVAC Controls/ EMS	2,173,141	2,173,141	100%	964.84	964.84	100%
Total	**2,173,141**	**2,173,141**	**100%**	**964.84**	**964.84**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- N/A

Site ID: 9018 (Custom HVAC)

Project Description

Based on the recommendations from an energy study, this project upgraded 657,000 square feet of roof insulation from R8 to R30 at a middle school. The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9018 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
Roof Insulation Upgrade	HVAC	35,854	15.92
	Total	**35,854**	**15.92**

Data Collection

To understand the scope of the project and the basis for estimated energy savings, the evaluation team reviewed all available project documents including the project application forms, project invoices, and the calculation spreadsheet provided with the project materials.

The project completion form was signed in November 2021. The evaluation team collected and reviewed billing data to compare whole building consumption but the consumption data for post completion was limited.

The evaluation team contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The site contact described the new roofing system, verified the roof size, described the sampling approach to measure the new R-value, and provided photos of existing equipment.

Analysis

The ex ante savings estimates are based on spreadsheet calculations for reduced cooling load and fan power. Key assumptions made in ex ante are heating degree days (HDD), cooling degree days (CDD), U-value for existing and new roof, efficiency of the fans, and IEER for cooling equipment. The total savings are about 3% of baseline annual energy consumption.

The ex post analysis reviewed and adopted the ex ante savings calculation methods. Equipment and operating parameters were verified based on data collected from site contact. In particular, the evaluation team verified the roof area and the U-Value for existing and new roof through email communication with the customer.

Since the project measures were installed as proposed, and the evaluation team found no errors in the ex ante calculation methods, the evaluation team accepted the estimated ex ante savings as ex post. The evaluation team then calculated demand savings using the Cooling end use for the cooling equipment savings and the HVAC enduse loadshape for the ventilation fan savings.

Results

The table below shows the evaluated energy and demand savings for this project. Based on the project document review, data collection, and consumption data review, the evaluation team confirmed the ex ante

kWh savings estimate, resulting in a 100% realization rate. The ex post demand savings are 30% higher, resulting in 130% realization rate.

Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Cooling Load Reduction	10,122	10,122	100%	4.49	9.22	205%
Fan Savings	25,732	25,732	100%	11.42	11.42	100%
Total	**35,854**	**35,854**	**100%**	**15.92**	**20.64**	**130%**

Reasons for Discrepancies

- Ex post applied the cooling coincidence factor to the cooling load reduction component of savings and the HVAC coincidence factor to the fan component of savings. Ex ante applied the HVAC coincidence factor to both components of savings. This change increased the ex post demand savings relative to ex ante.

Other Findings and Recommendations

- This project, which achieved significant energy savings from cooling load reductions, was completed in November 2021. The late-in-the-year project completion combined with the evaluation timeline limits the evaluation's ability to collect in-season consumption and/or performance data required to rigorously evaluate savings.

Site ID: 9019 (Custom HVAC)

Project Description

Based on the recommendations from a retro-commissioning (RCx) study, this Custom HVAC project implemented multiple control upgrades for the HVAC system at a 274,000 square feet high school.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9019 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 TAB/Calibration & Air Terminal/CO2 Control	Cooling	52,879	48.16
	Total	**52,879**	**48.16**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and savings calculations. The project materials included a RCx study for EEM-1 and five additional RCx EEMs but did not include the energy calculation workbook used to estimate the savings for each EEM.

EEM-1 includes the following HVAC and chiller control optimizations: (1) TAB, calibration and air terminal, and CO_2 control; (2) AHU supply air temperature (SAT) and duct static pressure (DSP) resets; and 3) sequence of operation, time of day, and RVS programming (turn off fan/calls during unoccupied hours)

The evaluation team contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The site contact described the implemented system programming and provided screenshots of the schedule and trend data. The invoice details also confirmed the contractor implemented the recommended HVAC optimizations.

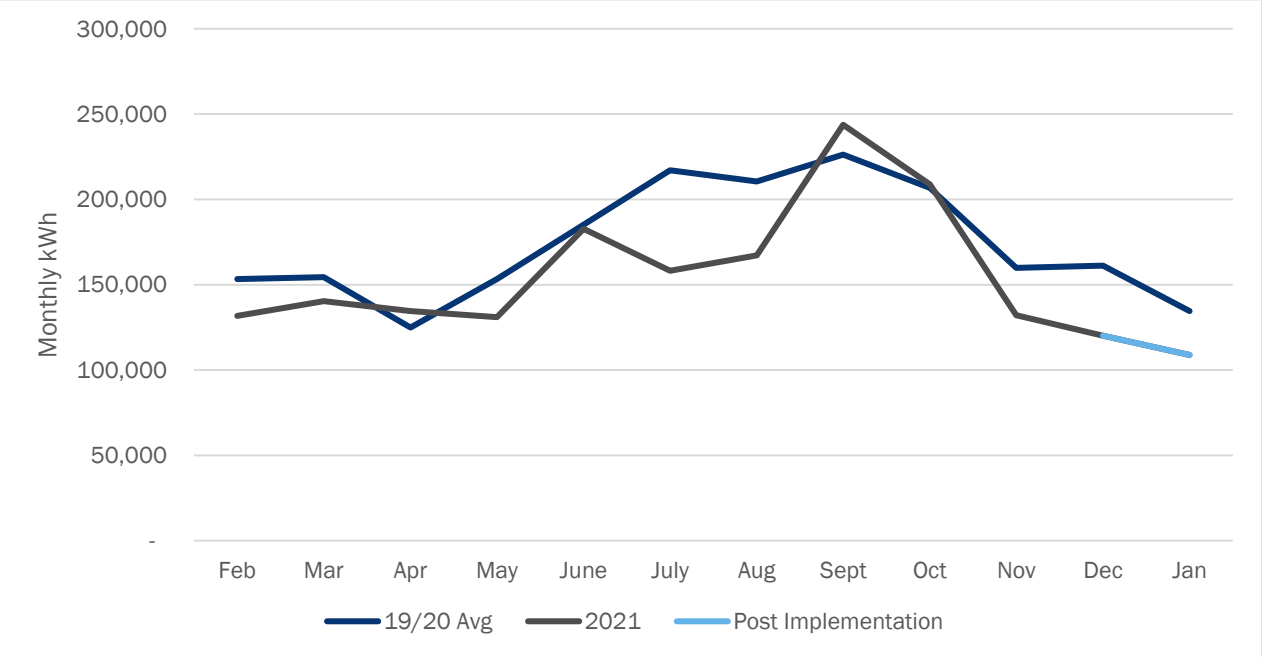
The project completion form was signed on December 2021. The evaluation team reviewed facility consumption data from January 2019 through December 2021. Due to the project's implementation in late 2021, there is limited post-implementation consumption data.

Analysis

The ex ante savings are estimated using energy models and some rule-of-thumb estimates based on past RCx projects and implementer's experience. The energy models and the details of these calculations were not provided to the evaluation team. Whole project savings (EEM-1 plus five RCx EEMs) are 17% of total baseline kWh and the savings estimate for EEM1 is 2% of the total baseline kWh.

Because the project was completed in late 2021, there are only two months of post installation utility data. The observed average savings for post implementation months (December 2021 and January 2022) is 22%, which is comparable with the savings estimates.

Based on the observed energy savings in the facility consumption data for the first two post-installation months and verification data collected from the site contact, the evaluation team accepted the ex ante assumptions savings assumptions. The evaluation team then calculated demand using the HVAC enduse loadshape.



Results

The table below shows the evaluated energy and demand savings for this project. Based on the project document review, data collection, and consumption data review, the evaluation team confirmed the ex ante savings estimate, resulting in a 100% realization rate.

Site 9019 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1 TAB/Calibration & Air Terminal/CO2 Control	52,879	52,879	100%	48.16	48.16	100%
Total	**52,879**	**52,879**	**100%**	**48.16**	**48.16**	**100%**

Reasons for Discrepancies

N/A

Other Findings and Recommendations

- Due to the December implementation and January/February evaluation period, the evaluation team was not able to observe cooling loads or collect post-installed equipment operation and performance data (since the facility was not in cooling mode).

- It was difficult to discern from the project documentation which measures were associated with this Custom HVAC project. The EEMs were defined differently in project's energy study than the description in the project materials. The implementer should ensure that project documentation is clear and transparent regarding the specific measure(s) installed, including definitions of baseline and proposed conditions, and the basis for estimated energy savings.

Site ID: 9020 (Custom HVAC)

Project Description

Based on the recommendations from retrofit study, this project implemented upgrades to the facility building automation system (BAS), including updated setpoints and schedules, and installation of a plasma filtration system, which allows for the reduction in the demand for outside air by improving the efficacy of air filtration. Energy savings are achieved by reduced equipment runtimes from the improved schedules and reduced air conditioning loads from the optimized setpoints and improved filtration system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9020 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls/EMS	HVAC	208,603	92.62
EEM-2 Plasma Filtration	Cooling	10,506	9.57
	Total	**219,109**	**102.18**

Data Collection

To understand the scope of the project and the basis for estimated energy savings, the evaluation team reviewed all available project documents including the project application forms, project invoices, and the calculation spreadsheet provided with the project materials.

The completion form was signed in December 2021. The evaluation team collected and reviewed billing data from January 2019 through December 2021 to examine whole building consumption and estimated heating and cooling loads. Due to the implementation of the project late in the year, we were limited in our ability to examine any post-implementation data. Further, a significant portion of the savings are estimated to occur during the cooling season. Due to the December implementation and January/February evaluation period, we are not able to observe cooling loads or collect equipment operation and performance data.

The evaluation team also contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The design-build contractor provided the equipment list and information on implementation progress and indicated they are continuing to optimize the building automation system as part of a continuous commissioning effort.

The evaluation team conducted a site visit on February 1, 2022. The field engineer inspected the facility heating and cooling equipment, verified the implementation of measures, and collected screenshots for building schedule and set points.

Analysis

The ex ante savings estimates are based on spreadsheet calculations. Savings for EEMs were based on standard engineering assumptions to calculate baseline and new loads, and the project developer used facility baseline consumption data to calibrate the engineering calculations.

The ex post analysis reviewed and adopted the ex ante savings calculation methods, updating equipment and operating parameters based on data collected and verified through the evaluations. The table below compares the ex ante and ex post values for key parameters in the savings calculation and shows the source of ex post values.

Site 9020 Key Parameters for Ex Ante and Ex Post Savings

Day of Week	Equipment Schedules	VRF Base	VRF New	RTU Base	RTU New	Verification Data	Ex Post Action
Monday through Friday	Hour of day system is turned ON	7	7	7	7	From BAS screenshot: VRF: Main Building: 5:30 a.m. to 9:00 p.m. DOAS: 8am-4pm (8 hours) RTU: no info	For VRF: Model both Baseline and Installed case as ON at 6 and OFF at 21 For RTU: maintain ex ante assumption in absence of verified schedules
	Hour of day system is turned OFF	19	16	19	16		
Saturday	Hour of day system is turned ON	0	8	0	8	From BAS screenshot VRF: Main Building: 8:00 a.m. to 5:00 p.m. (9hr on) DOAS: OFF RTU: no info	For VRF: Model both Baseline and Installed case as ON at 8 and OFF at 17 For RTU: maintain ex ante assumption in absence of verified schedules
	Hour of day system is turned OFF	0	12	0	12		
Sunday	Hour of day system is turned ON	0	8	0	8	From BAS screenshot VRF: Main Building: 10:00 a.m. to 4:00 p.m. (6hr on) DOAS: OFF RTU: no info	For VRF: Model both Baseline and Installed case as ON at 10 and OFF at 16 For RTU: maintain ex ante assumption in absence of verified schedules
	Hour of day system is turned OFF	0	12	0	12		

The evaluation team re-calculated energy savings by updated the ex ante calculation spreadsheets with verified equipment schedules and then calculated demand savings using the HVAC enduse loadshape.

Results

The table below shows the evaluated energy and demand savings for this project. The savings estimates with the updated schedule resulted in a reduction for EEM-1 savings. The overall realization rate for this project is 96% of estimated ex ante kWh savings.

Site 9020 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1 HVAC Controls/EMS	208,603	198,908	95%	92.62	88.31	95%
EEM-2 Plasma Filtration	10,506	10,506	100%	9.57	4.66	49%
Total	**219,109**	**209,414**	**96%**	**102.18**	**92.98**	**91%**

Reasons for Discrepancies

- For VRF equipment, ex post observed longer operating hours on weekdays and weekends than modeled in the ex ante analysis; ex post updated the calculation models to reflect these actual operating hours for both the baseline and installed cases.

- Ex post changed enduse for EEM-2 (Plasma Filtration) from Cooling to HVAC since this is a ventilation measure with savings throughout the year.

Other Findings and Recommendations

- Due to the December implementation and January/February evaluation period, evaluation team were not able to observe cooling loads or collect post-installed equipment operation and performance data (since the facility was not in cooling mode).

Site ID: 9021 (Custom HVAC)

Project Description

Based on the recommendations from an energy study, this project implemented upgrades to the facility building automation system (BAS), including updated setpoints and schedules, and installation of a plasma filtration system, which allows for the reduction in the demand for outside air by improving the efficacy of air filtration. Energy savings are achieved by reduced equipment runtimes from the improved schedules and reduced air conditioning loads from the optimized setpoints and improved filtration system.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9021 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls/EMS	HVAC	389,999	173.15
EEM-2 Plasma Filtration	HVAC	8,633	3.83
	Total	**398,632**	**176.99**

Data Collection

To understand the scope of the project and the basis for estimated energy savings, the evaluation team reviewed all available project documents including the project application forms, project invoices, and the calculation spreadsheet provided with the project materials.

The completion form was signed in December 2021. The evaluation team collected and reviewed billing data from January 2019 through December 2021 to examine whole building consumption and estimated heating and cooling loads. Due to the implementation of the project late in the year, we were limited in our ability to examine any post-implementation data. Further, a significant portion of the savings are estimated to occur during the cooling season. Due to the December implementation and January/February evaluation period, we were not able to observe cooling loads or collect equipment operation and performance data.

The evaluation team contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The design-build contractor provided the equipment list and information on implementation progress and indicated they are continuing to optimize the building automation system as part of a continuous commissioning effort.

Finally, the evaluation team conducted a site visit on February 1, 2022. The field engineer inspected the facility heating and cooling equipment, verified the implementation of measures, and collected screenshots for building schedule and set points.

Analysis

The ex ante savings estimates are based on spreadsheet calculations. Savings for EEMs were based on standard engineering assumptions to calculate baseline and new loads, and the project developer used facility baseline consumption data to calibrate the engineering calculations.

The ex post analysis reviewed and adopted the ex ante savings calculation methods, updating equipment and operating parameters based on data collected and verified through the evaluation. The table below compares ex ante and ex post values for key savings parameters and shows the source of ex post values.

Site 9021 Key Parameters for Ex Ante and Ex Post Savings

Day of Week	Equipment Schedules	VRF Base	VRF New	RTU Base	RTU New	Verification Data	Ex Post Action
Monday through Friday	Hour of day system is turned ON	5	7	5	7	From BAS screenshot: VRF, Main Building: 5:00 a.m.–9:00 p.m. DOAS: 8:00 a.m.–4:00 p.m. Woodshop RTU: 7:00 a.m.–4:00 p.m. Main Gym RTUs: 6:30 a.m.–9:00 p.m.	Use verified VRF schedules; Maintain Ex Ante assumptions for RTU schedules
	Hour of day system is turned OFF	19	16	19	16		
Saturday	Hour of day system is turned ON	5	8	5	8	From BAS screenshot VRF: Main Building: 8:00 a.m.–5:00 p.m. DOAS: OFF Woodshop RTU: OFF Main Gym RTUs: 8:00 a.m.–Noon	Use verified VRF schedules; Maintain Ex Ante assumptions for RTU schedules
	Hour of day system is turned OFF	19	12	19	12		
Sunday	Hour of day system is turned ON	5	8	5	8	From BAS screenshot VRF, Main Building: 10:00 a.m.–4:00 p.m. DOAS: OFF Woodshop RTU: OFF Main Gym RTUs: OFF	Use verified VRF schedules; Set RTU schedules to OFF based on data for all RTUs collected during on sites (all OFF)
	Hour of day system is turned OFF	19	12	19	12		

The evaluation team re-calculated energy savings by updated the ex ante calculation spreadsheets with verified equipment schedules and then calculated demand savings using the HVAC enduse loadshape.

Results

The table below shows the evaluated energy and demand savings for this project. The overall realization rate for this project is 82% of estimated ex ante savings.

Site 9021 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1 HVAC Controls/EMS	389,999	318,365	82%	173.15	141.35	82%
EEM-2 Plasma Filtration	8,633	8,633	100%	3.83	3.83	100%
Total	**398,632**	**326,998**	**82%**	**176.99**	**145.18**	**82%**

Reasons for Discrepancies

- For the VRF equipment, ex post observed longer operating hours on weekdays and weekends than modeled in the ex ante analysis; ex post updated the calculation models to reflect actual operating hours for both the baseline and installed cases. Longer runtimes resulted in lower savings. This was partially offset by an increase in savings for the RTU equipment, which the evaluation found to be OFF on Sundays.

Other Findings and Recommendations

- Due to the December implementation and January/February evaluation period, the evaluation team was not able to observe cooling loads or collect post-installed equipment operation and performance data (since the facility was not in cooling mode).

Site ID: 9022 (Custom HVAC)

Project Description

Based on the recommendations from a retrofit study, this project implemented multiple upgrades at an elementary school. The upgrades include (1) optimization of building automation system, (2) improved insulation for the building shell to reduce the buildings heating and cooling loads, and (3) installation of a plasma filtration system to reduce building ventilation requirements. Energy savings are achieved through reduced heating, ventilation, and air conditioning (HVAC) loads as a result of these upgrades and estimation of operation.

The table below describes the energy efficiency measures and ex ante gross savings claimed for this project. The total reported ex ante energy savings are slightly different than the observed sum of savings for each energy efficiency measure (EEM).

Site 9022 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Control/EMS	Cooling	63,792	58.09
EEM-2 Wall Insulation	HVAC	7,244	3.22
EEM-3 Demand Control Ventilation (Plasma Filtration)	HVAC	682	0.30
Total Calculated		**71,718**	**61.61**
Total Reported (Ex Ante)		**71,036**	**61.31**

Data Collection

To understand the scope of the project and the basis for estimated energy savings, the evaluation team reviewed all available project documents including the project application forms, project invoices, and the calculation spreadsheet provided with the project materials.

The evaluation team contacted the site contact to discuss project details and current facility operations, including building occupancy and equipment schedules. The site contact verified the HVAC equipment and operating parameters and provided information on the facility operating schedule and occupied/unoccupied setpoints.

The completion form was signed in December 2021. The evaluation team collected and reviewed billing data from January 2019 through December 2021 to examine whole building consumption and estimated heating and cooling loads. The estimated ex ante savings are 13% of 2021 baseline kWh consumption. Due to the implementation of the project late in the year, we were limited in our ability to examine any post-implementation data.

Analysis

The ex ante savings estimates are based on spreadsheet calculations developed for each measure with calibrations to adjust to baseline whole building electricity consumption. Savings for EEMs were based on

standard engineering assumptions to calculate baseline and new loads, and the project developer used facility baseline consumption data to calibrate the engineering calculations.

The ex post analysis reviewed and adopted the ex ante savings calculation methods, which utilized a weather bin analysis to estimate calibrated heating and cooling loads and energy use. Since the project measures were installed as proposed and the evaluation team found no errors in the ex ante calculation methods, the evaluation team accepted the estimated ex ante savings as ex post. The evaluation team then calculated demand using the HVAC enduse loadshape.

Results

The table below shows the evaluated energy and demand savings for this project. Based on the project document review, data collection, and consumption data review, the evaluation team confirmed the ex ante savings estimate, resulting in a 100% realization rate.

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1 HVAC Controls/EMS	63,792	63,792	100%	58.09	58.09	100%
EEM-2 Wall Insulation	7,244	7,244	100%	3.22	3.22	100%
Total	**71,036**	**71,036**	**100%**	**61.31**	**61.31**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- Due to the December implementation and January/February evaluation period, evaluation team were not able to observe cooling loads or collect post-installed equipment operation and performance data (since the facility was not in cooling mode).
- It was difficult to discern from the project documentation which measures were associated with this Custom HVAC project. The description and scope of measures selected for this custom project were not consistent with the definition of measures from the project's energy study. The implementer should ensure that project documentation is clear and transparent regarding the specific measure(s) installed, including definitions of baseline and proposed conditions, and the basis for estimated energy savings.

Appendix E. Desk Review and Onsite Reports: Custom Incentive Program, Compressed Air End Use

The evaluation of Custom compressed air projects included desk reviews for a sample of five projects. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Summary of Custom Compressed Air Project Reviews

Site ID	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
		Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
9023	Desk review	234,343	234,343	100%	32.33	32.33	100%
9024	Desk review with phone verification	274,837	274,837	100%	37.91	37.91	100%
9025	Desk review with phone verification	1,121,578	1,121,578	100%	154.71	154.71	100%
9026	Desk review with phone verification	475,656	475,656	100%	65.61	65.61	100%
9027	Desk review with phone verification	149,134	149,134	100%	20.57	20.57	100%

Site ID: 9023 (Custom Compressed Air)

Project Description

This project replaced an existing air compressor and existing non-cycling dryer with a new high-efficiency air compressor and new cycling dryer serving a process load at an industrial facility. These two custom energy efficiency measures (EEMs) were recommended after the site completed a retro-commissioning (RCx) study and completed leak repairs. (This custom project only counts savings for the two custom measures.) Energy savings are achieved through the improved efficiency of the compressor and dryer in supplying compressed air for its operations.

The table below describes the energy efficiency measures and ex ante gross savings claimed for this project.

Site 9023 Ex Ante Savings Summary

Measure Name	End Use Category	Ex Ante Gross	
		kWh	kW
Efficient Air Compressor	Compressed Air	197,003	27.18
Cycling Dryer	Compressed Air	37,340	5.15
	Total	**234,343**	**32.33**

Data Collection

The evaluation team reviewed all available project documents to understand the scope of the project, including the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings. We reviewed the invoices to verify the purchased air compressor and the compressor spec sheet to confirm the compressor performance used in the ex ante analysis.

The evaluation team communicated with the customer via email and phone calls to

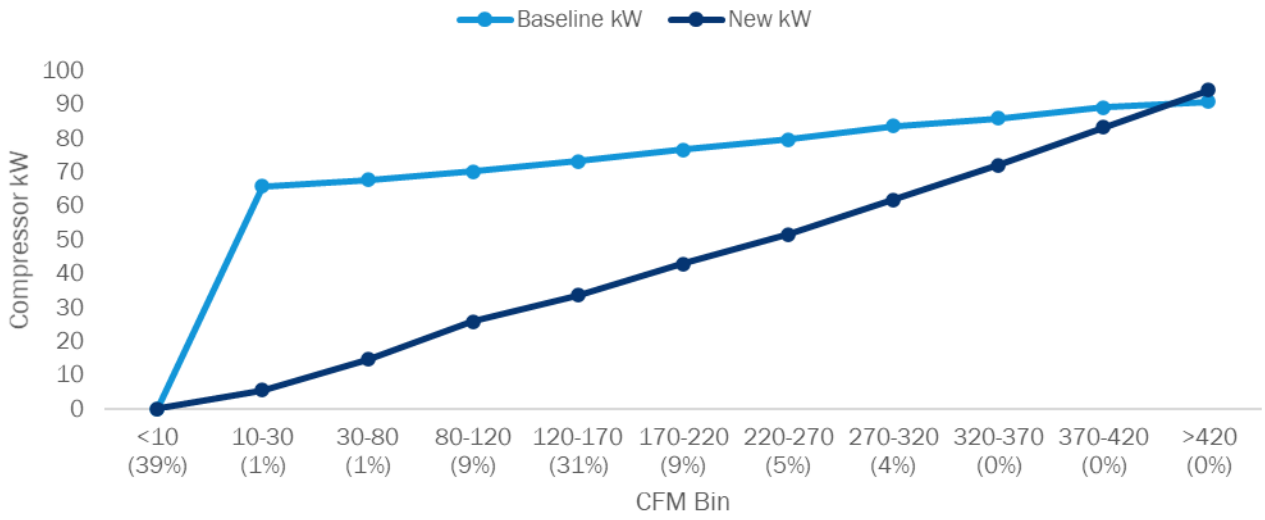
- Verify new equipment make/model/specs,
- Verify the compressor and dryer staging strategy,
- Verify annual operating hours, and
- Understand any substantive changes in equipment operating and/or production schedules since the initial energy study.

The evaluation team discussed the project with the project engineer and collected additional photo documentation of the new compressor and dryer. The project engineer also confirmed details from the energy study. The evaluation team was unable to collect updated equipment performance data.

Analysis

Ex ante savings were estimated using a load bin analysis and monitoring data collected through an energy audit for a period of one week in summer 2020. The monitoring data included amps for the existing compressors and was used to develop a CFM load profile. The load profile was then adjusted to account for leak repairs completed after the monitoring period. The ex ante analysis estimated the compressor power

required in each CFM load bin using equipment performance data and estimated average operating power demand for the existing and new compressors based on measured time in each CFM load bin. The figure below compares the power demand for the baseline and new compressor for each CFM bin as well as the measured percentage of time the compressors operate in each bin.



The ex ante analysis estimates energy savings for the dryer replacement based on the equipment's rated full load capacity and power, average operating CFM, and annual operating hours.

The ex post analysis reviewed and confirmed the energy savings calculation based on information collected and confirmed through the evaluation activities. The table below shows the key equipment information and parameters used in the ex ante and ex post energy analysis and source of evaluation verification data.

Site 9023 Key Parameters for Evaluation

Equipment or Parameter	Ex Ante	Ex Post	Source
New 100-HP Compressor	L75RS	L75RS	Photos of installed equipment
New Dryer	GTRC-600A	GTRC-600A	Photos of installed equipment
Existing Backup Compressor	Backup only	Backup only	Site Contact
Existing Backup Dryer	Backup only	Backup only	Site Contact
Baseline Compressor Average kW	45.2	45.2	Ex ante calculations based on performance data
New Compressor Average kW	22.3	22.3	Ex ante calculations based on performance data
Baseline Dryer Average kW	22.3	22.3	Ex ante calculations based on performance data
New Dryer Average kW	5.169	0.823	Ex ante calculations based on performance data
Annual HOU	8,592	8,592	Site Contact

Results

The table below shows the evaluated energy and demand savings for this project. The energy and demand realization rates are 100% based on the evaluation verification of installed equipment and operating assumptions and review of energy calculations.

Site 9023 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Efficient Air Compressor	197,003	197,003	100%	27.18	27.18	100%
Cycling Dryer	37,340	37,340	100%	5.15	5.15	100%
Total	**234,343**	**234,343**	**100%**	**32.33**	**32.33**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- Monitoring data to measure CFM demand is a good approach to modeling compressor performance and energy savings. Project documentation should document information used to extrapolate the monitoring period operation to annual operation.

Site ID: 9024 (Custom Compressed Air)

Project Description

This facility completed several distinct energy efficiency projects on the same equipment in recent years. After the completion of a previous custom energy efficiency project, one of the existing fixed speed compressors failed, and the customer planned to add about 1,632 CFM to the system demand serving manufacturing processes at an industrial building. Instead of replacing the failed equipment with an inefficient L250 fixed speed compressor, the project replaced the failed equipment with a new VST225 VSD compressor. Energy savings are achieved through the improved efficiency of the new compressor and variable speed operation.

The table below describes the energy efficiency measures and ex ante gross savings claimed for this project.

Site 9024 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
Efficient compressor	Compressed Air	274,837	37.91
	Total	**274,837**	**37.91**

Data Collection

The evaluation team reviewed all available project documents to understand the scope of the project, including the baseline and proposed equipment and conditions, previous custom projects, and to understand the basis for estimated energy savings. We reviewed the invoices and the nameplate picture to verify the purchased air compressor and the compressor data sheet to confirm the ex ante compressor performance assumptions.

The evaluation team communicated with the customer via e-mail and phone calls to try to

- Verify new equipment make/model/specs,
- Understand the compressor staging strategy,
- Verify the maximum CFM of the proposed and new compressors,
- Verify annual operating hours, and
- And understand any substantive changes in equipment production schedules and/or CFM or load requirements since the April 2018 energy study.

The site contact offered to provide current compressor loading information but was unable to provide the evaluation team with the requested information during the evaluation timeline. Therefore, the evaluation of this site focused on reviewing the ex ante methodology, assumptions, and calculations using the data available.

Analysis

Ex ante savings were estimated using a load bin analysis with manufacturer's design points and monitoring data collected for a period of one week in April 2018. The monitored data included CFM, amps, and psi for the failed 300-HP screw compressor that was replaced as well as four other 300-HP screw compressors. The

monitoring period was before the completion of five previous custom energy efficiency projects supported by Ameren Missouri.

Baseline energy usage was based on the total kW usage for the frequency bins during the monitoring period, manufacturer's specifications for the proposed L250 compressor, and 8,592 annual operating hours. The proposed energy usage was based on the total kW usage for the frequency bins during the monitoring period, manufacturing specifications for the installed VST225 compressor, and 8,592 operating hours.

Ex post savings reviewed the ex ante analysis, checking key input values based on technical specifications and verifying calculations were done correctly. Without any additional data from the customer, the ex post savings reviewed and confirmed the ex ante savings assumptions for the new compressor equipment. The evaluation team found the calculations were done correctly, used reasonable assumptions, and that the input values matched the project documentation for compressor performance. Specifically, the evaluation team checked that:

- The compressor horsepower and maximum CFM matched the technical specifications,
- The compressor strategy matched the description received from the implementer and met the load requirements,
- The performance curve used in the analysis matched the technical specifications, and
- Equations and values are applied correctly in the energy calculations.

Results

The table below compares the ex ante and ex post savings and shows the overall realization rates for energy and demand savings.

Site 9024 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Efficient Air Compressor	274,837	274,837	100%	37.91	37.91	100%
Total	**274,837**	**274,837**	**100%**	**37.91**	**37.91**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- There have been multiple custom projects at this facility since the original metering data which changed equipment horsepower, maximum CFM, and compressor staging. Project documentation also states that demand increased during this time. When the evaluation team spoke to the customer, he stated there are future plans to continually increase the efficiency of the facility. **The evaluation team recommends the implementer collect new monitored data which could serve as a more accurate baseline for any future custom projects.**

- As there were multiple compressor projects completed for this facility and included in the calculation workbook, it took a fair amount of time for the evaluation team to get oriented to the workbook and to interpret the calculations. Communication with the implementer was needed for the evaluation team to fully understand the calculations and assumptions. **The evaluation team recommends including a description of what calculations were made and why, which would support the evaluation team's understanding of the project and how energy savings were achieved**.
- **Information regarding the operation of the baseline equipment and proposed system outside of the monitored data and annual operating hours should be collected**. Understanding how production may vary throughout the year is important when extrapolating data using only one week of operation. Additionally, annual operating hours are used to calculate savings, especially since the monitored data contained periods of zero demand. Without further information on the operation of the facility it is hard to determine whether the reduction of annual operating hours from 8,760 and the periods of zero load are double counted.

Site ID: 9025 (Custom Compressed Air)

Project Description

This project replaced five existing oil-lubricated rotary screw vacuum pumps (425 total HP) with two dry variable speed 150-HP vacuum pumps (300 total HP) that are used to run envelope folding machines at an industrial building. Energy savings are achieved through the improved efficiency of the new pumps and variable speed operation.

The table below describes the energy efficiency measures and ex ante gross savings claimed for this project.

Site 9025 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
Dry Variable Speed Vacuum Pumps	Compressed Air	1,121,578	154.71
	Total	**1,121,578**	**154.71**

Data Collection

The evaluation team reviewed all available project documents to understand the scope of the project, including the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings. We reviewed the invoices and e-mail communications from the manufacturer to verify the purchased vacuum pumps and reviewed the performance chart and spec sheet to confirm the vacuum pumps' performance used in the ex ante analysis.

The evaluation team communicated with the customer via e-mail and a phone call to

- Verify new equipment make/model/specs,
- Understand the staging and operation strategy for the two new vacuum pumps,
- Verify annual operating hours,
- Understand if there have been any changes in the equipment production schedules or use of the vacuum pumps, and
- Understand whether production and load requirements vary during the year

The customer confirmed the make and model of the new vacuum pumps and confirmed that normal operation of the pumps is 24 hours per day, five days a week (6,240 annual operating hours).[6] However, the customer was unable to provide the evaluation team with any updated trend data or information regarding the operating conditions of the pumps. Therefore, this evaluation focused on reviewing the ex ante methodology, assumptions, and calculations using the data available.

[6] The customer noted that at the time of the evaluation they were running less than 24/5 due to staffing shortages related to the COVID-19 pandemic; the customer plans to return to 24/5 operation once staffing is back to full capacity.

Analysis

The calculation workbook did not contain energy savings calculations. The workbook had monitored data collected for a period of two weeks that was combined data for all five existing vacuum pumps and included total kW, total ACFM, and total inHG. The workbook also had a list of five pieces of equipment and a kW listed for each. It is not clear in the workbook whether the kW represents the max kW, the average kW, or some other kW value of the listed equipment. The evaluation team also assumed the pieces of equipment listed are the baseline vacuum pumps that were replaced, but that is not explicitly defined in the project documentation. The monitored data along with the kW listed for each piece of equipment was used to calculate the percent of total kW and percent of total flow. These percentages and the kW values, however, are not used elsewhere in the workbook. Calculations for scaling flow for 6" pipe velocity and 8" pipe velocity are also included in the workbook.

To recreate the kWh energy savings in the project documentation, the evaluation team used the manufacturer's design points and the monitored data. Baseline energy usage was based on the average total kW usage during the monitoring period and 6,240 annual operating hours.

The new vacuum pumps were designed for an average system capacity of 2,916 ACFM at 15 inHG, or 1,458 ACFM at 15 inHG per pump. The proposed energy usage was based on the performance chart for the new pump, where a selection program uses a line of best fit to determine operating conditions. This resulted in a design point of 1,458 ACFM at 15 inHG at 64.6 BHP. At 0.745 kW per HP, average usage is 48.13 kW per pump. This average kW usage was then multiplied by the annual operating hours to obtain annual kWh for each of the two new pumps.

The table below shows the calculated annual consumption for the baseline case (existing equipment) and the proposed/installed case (new equipment) and calculated energy savings. The calculated energy savings are similar but do not match the energy savings tracked in the program database. The evaluation team was not able to recreate the kWh savings cited in the tracker with the project information available.

Site 9025 Ex Ante Savings Summary

Equipment	Average kW Usage	Annual Operating Hours	Annual kWh
Baseline Case: Existing Vacuum Pumps (vmax, two Quincy 100s, Sullair 75, and Sullair 50)	276	6,240	1,722,273
Proposed/Installed CasE: New Vacuum Pumps (two VPC-SCD 215-150 HP)	96.26	6,240	600,662
Energy Savings from Project Workbook			**1,121,610**
Ex Ante Savings from Program Database [a]			**1,121,578**

[a] The calculated energy savings are similar but do not match the energy savings tracked in the program database. The evaluation team was not able to recreate the kWh savings cited in the tracker with the project information available.

Ex post savings used the ex ante analysis recreated by the evaluation team for kWh savings. The customer verified annual operating hours of 6,240. With no other data available on the variable operation of the pump (i.e., the pump may not work at the design point for the entire 6,240 hours), ex post kW savings were calculated

using the average kW from the monitoring period and the manufacturer's average kW design point of 48.13 kW per pump.

Results

The calculation workbook did not contain energy savings calculations, nor all the data needed to calculate the savings. The evaluation team used the annual operating hours from the project application and confirmed by the customer, the average kW from the monitored data in the calculation workbook, and the average kW for the new vacuum pumps as documented in the e-mail "34371 48.13kW explained" (provided with project documents) to recreate the reported savings. Without any additional data from the customer on the vacuum pump operation (and challenges with collecting new data due to abnormal operations impacted by COVID-19), the ex post savings confirm the ex ante savings.

Site 9025 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
New Vacuum Pumps (Two VPC-SCD 215-150 HP)	1,121,578	1,121,611	100%	154.71	154.71	100%
Total	**1,121,578**	**1,121,611**	**100%**	**154.71**	**154.71**	**100%**

Reasons for Discrepancies

- The evaluation team confirmed the new pump equipment and normal annual operation. No documentation was provided for the ex ante savings the evaluation team found in the project tracker. Therefore, the evaluation team used the average kW in the monitoring period and the average design kW.

Other Findings and Recommendations

- The calculation workbooks should contain all inputs and assumptions needed to calculate savings as well as all energy savings calculations used to estimate kWh savings.
- Equipment information such as make, model, and performance data should clearly state what the equipment is and whether it is used for the baseline or the proposed system.
- Information regarding the operation of the baseline equipment and proposed system outside of the monitored data and annual operating hours should be provided with the project documentation. Understanding how production may vary throughout the year is important when extrapolating data using only two weeks of operation and annual operating hours.

Site ID: 9026 (Custom Compressed Air)

Project Description

This facility completed several distinct energy efficiency projects on the same equipment in recent years. After the completion of a previous custom project, an existing centrifugal compressor was replaced with a new TA3000 500-HP centrifugal compressor serving manufacturing processes at an industrial building. Energy savings are achieved through the improved efficiency of the new compressor and variable speed operation.

The table below describes the energy efficiency measures and ex ante gross savings claimed for this project.

Site 9026 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
Efficient compressor	Compressed Air	475,656	65.61
	Total	**475,656**	**65.61**

Data Collection

The evaluation team reviewed all available project documents to understand the scope of the project, including the baseline and proposed equipment and conditions, previous custom projects, and to understand the basis for estimated energy savings. We reviewed the invoices to verify the purchased air compressor and the compressor spec sheet to confirm the compressor performance used in the ex ante analysis.

The evaluation team communicated with the customer via e-mail and phone calls to

- Verify new equipment make/model/specs,
- Understand the compressor staging strategy,
- Verify the maximum CFM of the proposed and new compressors,
- Verify annual operating hours, and
- Understand any substantive changes in equipment production schedules and/or CFM or load requirements since the April 2018 energy study.

The site contact offered to provide current compressor loading information but was unable to provide the evaluation team with the requested information during the evaluation timeline. Therefore, the evaluation of this site focused on reviewing the ex ante methodology, assumptions, and calculations using the data available.

Analysis

Ex ante savings were estimated using a load bin analysis with manufacturer's design points and monitoring data collected for a period of one week in April 2018. The monitored data included CFM, amps, and psi for the failed 300-HP screw compressor that was replaced as well as four other 300-HP screw compressors. The monitoring period was before the completion of six previous custom energy efficiency projects supported by Ameren Missouri, including this project. In the baseline configuration for this project, the failed compressor

(Compressor 8) was a 2,300 CFM centrifugal compressor and was the fourth compressor to come on. The new VST225 provides 2,771 CFM (471 more CFM than the failed compressor) and is now the third compressor to come on for the baseload system. As the maximum CFM of the baseload compressors increased (reducing the need trim load), the original monitoring data was adjusted using engineering calculations.

For the engineering calculations, in times when the original monitored data showed trim compressors were supplying less than 471 CFM, no adjustments were made. In times when the original monitored data showed the trim compressors were supplying more than 471 CFM, 471 CFM was moved from the trim compressors to the baseload. This resulted in changes to the bin frequencies between the baseline and the efficient cases.

Baseline energy usage was based on the total kW usage for the frequency bins during the monitoring period and 8,592 annual operating hours. The proposed energy usage was based on the total kW usage of the frequency bins modified by the engineering calculations and 8,592 operating hours.

Ex post savings used the same analysis methodology as the ex ante analysis, checking key input values based on technical specifications and verifying calculations were done correctly. Without any additional data from the customer, the ex post savings confirm the ex ante savings. The evaluation team found the calculations were done correctly, used reasonable assumptions, and that the input values matched the project documentation for compressor performance. Specifically, the evaluation team checked that

- The compressor horsepower and maximum CFM matched the technical specifications,
- The compressor strategy matched the description received from the implementer and met the load requirements,
- The performance curve used in the analysis matched the technical specifications, and
- Equations and values used in calculations.

Results

The table below compares the ex ante and ex post savings and shows the overall realization rates for energy and demand savings.

Site 9026 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Efficient Air Compressor	475,656	475,656	100%	65.61	65.61	100%
Total	**475,656**	**475,656**	**100%**	**65.61**	**65.61**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- There have been numerous custom projects since the original metering data which changed equipment horsepower, maximum CFM, and compressor staging. Project documentation also states

that demand increased during this time. When the evaluation team spoke to the customer, he stated that there are future plans to continually increase the efficiency of the facility. **Therefore, the evaluation team recommends the implementer collect new monitored data which could serve as a more accurate baseline for any future custom projects**.

- As there were multiple compressor projects completed for this facility and included in the calculation workbook, it took a fair amount of time for the evaluation team to get oriented to the workbook and to interpret the calculations. Communication with the implementer was needed for the evaluation team to fully understand the calculations and assumptions. **The evaluation team recommends including a description of what calculations were made and why, which would support the evaluation team's understanding of the project and how energy savings were achieved**.
- This facility had three compressors of the same make and model as the new compressor installed in this project. There was no designation in the calculation workbook indicating which compressor was replaced. Therefore, the evaluation team had to contact the implementer to verify which compressor was replaced and what drove the changes in the frequency bins and compressor staging. **The evaluation team recommends the calculation workbooks clearly document what equipment was replaced and any associated changes in equipment operation.**
- **Information regarding the operation of the baseline equipment and proposed system outside of the monitored data and annual operating hours should be collected**. Understanding how production may vary throughout the year is important when extrapolating data using only two weeks of operation and annual operating hours are used to calculate savings, especially since the monitored data contained periods of zero demand. Without further information on the operation of the facility it is hard to determine whether the reduction of annual operating hours from 8,760 and the periods of zero load are double counted.

Site ID: 9027 (Custom Compressed Air)

Project Description

This project replaced an existing 250-HP fixed speed compressor with one variable speed L110RS 150-HP compressor serving a manufacturing process at an industrial building. Energy savings are achieved through the improved efficiency of the new compressor, reduced total horsepower, and variable speed operation.

The table below describes the energy efficiency measures and ex ante gross savings claimed for this project.

Site 9027 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
Efficient compressor	Compressed Air	149,134	20.57
	Total	**149,134**	**20.57**

Data Collection

The evaluation team reviewed all available project documents to understand the scope of the project, including the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings. We reviewed the invoices to verify the purchased compressor and reviewed the spec sheet to confirm the compressors' performance used in the ex ante analysis.

The evaluation team communicated with the customer via e-mail to

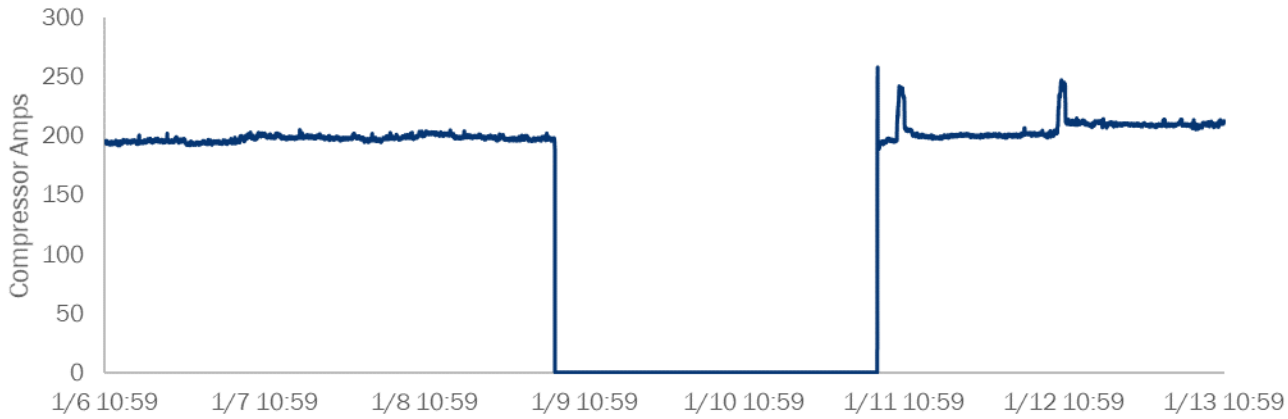
- Verify new equipment make/model/specs,
- Confirm the existing 100-HP compressor is only used for backup,
- Understand any substantive changes in equipment production schedules and/or CFM or load requirements since the January 2021 energy study,
- Verify annual operating hours, and
- Understand whether production and CFM requirements vary during a normal year.

The customer confirmed the make and model of the new compressor, confirmed the existing 100-HP backup compressor is only used for backup, and described that production is consistent throughout the year. The customer reported the facility typically runs 7,500 to 7,700 hours per year, saying "we are here almost every weekend, doing facility maintenance, but not running," adding sometimes they "run a partial weekend shift." Additionally, the customer stated they have periods of zero demand caused from "maintenance and non-operation of the unit due to processing machine usage requirements."

The customer offered to install a meter on the new compressor to supply updated trend data on compressor load and operation, but during the time of the evaluation the facility was operating below its normal capacity due to staffing shortages related to the COVID-19 pandemic. Since this operating period would not reflect normal facility loads or operations, the evaluation team did not collect updated trend data. Instead, the evaluation team focused on updating the ex ante methodology, assumptions, and calculations based on findings from our desk review and data provided by the customer.

Analysis

Ex ante savings were estimated using a load bin analysis with manufacturer's design points and monitoring data collected for a period of one week in January 2021 (see figure below). The monitored data included amps for the existing 250-HP compressor that was replaced as well as the existing 100-HP backup compressor. The backup 100-HP compressor was off during the entire monitoring period. Both compressors were off on Saturday and Sunday during the monitoring period.



Baseline energy usage was based on the total kW usage for the frequency bins during the monitoring period, manufacturer's specifications for the existing 250-HP compressor, and 8,592 annual operating hours. The proposed energy usage was based on the total kW usage for the frequency bins during the monitoring period, manufacturing specifications for the installed L110RS compressor, and 8,592 operating hours.

Ex post savings used the same analysis method as the ex ante analysis, checking critical assumptions and input values based on information from the customer and review of manufacturer's equipment performance data regarding maximum compressor kW. Because the evaluation could not collect updated load data, we relied on the available pre-installation compressor monitoring data provided with the project documentation.

Based on the customer's confirmation that the facility operations are consistent throughout the year, we adopted the ex ante approach (annual HOU = 8,592 hours) to extrapolate monitored data to annual operations. However, the evaluation team noted two areas where realized savings may be different from estimated savings:

- The customer noted they have periods of zero usage during operating hours to process machine usage requirements. There were zero usage periods in the monitoring period other than weekends, when the customer verified they typically do not operate. Therefore, extrapolating usage based on the monitoring period and no adjustment for processing machine usage requirements may overstate usage.
- Extrapolating the monitored data to the full year assumes operation 24 hours per day and 5 days per week with no weekend operation (6,240 hours). The customer stated they typically operate 7,500 to 7,700 hours per year and mentioned some weekend operation. Therefore, extrapolating usage based on the monitoring period and no adjustment for occasional weekend usage may understate usage.

Since the evaluation verified the installation and operation of the proposed equipment and without more detailed post-installation or annual performance data, the evaluation team accepted the ex ante savings estimated with no adjustments.

Results

The table below compares the ex ante and ex post savings and shows evaluated realization rates of 100% for both energy and summer peak demand savings.

Site 9027 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Efficient Air Compressor	149,134	149,134	100%	20.57	20.57	100%
Total	**149,134**	**149,134**	**100%**	**20.57**	**20.57**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- **Information regarding the operation of the baseline equipment and proposed system outside of the monitored data and annual operating hours should be collected.** Understanding how production may vary throughout the year is important when extrapolating data using only two weeks of operation and annual operating hours are used to calculate savings, especially since the monitored data and information provided by the customer indicated the results may be understating and/or overstating usage. Without further information on the operation of the facility it is hard to quantify potential under or over usage.
- **The implementation team should collect information on all equipment serving the load at facilities.** In communication with the customer, the evaluation team found that the customer would operate the new compressor and the 100-HP compressor during times of peak load as they are more efficient and have a VFD. The project documentation did not include the information needed to verify the specifications of the 100-HP compressor or its operation, especially since it did not come on during the baseline monitoring period.
- **Project documentation should include the final calculation spreadsheets that support the final ex ante savings claimed.** The project calculation files available to the evaluation team had savings of 318,678 kWh (more than twice the final claimed savings), used an incorrect value for the maximum kW of the new compressor, and included periods where the facility CFM exceeded the maximum CFM of the new compressor. After the evaluation team presented draft results, the implementer provided an updated calculation workbook that included calculations to account for the customer fixing leaks and the associated adjustments to the monitored data, with ex ante savings that matched the values in the tracking database. These calculations brought the facility CFM requirements in-line with the maximum CFM of the new compressor and also corrected the value for the maximum CFM of the new compressor. To ensure accurate and transparent project documentation and to optimize efficient use of evaluation resources, the program team should ensure the appropriate final calculations documents are savings in the tracking system and match the final claimed savings, especially when projects are sampled for evaluation.

Appendix F. Desk Review Reports: New Construction Program

The evaluation of New Construction projects included desk reviews and onsite visits for a sample of four projects. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Summary of New Construction Project Reviews

Site ID	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
		Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
9200	Desk review with onsite visit	16,173,090	14,110,429	87%	5,723.51	4,998.57	87%
9201	Desk review with onsite visit	6,420,142	6,121,314	95%	1,986.35	1,893.89	95%
9202	Desk review with onsite visit	2,824,461	2,628,249	93%	880.28	819.13	93%
9203	Desk review	1,950,762	1,905,475	98%	596.07	582.23	98%

Below, we provide general recommendations based on our review of the four indoor agriculture new construction projects listed above. Project-specific recommendations can be found in each project's section.

Overarching/General

- **Provide a Project Narrative summary document for every site.** A project narrative that provides a high-level description of the site and associated measures—including key baseline and high-efficiency parameter assumptions—should be provided for every site. These high-level descriptions of the site, equipment, and other relevant information can be very useful. This site did not have A Project Narrative document, but other New Construction sites did.
- **Provide more targeted organization and/or curation of project documentation.** An immense amount of project documentation is typically stored and available for project review and evaluation but identifying the documents most critical and applicable to the measure assumptions and calculations is currently very difficult. It would be helpful for both implementation and evaluation to either put all the most relevant documents that support the final calculations into a single directory or provide a curated list of the key documents. This would also avoid major omissions of files.
- **Provide a summary of the site activity types and associated floor areas.** A correct and consistent floor area inventory should be provided for every site. Floor areas are needed for LPD calculations, building simulation models, and even the application (total floor area). This summary is especially critical for the non-grow areas to determine the predominant activity type for selecting an appropriate LPD value to use. As a minimum, estimates for total site floor area, grow area total floor area, and non-grow (or support) area total floor area should be developed so they can be used consistently throughout the project documentation.

Lighting

- **Include the *Ameren Ag* Lighting Equivalent Quantity workbook with all indoor agricultural projects.** This workbook is used by the program implementer to determine the equivalent number of equivalent HPS or T5HO fixtures for grow area LED fixtures. A copy of the workbook should be included with each project, and the assumptions and calculations for each project fixture clearly identified, along with the file name containing the LED fixture performance specifications used in the calculations, with a date on the specification sheet if possible, as LED products are constantly being improved. In addition, while the basic approach used in the workbook appears sound, the reference sources and basic assumptions for the lighting performance metrics—especially the HPS and T5HO baseline fixtures—need to be better documented by including the references report in this workbook.
- **Project documentation for LED grow room lighting should include and clearly identify the manufacturer specification sheets used for every ex ante lighting fixture.** For grow room LED lighting, the relevant specification sheets should be clearly identified, and a full list of the relevant performance specifications used for the ex ante calculations (manufacturer, model number, fixture input watts, PPF, and PPFD) should be summarized to avoid discrepancies. This information could be stored in a project-specific version of the *Ag Lighting Equivalent Quantity* workbook. For some projects, instead of spec sheets for the fixtures used in the project, a full manufacturer product line catalog was provided. Other projects had manufacturer-proposals for the project-specific fixtures, which is ideal. The evaluation team found lighting discrepancies in the several of the PY2021 indoor agricultural projects reviewed, and also found that the manufacturers' offerings (and product specs for the same model) are also changing over time. We also saw evidence of custom versions of some fixtures that use the same basic model number but have different performance specifications. It is essential that the exact specifications for each project fixture be clearly identified.
- **Use the Space-by-Space approach for LPD-based calculations.** For indoor agricultural facilities, the LPD approach is typically only applied to part of the building, and usually a relatively small portion. As such, a space-by-space type approach vs. the current default Building Area Type approach—which has limited LPD options and is best suited for use on a whole-building level—can provide a more accurate baseline estimate. This will also help ensure that quality control is done on all floor areas used in the project application and analyses. The Ameren New Construction guide already allows for the use of a space-by-space type approach; however, only the Building Area Type tables are provided in the guide, and the program application Excel workbook only allows the Building Area Type approach to be used.
- **Use IECC 2018 for lighting LPD assumptions regardless of local code presence.** There have been so many advances in lighting that impact baseline lighting energy use that using an IECC 2009 baseline under any circumstances will not accurately reflect the lighting market. Lighting equipment is federally regulated, not driven by energy codes, and energy code LPDs are essentially designed to reflect the market to a certain extent. As such, the New Construction program guide should be changed to use IECC 2018 lighting power densities which should better reflect the current new construction lighting market.

HVAC

- **Provide a summary of HVAC systems and baseline and efficient scenario assumptions.** To facilitate a more complete evaluation of the site and provide a general overview of HVAC conditioning, the project documentation should include a summarized overview of all HVAC systems at the site, the areas they

serve, and most importantly a comparison summary of the key building simulation parameters used for the baseline and efficient scenarios so they can be checked and evaluated against the actual models, mechanical schedules, spec sheets, and other project documentation. Such a summary would likely have been needed to create the building simulation models so it should be readily available or can possibly be generated as a report from the building simulation tool.

- **Do not use human comfort-based HVAC codes to estimate savings for indoor agricultural HVAC systems.** These HVAC systems are serving process loads and more similar to an industrial or manufacturing environment, so it is not appropriate to use IECC or ASHRAE standards to set baseline equipment efficiencies. It is especially not applicable to custom-built HVAC systems not registered with AHRI for which equipment performance may not be independently validated. The baseline efficiency levels and standard system features would need to be developed via an industry standard practice (ISP) study or customer standard practice if they own multiple facilities. The ISP baseline values would need to be determined from local market studies and/or surveys (participant, trade allies, contractors, etc.), other similar projects, or secondary research in other jurisdictions, and could be documented in the TRM or program manuals.
- **The baseline HVAC system type for grow rooms should be the same as the installed system type.** The HVAC and dehumidification conditioning for grow spaces is accepted as process conditioning, not human comfort conditioning. Similar to many other process measures, efficiency should reflect a change in performance not a change in system type, unless a different system type and associated performance characteristics can be established via industry standard practice (ISP) research or guidance or shown to be a customer's current practice for other similar, existing facilities. For example, for grow rooms, the efficient configuration of a system would be one that uses an integrated design and control scheme vs. one assembled from completely separate elements with their own separate control systems and reacting independently to space conditions.
- **Incorporate LPD-based lighting into the building simulation models.** LPD-based lighting loads are not currently included in the building simulation models, likely because they are relatively small compared to the predominant LED grow area lighting loads. The evaluation team found the HVAC systems for the non-grow support areas are typically also included in the building simulation models; however, in which case the LPD-based lighting loads should also be included.

Create Guidelines/Standards for Indoor Agricultural Growing Facilities

- **Develop or adopt indoor agricultural growing facility baseline requirement guidelines.** The lighting and HVAC systems, baseline assumptions, and system operations are unique for these facility types, as recognized by the development of code minimum requirements in many other jurisdictions. If these facilities will continue to participate in energy efficiency efforts, it is highly recommended that a comprehensive guidance document be developed for consistency across these projects and to ensure claimed savings are appropriate. There is existing recent research and multiple resources from other jurisdictions that can be leveraged. Trane TRACE has also done extensive development of materials for modeling these complex HVAC systems that can also be leveraged.[7]

[7] One example of the materials developed by Trane: "Indoor Agriculture: HVAC System Design Considerations." *Engineer's Newsletter* 48-3 (2019). https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/airside-design/admapn071en-082019.pdf.

- **Develop Process HVAC system peak demand factors for Indoor Agricultural Growing HVAC systems.** Conventional TRM HVAC demand value factors are currently being used for these HVAC systems per the stipulation agreement last year.[8] These HVAC systems are serving process loads not human comfort; however, and HVAC loads for these facilities are also much flatter and less peaky than conventional HVAC conditioning, so it makes sense to develop a new factor. Existing building simulation runs for all of the projects in the program could be used to develop the new factors.
- **Detailed monitoring/metering of grow area custom-designed systems may be a more appropriate evaluation method.** The HVAC systems serving the grow rooms are highly engineered and controlled systems that cool/dehumidify, humidify, heat, and reheat to meet design conditions for agricultural products on multiple and variable growing cycles. A more rigorous evaluation of these systems would require at least short-term monitoring and metering of key system elements, or a much more extensive review of data from the onsite energy management system.
- **Conduct a post-occupancy evaluation** to **validate the building simulation modeled annual energy use against actual consumption.** This would have to be conducted as a special study or under evaluation for future years since at least a year of 100% operational energy use would be needed. If the building simulation results are a true reflection of actual operation and the energy use is relatively flat year-round; however, only several months or a complete growing season may be sufficient for the assessment. Results from this analysis could also be used to provide benchmarking of future projects and integrated into an indoor agricultural growing guidance document.

[8] State of Missouri Public Service Commission, File No. EO-2018-0211, "Order Approving Stipulation and Agreement." September 23, 2021: "HVAC-related equipment incentivized through the business program for indoor agriculture facilities will use an HVAC end-use load shape for purposes of the PY 2021 evaluation. Opinion Dynamics will develop additional PY 2021 evaluation plans to assess the net-to-gross of this emerging business segment."

Site ID: 9200 (New Construction)

Project Description

This new construction, gut-rehab project involves the conversion of a single-story, 94,000 square foot former warehouse/manufacturing space to an indoor agriculture facility plus associated office and support spaces. The project included energy efficiency upgrades to the HVAC systems serving the grow areas and LED lighting for the entire building (grow areas plus office/support spaces). The majority of the LED lighting is located in grow areas that are not currently covered by energy code minimum lighting power density (LPD) requirements (LPD-exempt) and assume high-pressure sodium (HPS) or T5 high-output (T5 HO) linear fluorescent fixtures as the baseline. For usage areas that would typically be subject to new construction, IECC 2018 LPD (as cited in the application) requirements provide the baseline. HVAC energy savings, reported to also be based on IECC 2018 baselines, are achieved through improved efficiency of the HVAC equipment plus the indirect reduced cooling load from LED lighting.

The first table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project. The second table provides a subtotal for the lighting measure savings which are 36% of the project savings.

Site 9200 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
Water-Cooled Scroll Chiller	HVAC	10,437,050	4,633.87
Lighting - Flower Rooms (LPD-exempt)	Lighting	3,308,638	628.52
Lighting - Vegetation Rooms (LPD-exempt)	Lighting	1,489,130	282.88
Lighting - Mother Clone Room (LPD-exempt)	Lighting	902,560	171.45
Lighting - Offices (LPD-compliant)	Lighting	35,712	6.78
	Total	**16,173,090**	**5,723.51**

Site 9200 Ex Ante Lighting Savings Subtotal

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
Grow Area Lighting	Lighting	5,700,328	1,083
LPD-Based Lighting	Lighting	35,712	6.78
	Total	**5,736,040**	**1,089.64**

Data Collection

Data collection for this project consisted of a desk review of project documentation and onsite verification.

Project Documentation Review. The evaluation team reviewed all available project documents to understand the scope of the project including the final application, all summary files, invoices, site plans, HVAC and lighting equipment specifications, building energy modeling (BEM) report files, and other supporting documents to determine the baseline and proposed equipment and conditions, and to understand the basis for estimated

energy savings. All of this information was referenced in developing an engineering analysis workbook used to estimate ex post savings and document the approach. Key information and project characteristics obtained from the final application and other documentation include:

General Notes

- A "Project Narrative" document was not provided for this project so the evaluation team compiled project overview information from a variety of other documents. The project narratives typically provide a high-level overview of the project, individual enduse elements (like HVAC and lighting systems) and relevant general information.
- All building simulation model files were initially missing from the project documentation but were provided on request by the program implementer and trade ally (TA) who runs the simulations.
- In the building simulation file directory, there was a summary workbook (Final Model Calcs ZR.xlsx) that was especially useful for project information and sources of savings values. The workbook contained a summary of the building simulation results, lighting calculations, and some useful notes about the HVAC and lighting systems that informed our analysis calculation workbooks.
- There were floor area inconsistencies throughout the project documentation. A total site floor area of 98,594 square feet (sq. ft.) is reported in the application, but this appears to be incorrect since the building simulation project summary shows this value as the roof area and 94,272 sq. ft. as the total floor area for the project. Another project document showed the total area as 98,594 sq. ft. (listing the Grow Area as 65,000 sq. ft. and Office area as 33,594 sq. ft.). For the lighting power density calculation, the floor area used for the office-support areas was 38,614 sq. ft. None of these values were supported by a summary tabulation of floor areas, though a site plan was available. The building simulation model seemed to incorporate all the activity areas and their corresponding floor areas, though the evaluation team only did a spot check not a detailed review. Accurate accounting of floor area is important for LPD-based calculations which use floor area as a key variable in energy savings calculations.
- Invoices appeared to be available for all lighting and HVAC equipment.

HVAC Notes

- The HVAC systems were described in the project application as a "water-cooled scroll chiller." The evaluation team found that there are two distinct and separate types of process HVAC systems serving the grow areas; however, and the chilled-water system is actually the smaller of the two systems.
  - The HVAC Measure Type is labeled as a "Water Cooled Chiller (incremental)" with a baseline equipment description of "Baseline HVAC" and new equipment as "WC Chiller WC Cultiva" and total capacity listed as 1,190 tons. However, the mechanical drawings show the primary systems are twenty-two 45-ton water-cooled direct expansion (DX) units serving the flower grow areas and two 100-ton chillers serving the other two grow areas (Veg and Mother Clone). The program implementer noted that the "Water Cooled Chiller" option in the application workbook was the closest match in the drop-down menu to the actual systems for this site, and creation of the application preceded knowledge of a water-cooled package unit system. This is just an issue with the application form, not the building simulation approach. But it illustrates that the application does not adequately document the complexity of the baseline and efficient HVAC systems.

- The Whole Building Performance tab of the final application shows a total area of 98,594 sq. ft. with modeled (Trane TRACE) energy use for the ASHRAE baseline of 32,761,225 kWh vs. the proposed design of 16,623,107 kWh and a savings estimate of 49.3% of baseline energy use.

- The baseline and efficient scenario configurations and input assumptions for the simulation model runs are not available from the documentation; only PDFs of the enduse results for the baseline and efficient runs and a variety of modeling reports were provided. The project documentation did not sufficiently describe the three different HVAC system types present at this site, and only two of them were mentioned in the estimate for the total cooling capacity reported in the application.

- After an extensive review of the documentation, the evaluation team was able to determine there are two HVAC system types serving the grow areas and one serving the office and support areas:

  - The largest HVAC system (990 tons) consists of twenty-two 45-ton water-cooled, DX HVAC units which are custom-made by a manufacturer (Cultiva Systems) whose equipment is not certified nor registered with AHRI and appears to be specifically designed for indoor agricultural applications (which could be the reason it is not AHRI certified). Project documentation included specification sheets for two configurations of this unit: one with hot gas reheat (HGR) rated 10.8 EER and the other without HGR rated at 9.3 EER. The mechanical drawings seem to show all units as having reheat capability, though the onsite verification indicated there is one of each unit (one with reheat, one without) serving the 11 flower rooms.

  - The second largest HVAC system (200 tons) consists of two 100-ton chillers and associated fan coil units which are AHRI-certified equipment from Daikin and serve the other two grow areas.

  - The third and smallest HVAC system (57.5 tons) consists of multiple package split systems that serve the non-grow room office and support areas. There are 17 small (five tons or less) split system units (14–16 SEER range, 80%–96% gas furnace) serving the office and support areas. These systems are not mentioned in the scope of the application but appear to be included in the building simulation models and could also contribute to savings where efficiencies are above the code minimums, though the baseline efficiency assumptions were not provided in the project documentation. The capacity-weighted average cooling efficiency for these units is 15.3 SEER.

Lighting Notes

- The LPD-exempt lighting uses HPS 1000W fixtures and T5HO four-foot/eight-lamp fixtures as the baseline fixtures. The ex ante analysis develops the *equivalent quantity* of baseline fixtures needed to provide the same lighting levels as the LED fixture using the *Ameren Ag Lighting Equivalent Quantity* workbook.[9] This workbook was not provided with the original project documentation but was provided in response to questions about development of the baselines for LED lighting. The calculation is based on the common practice of using PPFD (photosynthetic photon flux density) or PPF (photosynthetic photon flux) values for the LED lamps (determined from specification sheets) vs. the PPFD/PPF values for the baseline technologies to determine the equivalent number of baseline fixtures that would deliver a lighting level equal to that of the LEDs. For HPS baselines, the equivalent fixture factors in the workbook were close to 1 but vary from 0.85 to 1.65 with a maximum of 2.47 for the 1500W LED used for this project.

[9] "Ameren Ag Lighting Equivalent Quantity 7-21-21 rev.xlsx" uses a PPFD-based approach to determine the equivalent number of baseline fixtures needed.

- The largest of the LPD-exempt fixtures for this project is a 1500W LED fixture for the flower rooms with an ex ante equivalent baseline quantity of 3,157 HPS 1000W fixtures vs. 1,188 1500W LED fixtures. This HPS factor of 2.66 was an outlier compared to the factors for other LED fixtures. To check this value, the evaluation team used the performance values from the spec sheet provided with the project documentation (1500W, 4200 PPF) in the equivalent quantity calculator, which produced a factor of 2.47 as shown in the table below. Inputs and the calculated values are shown in bold text, and the PPF for HPS is shown in parentheses because it does not appear in the workbook results table, but it is the value used in the workbook for the calculations.

Site 9200 Equivalent Quantity of Baseline Fixtures for A3i 1500W Fixture

Fixture Type	Watts	PPFD (µmol/m2/s)	Equiv. Quantity Factor	PPF (µmol/s)	Equiv. Watts
HPS DE	1060	944	2.47	(1700)	2619
A3i 1500	1500		1.00	4200	1500

- We also contacted the manufacturer of the grow light fixtures who confirmed that, while the typical HPS factor is 1.2 to 1.4, they would use a factor of 2 for these specific fixtures (lower than the Ameren calculator). They also indicated that at that factor, the heat of the HPS lamps and impact on the HVAC system would be excessive. Project documentation indicated these lamps are not often operated at 100% but are dimmed to lower levels for a good part of their operation, as reflected in the lower HOU value of 2,115 hours (5.8 hours per day) vs. typical operation for flower rooms of 12 hours on and 12 hours off (4,380 hours per year). Based on these HOU values, the average dimmed percent operation would be about 48% (2,115/4,380) though the actual dimming schedule varies according to the grow cycle. The main point of this discussion is that HPS fixtures dimming capabilities are limited and it is unlikely they could be operated the way the LED fixtures are, so in this case a 1000W HPS baseline may not be applicable. No additional ex post adjustments were made for this finding, but this issue should be considered for future projects.

- The LED fixtures for the other grow rooms use T5HO four-foot/eight-lamp fixtures as the baseline technology. The Ameren equivalent baseline quantity workbook did not contain equivalent factors vs. T5HOs for either of the two lamps used in these areas (F1V 600W and F1V 420W). Using the spec sheets for these fixtures, however, the evaluation team validated the ex ante equivalent quantity baseline factors for both the F1V 600W fixture at 2.34 (898/384) and the F1V 400W fixture at 3.35 (543/162).

- The LPD-compliant portion of the site (non-grow, support areas) was estimated at 38,614 sq. ft. and the ex ante savings calculation used an “Office” space type with an LPD of 0.79 consistent with IECC 2018. Aa quick review of the site plan, however, showed that the majority of the non-grow space is actually mechanical/electrical support areas rather than office space.

- The lighting specification sheets and lighting scenario calculations included in the Lighting subdirectory of this project used completely different fixtures than those listed in the application. They may have been incorrectly uploaded from another project or perhaps were changed by the customer and then not updated. Spec sheets for the support area fixtures were not provided, but the spec sheets for the grow lighting were available.

Overall, the HVAC systems, layout, and operation of these sites is very unique and complex. The project was insufficiently documented, and some key information was missing, including a summary of the HVAC systems and baseline vs. efficient parameter comparisons.

Onsite Verification Results. The evaluation team conducted the onsite verification on February 1, 2022. The time onsite was very limited due to an impending snowstorm, so verification staff were directed to verify as many of the verification points as possible but to prioritize the equipment and areas responsible for the largest portion of project savings. Key findings from the onsite verification include:

- The site is not yet at full operation but expects to be at full operation in the next six months (i.e., in Summer 2022). The first plants had just arrived, some lighting equipment was in storage awaiting installation, and the HVAC systems are likely only partially operational and/or still being commissioned as a result.
- There was no disruption to site operation due to COVID-19 since the site is still not fully operational.
- Total project floor area and floor areas of the non-grow area activity areas could not be confirmed due to the interim state of operation. The field engineer estimated the number and area of the individual flower grow rooms to be 11 rooms @ 4000 sq. ft. each, which matched the number of rooms and was the approximate floor area per room shown on the building plans.
- The non-grow support area where the LPD-compliant lighting measures were located was more diverse than just office space, and the office space was a small portion of the area.
- HVAC systems operate continuously (24 hours per day, seven days per week, 365 days per year)
- The site contact describes lighting in the grow areas reported as operating 12 hours on, 12 hours off, seven days a week.
- There are two separate HVAC systems for the grow rooms at this site: (1) A water-cooled chiller (chilled-water) plant and fan coil units serving the occupied and support areas and (2) Multiple custom manufactured, non-AHRI-certified, water-cooled package DX units serving the grow areas. The HVAC systems and configurations were not clear from the simplified project application description, but the field engineer confirmed the make/model information for the chiller and the DX units.
- The fixture make/models for the grow areas were verified by visual inspection of the configuration and product labels. All of the claimed fixture lighting types except one were visually verified on site. The lighting fixtures installed in the office areas appeared to be different than the ex ante claimed equipment; it was probably substituted for the ex ante fixture that was not found. Some of the incented lighting equipment was also found in storage onsite still awaiting installation, which was not unexpected given the partial operation state of the site.
- The field engineer took photos of the HVAC control system (screen shots), HVAC system elements (chiller nameplate, chiller water lines, DX units, humidifier, etc.), installed lighting systems with room location reference, and uninstalled lighting equipment for the grow rooms and support areas in boxes in storage rooms with fixture make/model labels.

Analysis

The evaluation team combined onsite verification results with the ex ante project documentation review to evaluate this site. The ex post analysis approach is discussed below for each of the three project measures: HVAC, LPD-exempt (grow room) lighting, and LPD-compliant lighting.

HVAC Savings. Ex ante savings were estimated using the TRACE™ 3D Plus 4.01.97 (release date October 28, 2021) building simulation software with an IECC 2018 baseline according to the project application. The project summary documentation shows the total conditioned floor area as 94,272 sq. ft. and roof area of 98,594 sq. ft. The ex ante savings reported in the application agree with the values from the TRACE project summary document. The lighting savings values in the simulation are also roughly the same as the ex ante values directly calculated from fixture details.

For the ex post analysis, the evaluation team was unable to validate the underlying HVAC system configurations and efficiency assumptions, nor confirm the IECC 2018 baseline, from the documents that were provided. However, the claimed percent total savings (49.3%) seems excessive compared to real-world expectations for efficiency projects. One of the biggest drivers is the large baseline lighting loads, but the other component could be the baseline HVAC assumptions that the evaluation team was unable to review and validate.

The figure below presents a comparison of the baseline and efficient scenario simulated results excerpted from the *Final Model Calc ZR.xlsx* project document. This summary also contains some high-level notes about the approach which are listed below the figure:

Site 9200 Summary of Building Simulation Ex Ante Savings Results

	1.7L/kWh, Elec Heat		Efficient HVAC and LED 30%RH	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	15,585,760.00	2,732.38	7,056,087.00	1,430.15
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	3,060,542.00	349.37	1,252,947.00	143.03
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	17,998.99	7.27
Heating	2,518,431.00	288.06	2,321,690.87	1,289.80
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	11,511,970.00	3,193.47	5,810,904.00	1,640.47
Interior Receptacles	84,522.34	16.02	84,522.34	16.02
Pumps	0.00	0.00	78,957.34	9.84
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	32,761,225.34	6,579.30	16,623,107.54	4,536.58
		% Savings		
Total Model Savings	16,138,117.80	49.3%		
HVAC Savings	10,437,051.80	49.3%		
Lighting Savings	5,701,066.00	49.5%		
HVAC Baseline kWh/Yr	21,164,733.00			
Baseline kWh/Ton	17,785.49			
HVAC Efficient kWh/Yr	10,727,681.20			
Efficient kWh/Ton	9,014.86			
2- 100 Ton Chillers	200			
22- 45 Ton Cultiva Units	990			
Estimated Tons of HVAC	1190			

In the figure above, the two primary HVAC systems serving the grow areas are noted, although the source of those values is not provided, and the results are not broken out for the two systems. The HVAC split systems serving the office and support areas are not shown here but appear to be included in the model. It is not clear if the installed equipment SEER and heating efficiency levels vs. code minimum efficiency levels were used for the analysis, but if they were that would provide additional savings.

From the enduses listed, especially the presence of pumps and heat rejection in the efficient model, the baseline system was probably assumed to be 100% packaged air-cooled DX units. Because this is primarily a process application for the HVAC systems, a more appropriate baseline would have been the same water-cooled system used for the efficient scenario but with standard-practice efficiency and performance equipment, and references for those assumptions. The use of custom-made, non-AHRI process HVAC equipment which is likely not subject to federal equipment standards may also make this approach challenging.

Other relevant notes about the simulation approach that were copied as-is from an ex ante calculation workbook are listed below, with evaluation comments indicated in brackets [ ]:

- *"Two different systems (Cultiva) run in parallel per flower room, one has an EER of 10.8, the other 9.3, I averaged the two for a single system EER of 10.05"* [10.8 EER unit has hot gas reheat, 9.3 unit does not but the units are not AHRI-certified, so these are the manufacturer's reported values. Mechanical documents seem to show all installed units are hot gas reheat units, invoice only shows the total cost of the DX systems and does not contain a model number]

- *"Dimming of lights only takes place in the flower rooms; veg and mother rooms are at full brightness for 18 hours per day."* [This note explains the relatively low HOU value for the 1500 WLEDs, and this workbook also contained a detailed dimming schedule. Onsite verification indicated the schedule should be 12 on/12 off, but did not confirm dimming practices]

From a spot-check of the simulation reports provided, it appears that the building simulation model is detailed enough to capture the site configuration and multiple HVAC systems serving each area. However, without more complete information (especially the baseline) the evaluation team was not able to comprehensively evaluate the HVAC savings due to insufficient documentation. As lighting savings were adjusted (as discussed in the next sections), however, the evaluation team did adjust the HVAC savings proportionately to the lighting savings and explained this decision in the Results section.

The evaluation team tried to validate the modeled energy use and savings vs. actual billing data but could not draw conclusions from the consumption data because the site is not yet fully operational and had only a single month of post-implementation operation available. The evaluation team also tried to validate the annual energy use from the simulations by looking at the energy use intensity (EUI, kWh/sq. ft.). Using the ex post total floor area discussed above: The efficient case EUI was 176 kWh/sq. ft. and the baseline EUI was 348 kWh/sq. ft. Although the EUI's for this type of building can be expected to vary widely, a recent CEC CASE study report provided some average EUI values: "a California indoor cannabis facility averages 241 kWh per square foot of canopy" and "facilities using HPS lamps average 282 kWh/square foot while those using LEDs average 173 kwh per square foot."[10] While the efficient scenario is in line with the LED EUI, the baseline energy

[10] "Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code, Controlled Environment Horticulture." 2022-NR-COV-PROC4-F, March 2021 FINAL CASE REPORT (UPDATED). Prepared by Energy Solutions and Cultivate Energy and Optimization.

intensity for this site of 348 kWh/sq. ft. is 44% higher than the CEC study HPS baseline, which could further support the idea of a baseline that is too high.

LPD-Exempt Lighting Savings. Lighting in the grow areas is considered exempt from new construction code lighting power density (LPD) requirements because it is more like a process load, although some jurisdictions are now beginning to add requirements for indoor horticulture buildings.[11] Baselines for these lighting systems are instead based on industry standard practice (ISP) which is primarily HPS or T5HO fixtures, as discussed in detail in a recent California study.[12] The table below shows the key parameter values used in the estimation of energy savings for the LPD-exempt lighting measures:

Site 9200 Ex Ante Parameters for LPD-Exempt Lighting Measures

Space	Baseline				Efficient				
	Fixture Type	Quantity	Watt/Unit	Total kW	Fixture Type	Quantity	Watt/Unit	Total kW	HOU
Flower Rooms	HPS-1000W	3,157	1060	3346	Fohse A3i	1,188	1,500	1782	2,115
Veg Rooms	T5HO (4ft-8L)	898	432	388	F1V 420w	384	420	161	6,570
Mother Clone	T5HO (4ft-8L)	543	432	235	F1V 600w	162	600	97	6,570
Totals		**4,598**	-	**3,969**		**1,734**		**2,040**	

The ex post changes include adjustments for partial site operation and baseline fixture assumptions as follows:

- The majority of the lighting savings are from the flower room fixtures that use an HPS baseline. The ex ante assumptions use an equivalent fixture factor of 2.66 (3,157/1,188) HPS fixtures vs. efficient LED fixtures which seemed excessive. The basis for the baseline assumptions is the *Ameren Ag Lighting Equivalent* workbook (previously mentioned) which is used to calculate the equivalent number of baseline 1000W HPS fixtures needed to match LED performance. A discussed in the Data Collection section, the evaluation team calculated the equivalent baseline fixture value as 2.47 using the spec sheet provided with the project documentation, and this is the value we used for ex post calculations.
  - There is also the issue of the low assumed HOU value (2,115 hours) for these fixtures. Project notes indicated the fixtures are dimmed during the growing cycle, so the 2,115 hours represents an equivalent full-load (full-wattage) operation. Because HPS lamps have limited dimming capabilities, this adds some uncertainty to using HPS as the baseline system. However, we did not make any additional ex post adjustments for this finding.
- For the F1V LED fixtures in the other grow rooms, as previously discussed the evaluation team used the spec sheets provided with project documentation to validate the ex ante equivalent quantity baseline factors for both the 600W and 400W fixtures, so ex ante values were used for the ex post analysis.
- As discussed earlier, the onsite verification found that some of the lighting equipment for the veg rooms and mother clone rooms was found in storage and not installed yet. Although the site is not fully operational, the approximate counts of installed equipment were used as the ex post quantities and

[11] California's latest 2022 Title 24 Standards, which take effect January 1, 2023, include some requirements for controlled environment horticulture (CHE) facilities.
[12] "Market-Based Industry Standard Practice (ISP) Study of the Cannabis Grow Lighting" for the California Public Utilities Commission. SBW Consulting, Inc. Dec 21, 2021.

are summarized below. For ex post savings, the percentage installed values shown were applied as adjustment factors to the ex ante savings.

Site 9200 Ex Ante Parameters for LPD-Exempt Lighting Measures

Space	Ex Ante Quantity	Onsite Verified Quantity	Percent Installed
Flower Rooms	1,188	1,188	100%
Veg Rooms	384	352	91.7%
Mother Clone	162	144	88.9%

For reference, the full set of ex ante values are shown in the table below, including the HOU values with ex post changes shown in bold text. The site is not fully operational so the HOU could not be evaluated, though the onsite verification indicated the lights are operated 12 hours on/12 hours off every day which equates to 4,380 hours a year and is quite different than both of the ex ante HOU values. An HOU of 6,570 hours is 18 hours per day and 2,115 hours is 5.79 hours per day.

Site 9200 Ex Ante & Ex Post Parameters for LPD-Exempt Lighting Measures

Space	Efficient/Ex Ante			Verified/Ex Post			Ex Ante
	Quantity	Watt/Unit	Total kW	Quantity	Watt/Unit	Total kW	HOU
Flower Rooms	1,188	1,500	1,782	1,188	1,500	1,782	2,115
Veg Rooms	384	420	161	**352**	420	**148**	6,570
Mother Clone	162	600	97	**144**	600	**86**	6,570

LPD-Based Lighting Savings. For the lighting measures in the non-grow support areas, ex ante used a code-baseline LPD approach consistent with new construction. The table below provides a summary of the equipment and key parameter values used for the ex ante energy savings estimate.

Site 9200 Ex Ante Parameters for LPD-Compliant Lighting Measures

Building Area Type (LPD)	Fixture Type	Fixture Quantity	Watt/Fixture	Annual HOU
Office (0.79)	Luxterior TCP-GPS-8-U-ZD-A-835K	116	65	2,080
Office (0.79)	Oracle 24-0VHP-LED-4000L - DIM 10 MVOLT	161	36	2,080

The ex ante lighting power densities (LPDs) were based on 2018 IECC as stated in the application. The ex ante savings estimate used an LPD of 0.79 for an Office activity based on the Building Area Type method and a floor area of 38,614 sq. ft. However, these key ex ante assumptions were not supported by detailed area calculations. The evaluation team examined the site plans and found the office space was only a small portion of the support areas, so the evaluation team used the plans to develop an ex post estimate of support space floor area by activity area. These values are provided in the table below using the area names and floor areas shown on the site floor plan. The table also presents the floor area totals for all non-grow support areas, for grow rooms (Flower, Veg, Mother/Clone), and the total site floor area calculated from the sum.

Site 9200 Floor Area Breakdown

Area Label	Floor Area	Percent of Non-Grow Area
HVAC	18,292	48.9%
Elec/Mech	2,269	6.1%
Lab	4,739	12.7%
Dry	3,513	9.4%
Trim	2,355	6.3%
Secure Storage	1,550	4.1%
Office	1,205	3.2%
Fertigation	1,186	3.2%
Break	892	2.4%
Bathrooms	650	1.7%
Edible	522	1.4%
Security	145	0.4%
Storage	59	0.2%
Air	27	0.1%
Total Non-Grow Areas	**37,404**	**40%**
Total Grow Areas	**55,658**	**60%**
Total Site	**93,062**	**100%**

As can be seen from the tally, the ex ante selection of an "Office" LPD was not an appropriate choice since the predominant area type is electrical/mechanical rooms (the "HVAC" space is a mechanical room occupied by the large HVAC DX units). The HVAC plus electrical/mechanical floor area is about 55% of the non-grow space. Staying consistent with the LPD guidance provided in Ameren's *Guide to Energy Efficiency Incentives for New Construction,* which uses a Building Area Type approach, there is not a great fit for electrical/mechanical areas. For the ex post analysis, the evaluation team selected the Warehouse building type (0.48 LPD) as the best fit for the site's non-grow areas. Using the Space-by-Space LPD method instead of the Building Area Type method would likely yield a better estimate since the available areas and associated LPDs are more diverse. Example areas and LPDs are *Electrical/Mechanical Room*=0.43, *Office (Enclosed)*=0.93, *Lab (Other)* =1.45, *Storage Room*=0.46. The Electrical/Mechanical Room LPD is similar to the Building Area Type Warehouse value of 0.48 which validates the choice of this value for ex post evaluation.

As previously discussed, there were several floor area inconsistencies in the project documentation. Our ex post non-grow floor area estimate is slightly smaller than the value used for the ex ante LPD calculation: 37,404 sq. ft. vs. 38,614 sq. ft. The ex post estimated total site floor area (93,062 sq. ft.) is similar to, but also smaller than, 94,272 sq. ft. from the ex ante building simulation project summary. Another project document showed the total area as 98,594 sq. ft., with the grow area as 65,000 sq. ft. and the office area as 33,594 sq. ft. For future applications, it is essential that the total site floor area and the interior activity areas and their associated floor areas be summarized and used consistently throughout the application and calculations, especially in non-grow areas where an LPD approach will be used to establish the baseline lighting energy use. Given the variety of floor area values used and a lack of supporting calculations for any of

them, for the ex post calculations the evaluation team used our calculated non-grow floor area of 37,404 sq. ft.

In addition to the LPD issue, one of the lighting fixture types for this area was different than found onsite. It appears that the ex ante fixture (Oracle 24-OVHP-LED-4000L - DIM 10 MVOLT) was replaced by a different fixture (Lithonia CPX 2x4 4000LM 40k M2) rated at 38.9W per fixture vs. 36W for the ex ante fixture. A number of these fixtures were also found in storage. The onsite verification team was not able to assess the number of lights installed due to limited time on site; however, and the savings from these fixtures are relatively small, so the ex ante quantities were used as-is. Final ex post values for the LPD-based area fixtures are presented in the table below, with updated values shown in bold text.

Site 9200 Ex Post Adjusted Parameters for LPD-Compliant Lighting Measures

Building Area Type (LPD)	Fixture Type	Fixture Quantity	Watt/Fixture	Annual HOU
Warehouse (0.48)	Luxterior TCP-GPS-8-U-ZD-A-835K	116	65	2,080
Warehouse (0.48)	Lithonia CPX 2x4 4000LM 40k M2	161	38.9	2,080

Values in bold text indicate differences between ex ante and ex post

Lighting Savings Summary Totals. Ex post vs. ex ante energy savings results for both grow area and LPD-based lighting measures are presented in the table below.

Site 9200 Evaluation Savings Results for Lighting Measures

Measure Name	Annual Energy (kWh)		
	Ex Ante Gross	Ex Post Gross	Realization Rate
Grow Area Lighting	5,700,328	4,976,116	87%
LPD-Based Lighting	35,712	8,634	24%
All Lighting	**5,736,040**	**4,984,750**	**87%**

Results

The final ex post evaluated savings and realization rates are summarized in the table below. Since this new construction site was not fully functional at the time of the evaluation data collection, the achieved energy savings may further change as that project is completed. The 87% realization rate is primarily due to adjustments made to the lighting measures and the proportional adjustment of HVAC savings for those changes. The HVAC savings could not be directly evaluated due to a lack of sufficient project documentation, though indications are that an incorrect baseline was used that produced higher savings than a more correct baseline would have. Discrepancies, ex post adjustments, findings, and recommendations are discussed in more detail below.

Site 9200 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
Water-Cooled Scroll Chiller	10,437,050	9,125,678	87%	4,633.87	4,051.65	87%
Lighting - Flower Rooms	3,308,638	2,808,805	85%	628.52	533.57	85%
Lighting - Veg Rooms	1,489,130	1,365,036	92%	282.88	259.31	92%
Lighting - Mother Clone Rm	902,560	802,276	89%	171.45	152.40	89%
Lighting Offices	35,712	8,634	24%	6.78	1.64	24%
Total	**16,173,090**	**14,110,429**	**87%**	**5,723.51**	**4,998.57**	**87%**

Reasons for Discrepancies

Discrepancies and ex post adjustments for this project include:

- For LPD-exempt lighting measures, adjustments were made to the energy savings proportional to the lower fixture quantities found installed onsite for the veg room and mother clone room fixture. For the flower room fixtures, ex post calculations corrected an error in the ex ante baseline equivalent-fixture factor and changed the value from 2.66 to 2.47 based on project documentation spec sheets.
- For LPD-based lighting measures, ex post adjustments were made to the ex ante floor area and the LPD Building Area Type. The ex ante analysis used a floor area of 38,614 sq. ft. an Office LPD of 0.79 area vs. the ex post floor area of 37,404 and a Warehouse LPD of 0.48. In addition, one of the ex ante measure fixture types was replaced with a different model and wattage: ex ante was 36W and ex post was 38.9W.
- HVAC savings could not be evaluated due to insufficient HVAC system project documentation. To account for lighting/HVAC system interaction, the ex post applied the overall lighting energy realization rate to the ex ante HVAC savings.

Other Findings and Recommendations

- The evaluation of this site should be considered an interim assessment because it is still ramping up to full operation, which is expected to be achieved in 6 months. Although some adjustments were made to the ex ante calculations based on our review and onsite verification activities, no adjustments were made to any HOU values due to the state of the site. Ideally, savings for the site should not be claimed until it is fully operational and ex ante assumptions can be completely evaluated, although an indoor agricultural facility might always be in some state of partial operation due to grow cycles.
- The 17 smaller split-system HVAC units serving the non-grow support areas (the third type of HVAC system at this site) would be subject to HVAC equipment code-minimum efficiency requirements, and savings claimed, if applicable, but this equipment was not mentioned in the project documentation.
- The HVAC systems serving the grow areas should be considered process equipment especially in this case where the predominant cooling systems are large, water-cooled DX units which are custom-designed, non–AHRI certified units built by a manufacturer that exclusively produces units to meet the unique requirements of indoor agriculture. As recommended in the previous evaluation cycle, a new

Process HVAC kW factor should be developed for these units rather than continuing to use the human-comfort based HVAC kW factor.

- Given the seemingly late start of this project (end of 2021) and its current state of operation, it may be better to remove the project from PY2021 and claim savings instead in PY2022 when it should be fully operational, and all equipment is installed and running as claimed. An alternative would be to do a partial claim for PY2021 with the balance claimed in PY2022.
- The HVAC system, equipment and areas served are not itemized anywhere in the application and the HVAC measure description that was provided is insufficient and overly simplified. It was also not possible to confirm that the installed equipment matched the incented equipment. While building simulation files were provided in the project documentation, the evaluation team could not locate a summary of the actual modeling assumptions and key input parameter differences between the two models, only the detailed models and modeled results.

Site ID: 9201 (New Construction)

Project Description

This new construction project involves the conversion of a 94,000-square-foot warehouse facility to an indoor agricultural facility with associated office, lab, and production support spaces. The project included energy efficiency upgrades to the HVAC systems serving the grow areas and LED lighting for the entire building. The majority of the LED lighting is located in grow areas that are not currently covered by energy code minimum lighting power density (LPD) requirements (LPD-exempt) and assume high-pressure sodium (HPS) or T5 high-output (T5HO) linear fluorescent fixtures as the baseline. For usage areas that would typically be subject to new construction code, IECC 2018 LPD (as cited in the project application) requirements provide the baseline. HVAC energy savings, reported to also use an IECC 2018 baseline, are achieved through improved efficiency of the HVAC equipment plus the indirect reduced cooling load from LED lighting.

The first table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project. The HVAC measure accounts for 67% of ex ante energy savings, and the lighting measures account for 33% of ex ante energy savings.

Site 9201 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
HVAC	HVAC	3,018,493	1,340.16
Lighting – Flowering Rooms	Lighting	2,802,762	532.42
Lighting – Vegetative Rooms	Lighting	344,794	65.50
Lighting – Offices (LPD Approach)	Lighting	254,093	48.27
	Total	**6,420,142**	**1,986.35**

The second table provides a savings subtotal for lighting based on the LPD status (LPD exempt or non-exempt). The LPD-exempt lighting in the facility grow areas accounts for 93% of ex ante lighting savings, and the LPD-compliant lighting accounts for only 7% of ex ante lighting savings.

Site 9201 Ex Ante Lighting Savings by LPD Exempt/Compliance

Lighting Type	Ex Ante kWh	% Ex Ante kWh
LPD Exempt Grow Area Lighting	3,147,556	597.92
LPD-Compliant Lighting	254,093	48.27
Lighting Subtotal	**3,401,649**	**100%**

Data Collection

Data collection for this project consisted of a desk review of project documentation and an onsite verification.

A significant item to note is that the new indoor agriculture facility is only partially operational. The project completion form was signed October 2021, and the site contract estimated the site will each full operation within six months of the evaluation period (late Summer 2022).

Project Documentation Review. The evaluation team reviewed all available project documents to understand the scope of the project including the final application, all summary files, invoices, site plans, HVAC and lighting equipment specifications, building energy modeling (BEM) report files, and other supporting documents to determine the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings. All of this information was referenced in developing an engineering analysis workbook which was used to estimate ex post savings and document the approach. Key information and project characteristics obtained from the final application and other documentation include:

General Notes

- The project documentation included a "Project Narrative" document that provided a high-level overview of key aspects of the project including location, site photos, floor area, building configuration, and a brief description of the planned use for the site; a one-paragraph summary of the energy efficiency project and measures; a summary of building simulation modeled savings (but did not include the final claimed values); and additional notes and high-level descriptions about the measures and operation of the site. High-level HVAC notes (1) mention that Trane Trace 3D (v 3.01.25) will be used to model savings, (2) imply that that the baseline HVAC system is air-cooled systems while the efficient system is glycol-water cooled units, (3) mention a variable refrigerant flow (VRF) system, and (4) states that IECC 2018 will be used to set HVAC baselines. The narrative also includes a very abbreviated summary of the baseline and efficient HVAC systems and the areas each serves, as shown below.

Site 9201 Project Narrative HVAC Baseline and Efficient Equipment Summary

HVAC system DX

Size Range/Room	Baseline Main FR	Eff Main FR
Flower Rooms	CV 11.0 EER Elec Heat room dehum	Quest 11.19 EER w/HGR Elect Heat
Veg Rooms	CV 11.0 EER Elec Heat room dehum	CV 10 EER HGR gas unit heat
Clone Room	CV 11.0 EER Elec Heat room dehum	CV 10 EER HGR gas unit heat
Head House RTU	CV 11.00 EER Gas Heat	11.09 EER/14.6 IEER gas heat
Lab Processing DOAS	11.0 EER DX with Gas Heat	10.3 EER/16.4 IEER gas heat
Remaining Areas	CV 11.00 EER Elec Heat	Trane VRF 12.7 EER Heating COP 3.8

- Both the Project Narrative document and notes on the site plan drawings indicated three phases of this project and state that, "Phase 3 will follow this project." The project narrative does not discuss the implications of project phasing, but the implication could be that elements of this project will be coming online in stages rather than going to full operation immediately.
- Total floor area for the project was reported inconsistently throughout the documentation as 91,000; 93,839; 94,000; and even 102,886 sq. ft. in the building simulation model (which also reported conditioned area of 59,188 sq. ft.). The project narrative and application also reported a total grow area of 65,000 sq. ft. and 29,000 sq. ft. as office, lab use, and production support services. The multiple project phases could be a cause of this confusion.
- A summary of ex ante grow room lighting savings calculations and HVAC building simulation results that are consistent with the application and claimed savings was found in this file: *Final Model Calcs.xlsx*. Key elements of the results and calculations shown in this workbook are:
  - **Trane TRACE simulation results summary:** Results are shown in the figure below. Given that energy use for the pumps and heat rejection enduses are zero, it does not appear that a water(glycol)-

cooled HVAC system was modeled for either the efficient or baseline case. In addition, there is slight difference in the interior receptacles endues, which could indicate a structural difference in the baseline and efficient models, when they should be the same.

Trane TRACE Building Simulation Results used for Site 9201 Ex Ante Savings

11/10/2021				
	LED Hi Eff HVAC HGR		Baseline	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,178,816.00	455.71	4,874,579.00	877.5
Exterior Lighting	0	0	0	0
Exterior Receptacles	0	0	0	0
Fans	464,901.30	54.61	1,145,325.00	130.74
Heat Recovery	0	0	0	0
Heat Rejection	0	0	0	0
Heating	1,533,255.00	384.38	1,175,561.00	218.49
Humidification	0	0	0	0
Interior Lighting	4,447,415.00	914.57	7,354,655.00	1,590.80
Interior Receptacles	22,336.31	7.32	37,140.05	12.17
Pumps	0	0	0	0
Refrigeration	0	0	0	0
Service Water Heating	0	0	0	0
Grand Total	8,646,723.61	1,816.59	14,587,260.05	2,829.70
Total Model Savings	5,940,536.44			
Lighting Savings	3,147,556			
HVAC Baseline	7,195,465.00			
HVAC Efficient	4,176,972.30			
HVAC Savings	3,018,492.70			

- **Lighting calculations:** Equivalent 1000W HPS baseline fixture multipliers are provided for the 1500W and 600W LED grow room fixtures: Factors of 2.66 and 0.85 were used, respectively. The source of these values is not mentioned but the values are consistent with use of the *Ameren Ag Lighting Equivalent Quantity* Excel workbook as discussed in more detail in the Lighting Notes section.[13] The specs from program documentation for the two fixtures used for this project, and the standard version of the A3i fixture are presented in the table below.

[13] "Ameren Ag Lighting Equivalent Quantity 7-21-21 rev.xlsx" uses a PPFD-based approach to determine the equivalent number of HPS 1000W or T5HO baseline fixtures needed to produce an amount of lighting equivalent to that of the LED lamps.

Site 9201 Summary of Grow Room LED Lighting Performance Specs and Equivalent Baseline Fixture Quantity Factors

Fixture Type	Fixture Input Watts	PPF (µMol/s)	PPE (µMol/J)	Equivalent 1000W HPS Fixtures Factor
A3i 1500W (for this site)	1480 W	4,529	3.01 - 3.31	2.66
A3i 1500W (Std)	1500 W	4,200	2.8 - 3.0	2.47
F1V 600W	600 W	1,440	2.4 - 2.6	0.85

  - The parameters in the table were used in the *Ameren Ag Lighting Equivalent Quantity* workbook to validate the ex ante values for the baseline equivalent quantity of 1000W HPS fixtures. The specifications for the standard A3i fixture are presented because the ex ante calculations incorrectly used 1500W vs. 1480W for the calculations. The lower wattage with higher performance than the standard A3i for the same model number seemed like a specification discrepancy. After extensive investigation, however, the evaluation team determined this must just be a custom version of the fixture that was not clearly identified in the program documentation or on the specification sheet. Therefore, the ex ante equivalent baseline fixture factor of 2.66 was retained but the fixture wattage used for savings calculation was changed from the ex ante value of 1500W to 1480W.

- The project application "Operating Hours" tab indicates the site is open 24 hours per day, seven days per week, 365 days per year, but 8736 hours is shown in the calculator instead of 8760 because the calculation uses an input of weeks per year and requires a value of 52.14 to yield 8760 hours.

HVAC Notes

- Invoices and specification sheets were available for the HVAC and lighting equipment, including specifications for three QUEST manufacturing DX, water(glycol)-cooled dehumidifiers including a 6-ton veg room unit (AG-206), and 20-ton (AG-220) and 32-ton units (AG-232) serving the flower rooms.
- The project documentation is lacking a detailed description of the HVAC systems and energy savings features responsible for savings. A very abbreviated HVAC equipment summary table (shown above) was provided in the Project Narrative document, but the descriptions are insufficient to clarify the modeled systems and even present conflicting data. For example, for the HVAC system described to serve the veg rooms, (1) the size is not listed, (2) the baseline 11.0 EER efficiency is higher than the efficient case 10 EER, and (3) the meaning of "dehum" vs. "HGR gas unit heat" is unclear. Appropriate project documentation should include a detailed, side-by-side description for the baseline and efficient scenarios of the basic HVAC system configurations, areas served, unit features, sizes, and assumed efficiency and operational parameters.
- The project documentation does not include a mechanical plan, which would provide the inventory of HVAC equipment onsite including key equipment information (size, make, model, efficiency, features, etc.) and the locations and areas they serve. A project invoice contains an eight-page list of HVAC equipment make and model numbers, but there is no information indicating what areas each unit serves.
- The project documentation included 25 building simulation PDF report files, but none of these provide a detailed summary of the baseline vs. efficient case assumptions, nor can they be used to determine the baseline and efficient HVAC systems used and parameter assumptions.

Lighting Notes

The evaluation team reviewed the lighting system types and assumptions for both LPD-exempt and LPD-compliant lighting measures in the project application and found:

- The LPD approach used a floor area of 79,943 sq. ft., which conflicts significantly with other estimates of non-grow area space and is almost the entire site floor area.
- Ex ante calculations use IECC 2018 code baseline and assumed a "Manufacturing Facility" Building Type with a baseline LPD of 0.9.
- For the LPD-compliant spaces, an extensive and varied list of lighting make/model numbers, fixture watts, and quantities (12 different types, quantities of 1 to 50) was provided in the application and used for the ex ante calculations. However, the application did not list the actual activity area where the fixtures are physically located (office, storage, warehouse, etc.). The "Location" field of the application only showed the Building Area Type.
- For the LPD-exempt spaces, the ex ante calculations use HPS 1000W fixtures and T5HO four-foot/eight-lamp fixtures as the baseline fixtures. The ex ante analysis develops the equivalent quantity of baseline fixtures needed to provide the same lighting levels as the LED fixture using the *Ameren Ag Lighting Equivalent Quantity* Excel workbook.[14] This workbook was not provided with the original project documentation but was provided in response to questions about development of the baselines for LED lighting. The calculation is based on the common practice of using PPFD (photosynthetic photon flux density) or PPF (photosynthetic photon flux) values for the LED lamps (determined from specification sheets) vs. the PPFD/PPF values for the baseline technologies to determine the equivalent number of baseline fixtures that would deliver a lighting level equal to that of the LEDs. For HPS baselines, the equivalent fixture factors are close to 1 but vary from 0.85 to 1.65 with a maximum of 2.66 for the 1480W LED fixture used for this project.

Overall, the project HVAC assumptions are insufficiently documented, and there were discrepancies in the accounting of floor areas. However, the HVAC systems, layout, and operation of these sites is very unique and complex. There was very limited and conflicting information available from the program documentation; consequently, the evaluation team selected this site for onsite verification, results are described below.

Onsite Verification Results. The evaluation team conducted a site visit on February 1, 2022. To minimize onsite time, the field engineer prioritized verification points in areas responsible for the largest percentage of project savings. Key findings from the onsite verification include:

- This is a single building site with two floors, but the field engineer was not permitted to inspect the second floor. Portions of the building were still under construction. A second phase of the project is currently underway, but the verification staff were told this was not part of the current project application. Phase one and phase two are different rooms in different parts of the same building. This is consistent with notes on the site plans observed during the project documentation review. Phase one of the building is nearly operational and phase two is under construction.
- The building is approximately 70% grow areas, 25% warehouse/mechanical/electrical rooms, and <5% office, labs, bathrooms, etc.

[14] "Ameren Ag Lighting Equivalent Quantity 7-21-21 rev.xlsx" uses a PPFD-based approach to determine the equivalent number of baseline fixtures needed.

- The site is just starting phase one of production, and they were in the process of testing and stocking grow rooms at the time of the site visit. They had just received plants and said full production would take six months. At the time of the evaluation, the site contact estimated the whole site was at about 3% to 5% of full operation.
- The proposed hours of production and operation will be from 6:00 a.m. to 6:00 p.m., seven days per week. Grow rooms operate at 75°Fahrenheit and 60% to 70% humidity.
- The onsite verification team attempted to identify the HVAC systems using the HVAC equipment information available from the project documentation and additional help from the onsite contact. The field engineer collected photos and make/model nameplate information for all but one of the installed HVAC systems. However, all of these systems are described on the manufacturer's specification sheet as "dehumidifiers." These systems do not contain any efficiency ratings (EER, IEER), do not appear to be AHRI-certified, and are custom designed and manufactured. The field engineer also found some large dedicated outdoor air units (DOAS) that are AHRI-certified, but the site contact could not explain where or how these are used in the system.
- For the LPD-exempt lighting fixtures, the field engineer verified the ex ante lighting fixture make/model numbers by visual inspection of the configuration, model numbers visible on the installed fixtures, and also from product labels on boxed fixtures in storage. The field engineer confirmed that all of the ex ante fixture lighting quantities were installed.
- For the LPD-compliant lighting fixtures, due to the small quantity and variety of fixture types (12 different types, quantities of 1 to 50) and because there were no available spares onsite, the field engineer could not verify the actual make/model and quantities. The field engineer collected photos of the lighting systems in a few areas (offices and hallway).

Analysis

Ex ante savings were estimated using standard engineering algorithms for the lighting measures and Trane Trace 3D (v 3.20.18) was used to model savings building simulation software for the HVAC measures.

HVAC Savings. The table below shows the project description of the HVAC system baseline and efficient case assumptions (taken directly from the project narrative document) and is the most detailed description of the HVAC systems contained in the project documentation.

Site 9201 Ex Ante Summary of Baseline and Efficient HVAC Equipment from Project Narrative

Size Range/Room	Baseline Main FR	Efficient Main FR
Flower Rooms	CV 11.0 EER Elec Heat room dehum	Quest 11.19 EER w/HGR Elect Heat
Veg Rooms	CV 11.0 EER Elec Heat room dehum	CV 10 EER HGR gas unit heat
Clone Room	CV 11.0 EER Elec Heat room dehum	CV 10 EER HGR gas unit heat
Head House RTU	CV 11.00 EER Gas Heat	11.09 EER/14.6 IEER gas heat
Lab Processing DOAS	11.0 EER DX with Gas Heat	10.3 EER/16.4 IEER gas heat
Remaining Areas	CV 11.00 EER Elec Heat	Trane VRF 12.7 EER Heating COP 3.8

The specification sheets indicated the QUEST dehumidifiers are water-cooled, and the application indicates they are evaluated vs. an air-cooled, package/rooftop unit baseline scenario, but the building simulation

results do not reflect water-cooled HVAC equipment. The HVAC savings for this site cannot be evaluated for a number of reasons:

- Project documentation does not describe the baseline and efficient HVAC system or parameters that produce savings.
- Project documentation did not contain a mechanical plan or schedule that lists the HVAC equipment nor the areas they serve. The summary table above does not show unit sizes or model information, which the evaluation team could use identify equipment specification sheets for the HVAC items.
- The QUEST "dehumidifier" units, do not appear to have efficiency ratings, such as the EER and IEER values indicated in the HVAC equipment summary table. There is no basis provided for the EER and IEER values shown in the table above, and the EER ratings for several of the efficient units are less than the baseline EER. These units appear to be custom-made for indoor agriculture applications and are not AHRI-certified.
- The site is still under construction (estimated at 3% to 5% full operation) and has at least two more projects stages before it reaches full operation consistent with the ex ante assumptions.

Due to these challenges, the evaluation could not estimate ex post savings for the HVAC system. However, the evaluation team applied an ex post adjustment to HVAC savings to account for ex post lighting adjustments as associated impact on HVAC load due to interactive effects. Ideally the building simulation model should be rerun with the adjusted lighting loads but adjusting the HVAC savings proportionally to lighting changes should serve as a sufficient approximation of the expected impact.

LPD-Exempt Lighting Savings. Ex ante savings were estimated using standard engineering algorithms for the lighting measures and assumed 1000W HPS (1060W with ballast) as the baseline, as shown in the table below. The ex ante efficient lighting fixture types and quantities were confirmed by the onsite verification, but as previously discussed the ex ante calculations did not use the correct wattage for the flower room fixtures (A3i 1500W). The hours of use for the two areas were not validated but the site is still ramping up operations so HOU would likely vary from the ex ante values. An interim adjustment to operating hours or percentage of lights actually operating could be made to account for partial operation, but ideally the evaluation should be delayed until all project phases are completed and the site is fully operational consistent with ex ante assumptions.

Site 9201 Ex Ante Parameters for LPD-Exempt Lighting Measures

Space	Baseline		Efficient (Ex Post Verified)				
	Quantity	Watt/Unit	Total kW	Quantity	Watt/Unit	Total kW	HOU
Flower Room 1	120	1,060	127.2	45	1,480	66.6	4,380
Flower Room 2	1,170	1,060	1240.2	440	1,480	651.2	4,380
Veg Room 1	18	1,060	19.08	21	600	12.6	6,570
Veg Room 2	130	1,060	137.8	153	600	91.8	6,570

The result of the ex post adjustment to fixture watts for the flower room fixtures is shown in the table below. The change to the efficient case energy use increases the savings to 102% of ex ante.

Site 9201 Impact on Flower Room Lighting Savings Due to Ex Post Fixture Watts Correction

Case	Fixture Watts	Baseline kWh	Efficient kWh	Savings kWh	Percent Change
Ex Ante	1500W	5,989,212	3,186,450	2,802,762	102%
Ex Post	1480W	5,989,212	3,143,964	2,845,248	

LPD-Based Lighting Savings. The table below shows the equipment and key parameter values used for the ex ante energy savings estimate for LPD-compliant areas subject to new construction energy code requirements. No changes were made to the ex ante lighting fixtures quantities, wattages, or hours as there was limited time onsite and fixtures are not aligned to physical areas (office, bathroom, hallway, etc.) so could not have been verified anyway except for random spot-checks. The ex ante hours of use for all fixtures and all support areas was listed as 4,380 hours (equivalent to 12 hours on/12 hours off per day).

Site 9201 Ex Ante Parameters for LPD-Compliant Lighting Measures

Building Area Type (LPD)	Fixture Type	Fixture Quantity	Watt/Fixture	Total Watts
Manufacturing (0.9)	F1 Delviro Zip 8-100-35K-U-FR-WH-V-WFC-N-N	44	99.2	4364.8
Manufacturing (0.9)	F1E Delviro 8-100-35K-U-FR-WH-V-WFC-EM-N	13	99.2	1289.6
Manufacturing (0.9)	F2 TGS 882440-35-L-F	50	40	2000
Manufacturing (0.9)	F2E TGS 882440-35-L-F + Em Batt	17	40	680
Manufacturing (0.9)	F3 TGS 882460-35-S-F	44	60	2640
Manufacturing (0.9)	F3E TGS 882460-35-S-F/90016-L	16	60	960
Manufacturing (0.9)	F4 TGS 882240-35-L-F	8	40	320
Manufacturing (0.9)	F6 Growlite GLE-GL-BB	43	20	860
Manufacturing (0.9)	F7 Columbia ESL4-35VW-FAW-EDU-ELL14NXOs	3	26.7	80.1
Manufacturing (0.9)	F8 Delviro Zip 8-40-35K-U-FR-WH-V-WFC-N-N	4	38	152
Manufacturing (0.9)	F9 Philips V3W Vaporplume V3W470L835-UNV-DIM-SSLLFA-	1	50	50
Manufacturing (0.9)	F10 Utopia DWP2-2G-45LED-40K-UNV-BZ	12	45	540

The LPD basis was IECC 2018. The ex ante savings estimate used an LPD of 0.90 for a Manufacturing Facility based on the Building Area Type method, and a total area of 79,943 sq. ft. However, this sq. ft. value was not supported by detailed area calculations. The evaluation team also tried to independently compute the floor area from site plans, but the building footprint is complex, there are two floors in at least part of the facility, and some areas did not have floor area indicated on the site plan.

As previously mentioned, the project narrative cited a value of 29,000 sq. ft. for "office, lab use and production services," so the evaluation team used this value for the ex post calculation. The reduction of sq. ft. made the LPD for the efficient fixtures more realistic. The ex ante efficient LPD was unrealistically low at 0.174 W/sq. ft., and the ex post efficient LPD was a much more reasonable 0.48 W/sq. ft., similar to the LPD for a Warehouse. Ex post maintained the ex ante Building Area Type of "Manufacturing Facility" as there may be some light assembly or processing areas in the facility.

Lighting Savings Summary Totals. Ex post vs. ex ante energy savings results for both grow area and LPD-based lighting measures are presented in the table below.

Site 9201 Evaluation Savings Results for Lighting Measures

Measure Name	Annual Energy (kWh)		
	Ex Ante Gross	Ex Post Gross	Realization Rate
Grow Area Lighting	3,147,556	3,190,042	101%
LPD-Based Lighting	254,093	53,276	21%
All Lighting	**3,401,649**	**3,243,318**	**95%**

Results

The table below shows the final ex post evaluated savings and realization rates. The 95% realization rate is primarily due to adjustments made to the lighting measures and the proportional adjustment of HVAC savings to account for the lighting/HVAC interaction.

Site 9201 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
HVAC	3,018,493	2,877,996	95%	1,340.16	1,277.78	95%
Lighting - Flowering Rooms	2,802,762	2,845,248	102%	532.42	540.49	102%
Lighting - Vegetative Rooms	344,794	344,794	100%	65.50	65.50	100%
Lighting - LPD Approach	254,093	53,276	21%	48.27	10.12	21%
Total	**6,420,142**	**6,121,314**	**95%**	**1,986.35**	**1,893.89**	**95%**

Reasons for Discrepancies

- For LPD-exempt lighting, ex post calculations corrected an error in the ex ante efficient fixture wattage for the flower room lighting.
- For LPD-compliant lighting, the ex ante floor area assumption was corrected to reflect only the support areas. The ex post floor area was 36% of the ex ante value which resulted in a 21% realization rate.
- HVAC savings could not be evaluated due to insufficient HVAC system project documentation. To account for lighting/HVAC system interaction, the ex post analysis applied the overall lighting energy realization rate to the ex ante HVAC savings.

Other Findings and Recommendations

- A project cannot be effectively evaluated until it is 100% complete and the site and claimed measures are fully operational consistent with the ex ante estimates. The many phases of this project may be one reason for the floor area discrepancies. Ideally, a project should also only be claimed in the program year in which it is fully operational.

Overarching/General

- **Provide a Project Narrative summary document for every site.** A project narrative that provides a high-level description of the site and associated measures—including key baseline and high-efficiency

parameter assumptions—should be provided for every site. These high-level descriptions of the site, equipment, and other relevant information can be very useful. This site did provide a Project Narrative document in the project documentation.

- **Provide more targeted organization and/or curation of project documentation.** An immense amount of project documentation is typically stored and available for project review and evaluation but identifying the documents most critical and applicable to the measure assumptions and calculations is currently very difficult. It would be helpful for both implementation and evaluation to either put all the most relevant documents that support the final calculations into a single directory or provide a curated list of the key documents. This would also avoid major omissions of files.
- **Provide a summary of the site activity types and associated floor areas.** A correct and consistent floor area inventory should be provided for every site. Floor areas are needed for LPD calculations, building simulation models, and even the application (total floor area). This summary is especially critical for the non-grow areas to determine the predominant activity type for selecting an appropriate LPD value to use. As a minimum, estimates for total site floor area, grow area total floor area, and non-grow (or support) area total floor area should be developed so they can be used consistently throughout the project documentation.

Lighting

- **Include the *Ameren Ag Lighting Equivalent Quantity* workbook with all indoor agricultural projects.** This workbook is used by the program implementer to determine the equivalent number of equivalent HPS or T5HO fixtures for grow area LED fixtures. A copy of the workbook should be included with each project, and the assumptions and calculations for each project fixture clearly identified, along with the file name containing the LED fixture performance specifications used in the calculations and a date on the specification sheet, if possible, as LED products are constantly being improved. In addition, while the basic approach used in the workbook appears sound, the reference sources and basic assumptions for the lighting performance metrics—especially the HPS and T5HO baseline fixtures—need to be better documented by including the references report in this workbook.
- **Project documentation for LED grow room lighting should include and clearly identify the manufacturer specification sheets used for every ex ante lighting fixture.** For grow room LED lighting, the relevant specification sheets should be clearly identified, and a full list of the relevant performance specifications used for the ex ante calculations (manufacturer, model number, fixture input watts, PPF, and PPFD) should be summarized to avoid discrepancies. This information could be stored in a project-specific version of the *Ag Lighting Equivalent Quantity* workbook. For some projects, instead of spec sheets for the fixtures used in the project, a full manufacturer product line catalog was provided. Other projects had manufacturer-proposals for the project-specific fixtures, which is ideal. The evaluation team found lighting discrepancies in the several of the PY2021 indoor agricultural projects reviewed, and found that the manufacturers offerings (and product specs for the same model) are also changing over time. We also saw evidence of custom versions of some fixtures that use the same basic model number but have different performance specifications. It is essential that the exact specifications for each project fixture be clearly identified.
- **Use the Space-by-Space approach for LPD-based calculations.** For indoor agricultural facilities, the LPD approach is typically only applied to part of the building, and usually a relatively small portion. As such, a space-by-space type approach vs. the current default Building Area Type approach—which has

limited LPD options and is best suited for use on a whole-building level—can provide a more accurate baseline estimate. This will also help ensure that quality control is done on all floor areas used in the project application and analyses. The Ameren New Construction guide already allows for the use of a space-by-space type approach; however, only the Building Area Type tables are provided in the guide, and the program application Excel workbook only allows the Building Area Type approach to be used.

- **Use IECC 2018 for lighting LPD assumptions regardless of local code presence.** There have been many advances in lighting that impact baseline lighting energy use. As a result, using an IECC 2009 baseline under any circumstances will not accurately reflect the lighting market. Lighting equipment is federally regulated, not driven by energy codes, and energy code LPDs are essentially designed to reflect the market to a certain extent. As such, the New Construction program guide should be changed to use IECC 2018 lighting power densities which should better reflect the current new construction lighting market.

HVAC

- **Provide a summary of HVAC systems and baseline and efficient scenario assumptions.** To facilitate a more complete evaluation of the site and provide a general overview of HVAC conditioning, the project documentation should include a summarized overview of all HVAC systems at the site, the areas they serve, and most importantly a comparison summary of the key building simulation parameters used for the baseline and efficient scenarios. This would enable them to be checked and evaluated against the actual models, mechanical schedules, spec sheets, and other project documentation. Such a summary would likely have been needed to create the building simulation models, and consequently, should be readily available or possibly able to be generated as a report from the building simulation tool.
- **Do not use human comfort-based HVAC codes to estimate savings for indoor agricultural HVAC systems.** These HVAC systems are serving process loads and more similar to an industrial or manufacturing environment, so it is not appropriate to use IECC or ASHRAE standards to set baseline equipment efficiencies. It is especially not applicable to custom-built HVAC systems not registered with AHRI for which equipment performance may not be independently validated. The baseline efficiency levels and standard system features would need to be developed via an industry standard practice (ISP) study or customer standard practice if they own multiple facilities. The ISP baseline values would need to be determined from local market studies and/or surveys (participant, trade allies, contractors, etc.), other similar projects, or secondary research in other jurisdictions, and could be documented in the TRM or program manuals.
- **The baseline HVAC system type for grow rooms should be the same as the installed system type.** The HVAC and dehumidification conditioning for grow spaces is accepted as process conditioning, not human comfort conditioning. Similar to many other process measures, efficiency should reflect a change in performance not a change in system type, unless a different system type and associated performance characteristics can be established via ISP research or guidance or shown to be a customer's current practice for other similar, existing facilities. For example, for grow rooms, the efficient configuration of a system would be one that uses an integrated design and control scheme vs. one assembled from completely separate elements with their own separate control systems and reacting independently to space conditions.

- **Incorporate LPD-based lighting into the building simulation models.** LPD-based lighting loads are not currently included in the building simulation models, likely because they are relatively small compared to the predominant LED grow area lighting loads. The evaluation team found the HVAC systems for the non-grow support areas are typically also included in the building simulation models; however, in which case the LPD-based lighting loads should also be included.

Create Guidelines/Standards for Indoor Agricultural Growing Facilities

- **Develop or adopt indoor agricultural growing facility baseline requirement guidelines.** The lighting and HVAC systems, baseline assumptions, and system operations are unique for these facility types, as recognized by the development of code minimum requirements in many other jurisdictions. If these facilities will continue to participate in energy efficiency efforts, it is highly recommended that a comprehensive guidance document is developed for consistency across these projects and to ensure claimed savings are appropriate. There is existing recent research and multiple resources from other jurisdictions that can be leveraged. Trane TRACE has also done extensive development of materials for modeling these complex HVAC systems that can also be leveraged.[15]
- **Develop Process HVAC system peak demand factors for Indoor Agricultural Growing HVAC systems.** Conventional TRM HVAC demand value factors are currently being used for these HVAC systems per the stipulation agreement last year.[16] These HVAC systems are serving process loads no human comfort; however, and HVAC loads for these facilities are also much flatter and less peaky than conventional HVAC conditioning, so it makes sense to develop a new factor. Existing building simulation runs for all the projects in the program could be used to develop the new factors.
- **Detailed monitoring/metering of grow area custom-designed systems may be a more appropriate evaluation method.** The HVAC systems serving the grow rooms are highly engineered and controlled systems that cool/dehumidify, humidify, heat, and reheat to meet design conditions for agricultural products on multiple and variable growing cycles. A more rigorous evaluation of these systems would require at least short-term monitoring and metering of key system elements, or a much more extensive review of data from the onsite energy management system.
- **Conduct a post-occupancy evaluation to validate the building simulation modeled annual energy use against actual consumption.** This would have to be conducted as a special study or under evaluation for future years since at least a year of 100% operational energy use would be needed. If the building simulation results are a true reflection of actual operation and the energy use is relatively flat year-round; however, only several months or a complete growing season may be sufficient for the assessment. Results from this analysis could also be used to provide benchmarking of future projects and integrated into an indoor agricultural growing guidance document.

[15] One example of the materials developed by Trane: "Indoor Agriculture: HVAC System Design Considerations." *Engineer's Newsletter* 48-3 (2019). https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/airside-design/admapn071en-082019.pdf.

[16] State of Missouri Public Service Commission, File No. EO-2018-0211, "Order Approving Stipulation and Agreement." September 23, 2021: "HVAC-related equipment incentivized through the business program for indoor agriculture facilities will use an HVAC end-use load shape for purposes of the PY 2021 evaluation. Opinion Dynamics will develop additional PY 2021 evaluation plans to assess the net-to-gross of this emerging business segment."

Site ID: 9202 (New Construction)

Project Description

This project involves the new construction of an 18,000 square-foot indoor agricultural growing facility with multiple skylights providing daylighting to the nursery, vegetative, and flowering rooms and which has the potential to expand up to 30,000 sq. ft. The future facility expansion is not included in this project description nor the savings estimates, though the impact of the future expansion on the equipment and operation of this project is unknown. The project supported energy efficiency upgrades to the HVAC and lighting equipment. The majority of the LED lighting is located in grow areas that are not currently covered by energy code minimum lighting power density (LPD) requirements (LPD-exempt) and assume high-pressure sodium (HPS) or T5 high-output (T5HO) linear fluorescent fixtures as the baseline. For usage areas that would typically be subject to new construction code, IECC 2009 LPD requirements provide the baseline based on the code adopted by the facility's local jurisdiction. HVAC energy savings, also using an IECC 2009 baseline, are achieved through improved efficiency of the HVAC equipment plus the reduced cooling load from LED lighting.

The first table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project. The HVAC measure accounts for 48% of ex ante energy savings, and the lighting measures account for 52% of ex ante energy savings.

Site 9202 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
HVAC	HVAC	1,353,176	600.79
Lighting – Flower Rooms	Lighting	804,659	152.86
Lighting – Veg	Lighting	526,493	100.01
Lighting – Nursery	Lighting	4,612	0.88
Lighting – Mom1/Mom2	Lighting	22,549	4.28
Lighting – LPD Approach	Lighting	112,972	21.46
	Total	**2,824,461**	**880.28**

The table below provides a savings subtotal for the lighting based on the LPD status (LPD exempt or LPD-compliant). The LPD-exempt lighting in the facility grow areas accounts for 92% of ex ante lighting savings, and the LPD-compliant lighting accounts for only 8% of ex ante lighting savings.

Site 9202 Ex Ante Lighting Savings Subtotal

Lighting Type	kWh	% Ex Ante Lighting kWh
LPD-Exempt Grow Area Lighting	1,358,313	92%
LPD-Compliant Lighting	112,972	8%
Total	**1,471,284**	100%

Data Collection

Data collection for this project consisted of a desk review of project documentation and an onsite verification.

Project Documentation Review. The evaluation team reviewed all available project documents to understand the scope of the project including the final application, all summary files, invoices, site plans, HVAC and lighting equipment specifications, building energy modeling (BEM) report files, and other supporting documents to determine the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings. All of this information was referenced in developing an engineering analysis workbook which was used to estimate ex post savings and document the approach. Key information and project characteristics obtained from the final application and other documentation include:

General Notes

- The project documentation included a "Project Narrative" document that provided a high-level overview of key aspects of the project, including location, site photos, floor area, building configuration, and a brief description of the planned use for the site; a one paragraph summary of the energy efficiency project and measures; a summary of building simulation modeled savings; and additional notes and high-level descriptions of the measures and operation of the site relevant to energy use. The project narrative also specified the use of IECC 2009 for lighting and HVAC baselines.
- The project documentation was not organized into subdirectories except for the building simulation files. Most projects have subdirectories for invoices, building simulation modeling reports, site plans, and equipment specs. This made it even more difficult than usual to find the specific files needed for evaluation though the evaluation team reorganized the files internally. Only the building simulation model reports were located in a separate subdirectory.
- There were inconsistencies in floor areas used throughout the documentation. The final project application "Whole Building Performance" tab shows a gross total area of 35,410 sq. ft. and conditioned area of 3,541 sq. ft., but the LPD Lighting tab uses an area of 18,750 sq. ft. The Project Narrative document cites a total floor area of 18,000 sq. ft., but mentions a potential future expansion to 30,000 sq. ft. The building simulation project summary shows a total building area of 35,410 sq. ft., a conditioned area of 16,101 sq. ft., and a roof area of 18, 581 sq. ft. The evaluation team also did our own estimate of the floor area for grow and non-grow/support areas using a site plan that was labeled with area names and their associated floor areas, though not all areas were labeled and some had to be estimated. That tabulation produced a total floor area of 18,158 sq. ft., non-grow/support floor area of 5,247 sq. ft., and grow area of 12,911 sq. ft.
- The project application "Operating Hours" tab indicates the site is open all year, and operates 14 hours a day, 7 days a week (98 hours per week) for an annual total of 5,110 hours.
- The ex ante claimed savings reference calculations were located in the file *ZR Calculations (Lights & HVAC) 9-13-21.xlsx*, which contained two tabs. The first tab presents consolidated ex ante savings estimates for HVAC and grow room lighting. The second tab provides a simple tally of humidifier, packaged unit, and condensing unit tag IDs and their cooling capacities, but the source of these values was not identified in the project documentation. Total cooling capacity for all HVAC systems at the site is about 203.9 tons. The results on the first tab are discussed below in more detail.

- **HVAC**: Building simulation results from the workbook are presented below. Reductions in cooling and ventilation (Fans) are shown, but there is an increase in heating (which could be due to the reduced lighting). There is also a small difference in the Interior Receptacles use that could indicate a difference in the baseline and efficient models as they should be the same except for changes in equipment efficiency values.

Site 9202 Building Simulation Results for the Baseline and Efficient Scenarios

9/13/21 Revised ZR Trace Model	HID Lighting CV HVAC Code mi		LED Lighting VAV HVAC HGR	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	1,853,209.00	337.37	749,558.60	222.01
Exterior Lighting	0	0	0	0
Exterior Receptacles	0	0	0	0
Fans	322,484.80	36.81	54,949.70	14.53
Heat Recovery	0	0	0	0
Heat Rejection	0	0	0	0
Heating	74.43	1.16	8,684.04	15.29
Humidification	0	0	0	0
Interior Lighting	2,996,307.00	613.24	1,647,802.00	346.75
Interior Receptacles	72,158.94	9.91	71,751.08	9.83
Pumps	0	0	0	0
Refrigeration	0	0	0	0
Service Water Heating	0	0	0	0
Total	5,244,234.17	998.49	2,532,745.42	608.41

Model Total Savings	2,711,488.75
Total Lighting Savings	1,358,312
difference	1,353,176.29
Model HVAC Savings	1,362,575.89
Claimed HVAC Savings	1,353,176.29

HVAC Savings Application				
Base Quantity	Annual kWh/Unit	New Quantity	Annual kWh/Unit	Total Savings
203.88	13,274.24	203.88	6,637.12	1,353,176.29

- **Grow Room Lighting**: The ex ante calculation details for grow room lighting match the claimed ex ante savings. The evaluation team verified the fixture wattages and lighting performance specifications against spec sheets provided in the project documentation, and all were correct. Equivalent 1000W HPS and T5HO baseline fixture multipliers were also provided for all of the grow room lighting. The source of these values is not directly mentioned in this workbook, but the values are consistent with use of the *Ameren Ag Lighting Equivalent Quantity* Excel workbook[17]. The evaluation team checked the ex ante equivalent baseline fixture quantity factors using the equivalent quantity workbook; the values were all correct and are summarized in the table below.

Site 9202 Summary of Grow Room LED Lighting Performance Specs and Equivalent Baseline Fixture Quantity Factors

Location	Fixture Model	Fixture Input Watts	PPF (µMol/s)	Baseline Fixture Type	Equiv. Baseline Fixt. Factor
Flower & Mom12	LED VYPR 2P	631	1700	1000W HPS	1.00
Flower	LED SPYDR 2i 40	631	1600	1000W HPS	0.94
Veg	LED SPYDR 2X	342	852	T5HO 4 ft/8 lamp	1.98
Nursery	RAZRx	114	210	T5HO 4 ft/8 lamp	0.49

HVAC Notes

[17] "Ameren Ag Lighting Equivalent Quantity 7-21-21 rev.xlsx" uses a PPFD-based approach to determine the equivalent number of HPS 1000W or T5HO baseline fixtures needed to produce an amount of lighting equivalent to that of the LED lamps.

- The project documentation did not contain a mechanical plan or schedule that lists the HVAC equipment and the areas they serve. Although a full list of building simulation model reports was provided, the baseline and efficient case configurations and input assumptions for the simulation model runs are not discernible from the files. Only the enduse results for the runs and a variety of detailed modeling reports were provided.

- Only a single HVAC specification sheet was provided (*Spec Sheets - Custom.pdf*) for 12.5–25-ton packaged rooftop cooling units with gas/electric heating, and efficiency depending on size that ranges from 10 to 12.1 EER and two IEER ratings (for single and variable speed fans) ranging from 10.4/12.0 to 14.0/15.0. However, the project documentation does not specify the actual equipment installed. There are also no invoices for the HVAC equipment. There are three one-page invoices billing for design and installation of the units "per mechanical plans M1.0 and M2.0," but those mechanical plans were not included in the project documentation.

- The project narrative contains an abbreviated description of the HVAC systems (see table below), which roughly identifies the areas served by name, and provides EERs/SEERs and key features like hot gas reheat (HGR) but lacks a narrative to explain the table or to provide additional detail such as mechanical schedules that would show actual unit cooling capacities, make/model numbers, etc.

Site 9202 Project Narrative HVAC Baseline and Efficient Equipment Summary

HVAC system DX

Size Range/Room	Baseline Main FR	Eff Main FR
100-120T Main FR	CV 9.5 EER gas heat	CV 10 EER HGR gas unit heat
45-60T Small FR	CV 9.3 EER gas heat	CV 10 EER HGR gas unit heat
20-30T VEG	CV 9.3 EER gas heat	CV 10 EER HGR gas unit heat
4-8T Nursery	11.0 EER SS	11.09 EER SS
<5T Non Grow	11.0 EER DX	13 SEER DX

Lighting Notes

- LPD-exempt lighting uses HPS 1000W fixtures and T5HO four-foot/eight-lamp fixtures as the baseline fixtures. The ex ante analysis develops the equivalent quantity of baseline fixtures needed to provide the same lighting levels as the LED fixture using the *Ameren Ag Lighting Equivalent Quantity* Excel workbook.[18] The baseline calculation is based on the common practice of using PPFD (photosynthetic photon flux density) values for the LED lamps (determined from specification sheets) vs. the PPFD values for the baseline technologies to determine the equivalent number of baseline fixtures that would deliver a lighting level equal to that of the LEDs. For HPS baselines, the equivalent fixture factors are close to 1 but vary from 0.85 to 1.65 with a max of 2.47 for a 1500W LED fixture.

- For the LPD-compliant support area lighting, the ex ante calculations used IECC 2009 for the baseline LPD value. The Building Area Type approach is used as standard practice, and for this project a Manufacturing Facility LPD value of 1.3 was used with a floor area of 18,750 sq. ft. (the entire facility floor area). Per the Project Narrative, IECC 2009 was selected because there is no local energy code. For reference, the IECC 2018 LPD value for Manufacturing Facility is 0.9. There are four unique fixture types and 89 fixtures in the support area. The application did not list the actual activity areas (office,

[18] "Ameren Ag Lighting Equivalent Quantity 7-21-21 rev.xlsx" uses a PPFD-based approach to determine the equivalent number of baseline fixtures needed.

storage, warehouse, etc.) where the fixtures are physically located, only the Building Area Type was listed in the Location field of the application.

Overall, the project HVAC assumptions are insufficiently documented, and there were also significant floor area discrepancies. However, the HVAC systems, layout, and operation of these sites is very unique and complex. Because there was limited and conflicting information available from the program documentation, the evaluation team selected this site for onsite verification and results of that effort are described below.

Onsite Verification Results.

The evaluation team conducted a site visit on February 9. 2022. To minimize time on site, the field engineer prioritized verification points for the equipment and areas responsible for the largest percentage of project savings. Key findings from the onsite verification include:

- The total floor area of the site was just under 19,000 sq. ft., and the majority of the facility is used for grow areas. The total area for the non-grow areas, including office, corridor, mechanical room, security, garage, warehouse, break room, and restrooms, was very roughly estimated at less than 10% of the total facility floor area or about 1,800 sq. ft.
- The site is fully operational. Operating hours are 7:00 a.m. to 7:00 p.m. (12 hours a day), and the grow areas are on timers. The grow rooms are maintained at 75°F and 60% to 70% humidity.
- The table below shows an inventory of the HVAC units including make/model, quantity, size, and areas served. Reznor heating units and QUEST brand dehumidifiers were also found in the grow rooms.

Site 9202 Onsite Verification HVAC Equipment Inventory Summary

Manufacturer	Model Number	Size (tons)	Quantity	Area Served
Lennox	LGH060S4TH5G	5	1	Small Flower Room
Lennox	LCH300S4MN4G	25	6	Grow Room
Lennox	LCH150H4MN2G	12.5	3	Main Flower Room 1
Daikin	RK18AXVJU	1.5	3	Clone Room, Support
Daikin	RKAXVJU	1	5	Clone Room, Support
	Totals	**202**	**18**	

- For the LPD-exempt grow room lighting, onsite verification confirmed the ex ante fixture type and quantities for all three flower rooms and for the nursery and mother clone rooms (Mom1/Mom2). In the vegetative rooms, four fewer fixtures were installed (152 verified onsite vs. 156 in ex ante), and the lamp type was a SPYDER 2i40 (ex ante listed two possible types).
- For the LPD-compliant lighting support areas, the field engineer did not verify quantities of lamps as the project documentation did not provide sufficient details to identify the specific areas in which the reported fixtures were installed. The field engineer did collect photos of a few lighting fixtures in those support spaces.
- The field engineer collected an extensive set of photos of the HVAC control system (screen shots), HVAC system elements (chiller nameplate, chilled water lines, direct expansion [DX] units, humidifier, etc.), and lighting systems both installed with room location reference and uninstalled boxes in storage rooms with fixture make/model labels.

Analysis

Ex ante savings were estimated using standard engineering algorithms for the lighting measures and Trane Trace 3D (v 3.20.18) was used to model savings building simulation software for the HVAC measures.

The evaluation team combined the ex ante project documentation review with onsite verification results to evaluate this site and produce an ex post savings estimate.

HVAC Savings. The table below shows the ex ante description of the HVAC system baseline and efficient case assumptions and is the most detailed description of the baseline and efficient HVAC systems contained in the project documentation. This ex ante summary provides no quantities or equipment sizes (only size ranges are provided). Given the complexity of the indoor agriculture HVAC system, which uses dehumidifiers, heaters, and large conventional package units with advance hot gas reheat (HGR), and the extensive details needed to create the Trane TRACE building simulation models, a more complete HVAC system summary should have been provided in the project documentation.

Site 9202 Ex Ante Summary of Baseline and Efficient HVAC Equipment from Project Narrative

Size Range/Room	Baseline Main FR	Efficient Main FR
100-120T Main FR	CV 9.5 EER gas heat	CV 10 EER HGR gas unit heat
45-60T Small FR	CV 9.3 EER gas heat	CV 10 EER HGR gas unit heat
20-30T VEG	CV 9.3 EER gas heat	CV 10 EER HGR gas unit heat
4-8T Nursery	11.0 EER SS	11.09 EER SS
<5T Non Grow	11.0 EER DX	13 SEER DX

Although the project documentation does not provide mechanical drawings, the evaluation team found a summary of the equipment sizes in the calculation workbook. The tabulations for the cooling units are summarized in the table below.

Site 9202 Summary of HVAC Equipment Types and Sizes from Final Calculation Workbook

Unit Type	Size (tons)	Quantity
Packaged Unit	5	1
Packaged Unit	12.5	2
Packaged Unit	25	6
Condensing Unit	0.75	1
Condensing Unit	1	5
Condensing Unit	1.5	2
Condensing Unit	3	1
Totals	**191.75**	**18**

The HVAC savings for this site cannot be evaluated for a number of reasons:

- The project documentation does not include sufficient detail to define the HVAC system and the baseline and efficient parameters that produce savings.

- The installed QUEST dehumidifier units do not appear to have efficiency ratings, especially not the EER and IEER values. Even if they did, there is no basis provided for the EER and IEER values shown in the table above, and the EER ratings for several of the efficient units are less than the baseline EER. In addition, these units appear to be custom-made and not AHRI-certified.

Due to these challenges, the evaluation could not estimate ex post savings for the HVAC system. The evaluation team applied an ex post adjustment to HVAC savings; however, to account for ex post lighting adjustments as associated impact on HVAC load due to interactive effects. Ideally the building simulation model should be rerun with the adjusted lighting loads but adjusting the HVAC savings proportionally to lighting changes should serve as a sufficient approximation of the expected impact.

LPD-Exempt Lighting Savings. The table below shows the key parameter values used in the estimation of energy savings for the LPD-exempt lighting measures. The evaluation team confirmed lamp quantities and types during the onsite visit and confirmed lamp fixtures wattages in the desk review of specification sheets. The hours of use for the flower rooms are consistent with 12 hour on/12 hour off operation (4380 annual hours) verified onsite. HOU for the Veg, Nursery, and Mom1/Mom2 rooms are higher (6,570=18 hours a day). Although the project documentation did not provide a basis for these higher hours, the evaluation did not identify information to warrant revising these values. The evaluation also verified the ex ante values of equivalent baseline fixtures. Therefore, the evaluation made no changes were made to the ex ante savings for grow area lighting.

Site 9202 Ex Ante Parameters for LPD-Exempt Lighting Measures

Space	Baseline				Efficient				
	Fixture Type	Quantity	Watt/Unit	Total kW	Fixture Type	Quantity	Watt/Unit	Total kW	HOU
Flower 1–3	HPS - 1000 W	320	1,060	3346	Fluence VYPR2P FR 1&2 Combined	320	631	1782	4,380
Flower 1–3	HPS - 1000 W	120	1,060	3346	Fluence SPYDR 2i in FR3	128	631	1782	4,380
VEG	T5HO - 4 ft - 8 Lamp	309	432	3346	Fluence SPYDR 2x	156	342	1782	6,570
Nursery	T5HO - 4 ft - 8 Lamp	4	432	388	Fluence RAZR	9	114	161	6,570
Mom1/Mom 2	HPS - 1000 W	8	1,060	235	VYPR2P	8	631	97	6,570
	Totals	**4,598**	**-**	**3,969**		**1,734**		**2,040**	

LPD-Based Lighting Savings. The table below summarizes the lighting fixtures and key parameter values used to estimate ex ante energy savings for the non-grow support areas. The evaluation team made no changes to the lighting fixture quantities as these were only visually spot-checked by the onsite verification. However, the evaluation team reduced wattages for two fixtures as a result of the desk review of lighting specification sheets. One fixture was only a very small reduction (0.1W), but the other fixture was a significant reduction from 50.5W to 41.1W, and also a significant portion of support area lighting.

Site 9202 Ex Ante Parameters for LPD-Compliant Lighting Measures

Building Area Type (LPD)	Fixture Type	Fixture Quantity	Ex Ante Watt/Fixture	Ex Post Watt/Fixture	Ex Post Total Watts
Manufacturing (1.3 W/sqft)	F1 VHB-24-W-UNV-L850-CD-U	7	174.1	174.1	1218.7
Manufacturing (1.3 W/sqft)	F2 4VT3-LD5-8-G-UNV-L850-CD1-U	22	67.1	67.0	1474
Manufacturing (1.3 W/sqft)	F3 SLD612840WH	5	14.8	14.8	74
Manufacturing (1.3 W/sqft)	F4 24CZ2-55-UNV-L840-CD1-U	55	50.5	41.1	2260.5

The ex ante IECC 2009 LPD value for a Manufacturing Facility Building Area Type is also shown in the table above. Although an IECC 2009 LPD is too dated to use as a baseline and does not reflect the advances made in lighting equipment since then and commonly available on the market today, the evaluation team retained the existing IECC 2009 LPD values because it was chosen due to absence of a local energy code consistent with the *Guide to Energy Efficiency Incentives for New Construction.*[19]

The ex ante calculations used 6,000 annual hours of use for all lighting fixtures in the non-grow support areas. The project documentation did not provide the basis for this value, which equates to about 16.44 hours per day, 365 days per year. This HOU value exceeds the application reported business operation hours of 5,110 hours. The onsite verification reported 12 hours per day operation, which is 4,380 annual hours. Despite the lack of documentation and inconsistencies in reported HOU, lacking definitive information on how the non-grow areas operate, the evaluation team made no change to the ex ante hours for the ex post savings estimate.

As previously discussed, project documentation showed a significant discrepancy with the floor area used for the ex ante calculation. The ex ante calculation used a value of 18,750 sq. ft., which exceeds the floor area reported for the entire facility (18,000 sq. ft.). The evaluation team used the site plan to estimate the floor area for the support areas, which yielded the values shown in the table below. The evaluation team calculated ex post savings using a total floor area of 5,247 for the LPD-compliant lighting measures. This value differs from the onsite verification rough estimate of 1,800 sq. ft. but the focus was on the grow rooms, so they may not have had complete access to all the areas, and the hallway area would have been very difficult to physically estimate on site without taking actual measurements.

Site 9202 Ex Ante Parameters for LPD-Compliant Lighting Measures

Area Label from Plan	Floor Area	Percent of Non-Grow Area
Garage/Loading Dock	2,100	40.0%
Hallway (estimated)	1,100	21.0%
Open Office	385	7.3%

[19] "Guide to Energy Efficiency Incentives for New Construction." Effective July 1, 2020, pg 3: "Since the state of Missouri does not have a statewide building code, the building design baseline will be established on a case-by-case basis. The baseline will be established by identifying the highest baseline from the following: IECC 2009, Local energy code or building code, Equipment that the participant has committed to purchase."

Area Label from Plan	Floor Area	Percent of Non-Grow Area
Cure	300	5.7%
Trim and Packaging	300	5.7%
Break Room	220	4.2%
Secure Waste	200	3.8%
Secure Storage	200	3.8%
Storage	200	3.8%
Security	150	2.9%
IT Closet	92	1.8%
Total Non-Grow Areas	5,247	28.9%
Total Grow Areas	12,911	71.1%
Total Site	**18,158**	**100%**

Based on the types of areas listed in the table above, with the largest percentage of the support areas as garage/loading dock and hallways, the ex ante selection of a "Manufacturing Facility" LPD is not appropriate. Staying consistent with the LPD guidance provided in Ameren's "Guide to Energy Efficiency Incentives for New Construction," which uses a Building Area Type approach, the "Warehouse" Building Type is more accurate. This building type has an LPD of 0.48 W/sq. ft.[20] Despite this discrepancy, the evaluation team did not change the ex ante Building Type as savings would have gone negative.

The table below summarizes the ex ante and ex post analysis for LPD-compliant lighting. The ex post updates result in a slightly negative savings as shown because the efficient LPD exceeds the baseline LPD. Rather than use a negative ex post savings value, the evaluation team zeroed out the savings for this measure (0% realization rate).

Site 9202 LPD Lighting Analysis: Comparison of Ex Ante and Ex Post Parameters and Results

Parameter	Ex Ante	Ex Post	Revision Notes
Baseline Code	IECC 2009	IECC 2009	Same as ex ante
Area	18,750	5,247	Updated to plan take-off values
Space Type	Manuf. Facility	Manuf. Facility	Same as ex ante
Annual HOU	6,000	6,000	Same as ex ante
Baseline LPD Allowance	1.3	1.3	Same as ex ante
Efficient LPD	0.296	0.958	Ex ante contained an error; Ex post uses correct sq. ft. value
Total Connected kW - Baseline	24.375	6.8211	Includes floor area and LPD adjustments

[20] Using the Space-by-Space LPD method would be a better approach and yield a more accurate overall LPD estimate since the available areas and associated LPDs are so diverse. Example areas and LPDs are *Loading dock, interior=0.58, Corridor in a manufacturing facility = 0.29, Office (Enclosed)=0.93, Storage Room=0.46, Electrical/Mechanical Room=0.43.*

Parameter	Ex Ante	Ex Post	Revision Notes
Total Connected kW - Installed	5.5464	5.0272	Includes fixture wattage reduction based on desk review
Annual kWh - Baseline	146,250	40,927	(Calculated)
Annual kWh - Installed	33,278	30,163	(Calculated)
Annual kWh - Savings	**112,972**	**10,763**	**10% of ex ante savings**

Lighting Savings Summary Totals. Ex post vs. ex ante energy savings results for both grow area and LPD-based lighting measures are presented in the table below.

Site 9202 Evaluation Savings Results for Lighting Measures

Measure Name	Annual Energy (kWh)		
	Ex Ante Gross	Ex Post Gross	Realization Rate
Grow Area Lighting	1,358,313	1,358,312	100%
LPD-Based Lighting	112,972	10,763	10%
Lighting Subtotal	**1,471,284**	**1,369,076**	**93%**

Results

The table below shows the final ex post evaluated savings and realization rates. The 93% realization rate is primarily due to adjustments made to the lighting measures and the proportional adjustment of HVAC savings to account for lighting/HVAC interaction.

Site 9202 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
HVAC	1,353,176	1,259,173	93%	600.79	559.05	93%
Lighting - Flower Rooms	804,659	804,659	100%	152.86	152.86	100%
Lighting - Veg	526,493	526,494	100%	100.01	100.01	100%
Lighting - Nursery	4,612	4,612	100%	0.88	0.88	100%
Lighting - Mom1/Mom2	22,549	22,548	100%	4.28	4.28	100%
Lighting - LPD Approach	112,972	10,763	10%	21.46	2.04	10%
Total	**2,824,461**	**2,628,249**	**93%**	**880.28**	**819.13**	**93%**

Reasons for Discrepancies

- For LPD-compliant lighting, ex post corrected the floor area assumption used in ex ante. The ex ante calculations incorrectly used the floor area for the *entire* facility instead of just the support areas. Ex post used 5,247 sq. ft. dedicated to support areas as determined from the evaluation team's review of the site plans. Wattage reduction corrections were also made to two of the four fixtures.

- HVAC savings could not be evaluated due to insufficient HVAC system project documentation. To account for lighting/HVAC system interaction, the ex post applied the overall lighting energy realization rate to the ex ante HVAC savings.

Other Findings and Recommendations

Overarching/General

- **Provide a Project Narrative summary document for every site.** A project narrative that provides a high-level description of the site and associated measures—including key baseline and high-efficiency parameter assumptions—should be provided for every site. These high-level descriptions of the site, equipment, and other relevant information can be very useful. This site did provide Project Narrative document with the project documentation.
- **Provide more targeted organization and/or curation of project documentation.** An immense amount of project documentation is typically stored and available for project review and evaluation but identifying the documents most critical and applicable to the measure assumptions and calculations is currently very difficult. It would be helpful for both implementation and evaluation to either put all the most relevant documents that support the final calculations into a single directory or provide a curated list of the key documents. This would also avoid major omissions of files.
- **Provide a summary of the site activity types and associated floor areas.** A correct and consistent floor area inventory should be provided for every site. Floor areas are needed for LPD calculations, building simulation models, and even the application (total floor area). This summary is especially critical for the non-grow areas to determine the predominant activity type for selecting an appropriate LPD value to use. As a minimum, estimates for total site floor area, grow area total floor area, and non-grow (or support) area total floor area should be developed so they can be used consistently throughout the project documentation.

Lighting

- **Include the *Ameren Ag Lighting Equivalent Quantity* workbook with all indoor agricultural projects.** This workbook is used by the program implementer to determine the equivalent number of equivalent HPS or T5HO fixtures for grow area LED fixtures. A copy of the workbook should be included with each project, and the assumptions and calculations for each project fixture clearly identified, along with the file name containing the LED fixture performance specifications used in the calculations, with a date on the specification sheet if possible as LED products are constantly being improved. In addition, while the basic approach used in the workbook appears sound, the reference sources and basic assumptions for the lighting performance metrics—especially the HPS and T5HO baseline fixtures—need to be better documented by including the references report in this workbook.
- **Project documentation for LED grow room lighting should include and clearly identify the manufacturer specification sheets used for every ex ante lighting fixture.** For grow room LED lighting, the relevant specification sheets should be clearly identified, and a full list of the relevant performance specifications used for the ex ante calculations (manufacturer, model number, fixture input watts, PPF, and PPFD) should be summarized to avoid discrepancies. This information could be stored in a project-specific version of the *Ag Lighting Equivalent Quantity* workbook. For some projects, instead of spec sheets for the fixtures used in the project, a full manufacturer product line catalog was provided. Other projects had manufacturer-proposals for the project-specific fixtures, which is ideal. The evaluation team found lighting discrepancies in the several of the PY2021 indoor agricultural projects reviewed, and also found that the manufacturers offerings (and product specs for the same model) are changing

over time. Additionally, we saw evidence of custom versions of some fixtures that use the same basic model number but have different performance specifications. It is essential that the exact specifications for each project fixture be clearly identified.

- **Use the Space-by-Space approach for LPD-based calculations.** For indoor agricultural facilities, the LPD approach is typically only applied to part of the building, and usually a relatively small portion. As such, a space-by-space type approach vs. the current default Building Area Type approach—which has limited LPD options and is best suited for use on a whole-building level—can provide a more accurate baseline estimate. This will also help ensure that quality control is done on all floor areas used in the project application and analyses. The Ameren New Construction guide already allows for the use of a space-by-space type approach; however, only the Building Area Type tables are provided in the guide, and the program application Excel workbook only allows the Building Area Type approach to be used.
- **Use IECC 2018 for lighting LPD assumptions regardless of local code presence.** There have been many advances in lighting that impact baseline lighting energy use. Therefore, using an IECC 2009 baseline under any circumstances will not accurately reflect the lighting market. Lighting equipment is federally regulated not driven by energy codes, and energy code LPDs are essentially designed to reflect the market to a certain extent. As such, the New Construction program guide should be changed to use IECC 2018 LPDs, which should better reflect the current new construction lighting market.

HVAC

- **Provide a summary of HVAC systems and baseline and efficient scenario assumptions.** To facilitate a more complete evaluation of the site and provide a general overview of HVAC conditioning, the project documentation should include a summarized overview of all HVAC systems at the site, the areas they serve, and most importantly a comparison summary of the key building simulation parameters used for the baseline and efficient scenarios, enabling them to be checked and evaluated against the actual models, mechanical schedules, spec sheets, and other project documentation. This type of summary would likely have been needed to create the building simulation models, and consequently, should be readily available or can possibly be generated as a report from the building simulation tool.
- **Do not use human comfort-based HVAC codes to estimate savings for indoor agricultural HVAC systems.** These HVAC systems are serving process loads and more similar to an industrial or manufacturing environment; it is not appropriate to use IECC or ASHRAE standards to set baseline equipment efficiencies. It is especially not applicable to custom-built HVAC systems not registered with AHRI for which equipment performance may not be independently validated. The baseline efficiency levels and standard system features would need to be developed via an industry standard practice (ISP) study or customer standard practice if they own multiple facilities. The ISP baseline values would need to be determined from local market studies and/or surveys (participant, trade allies, contractors, etc.), other similar projects, or secondary research in other jurisdictions, and could be documented in the TRM or program manuals.
- **The baseline HVAC system type for grow rooms should be the same as the installed system type.** The HVAC and dehumidification conditioning for grow spaces is accepted as process conditioning, not human comfort conditioning. Similar to many other process measures, efficiency should reflect a change in performance not a change in system type, unless a different system type and associated performance characteristics can be established via ISP research or guidance or shown to be a customer's current practice for other similar, existing facilities. For example, for grow rooms, the efficient configuration of a system would be one that uses an integrated design and control scheme vs. one assembled from completely separate elements with their own separate control systems and reacting independently to space conditions.

- **Incorporate LPD-based lighting into the building simulation models.** LPD-based lighting loads are not currently included in the building simulation models, likely because they are relatively small compared to the predominant LED grow area lighting loads. The evaluation team found the HVAC systems for the non-grow support areas are typically also included in the building simulation models; however, in which case the LPD-based lighting loads should also be included.

Create Guidelines/Standards for Indoor Agricultural Growing Facilities

- **Develop or adopt indoor agricultural growing facility baseline requirement guidelines.** The lighting and HVAC systems, baseline assumptions, and system operations are unique for these facility types, as recognized by the development of code minimum requirements in many other jurisdictions. If these facilities will continue to participate in energy efficiency efforts, it is highly recommended that a comprehensive guidance document is developed for consistency across these projects and to ensure claimed savings are appropriate. There is existing recent research and multiple resources from other jurisdictions that can be leveraged. Trane TRACE has also done extensive development of materials for modeling these complex HVAC systems that can also be leveraged.[21]

- **Develop Process HVAC system peak demand factors for Indoor Agricultural Growing HVAC systems.** Conventional TRM HVAC demand value factors are currently being used for these HVAC systems per the stipulation agreement last year.[22] These HVAC systems are serving process loads not human comfort, however, and HVAC loads for these facilities are also much flatter and less peaky than conventional HVAC conditioning. Resultingly, it makes sense to develop a new factor. Existing building simulation runs for all the projects in the program could be used to develop the new factors.

- **Detailed monitoring/metering of grow area custom-designed systems may be a more appropriate evaluation method.** The HVAC systems serving the grow rooms are highly engineered and controlled systems that cool/dehumidify, humidify, heat, and reheat to meet design conditions for agricultural products on multiple and variable growing cycles. A more rigorous evaluation of these systems would require at least short-term monitoring and metering of key system elements, or a much more extensive review of data from the onsite energy management system.

- **Conduct a post-occupancy evaluation to validate the building simulation modeled annual energy use against actual consumption.** This would have to be conducted as a special study or under evaluation for future years since at least a year of 100% operational energy use would be needed. If the building simulation results are a true reflection of actual operation and the energy use is relatively flat year-round; however, only several months or a complete growing season may be sufficient for the assessment. Results from this analysis could also be used to provide benchmarking of future projects and integrated into an indoor cannabis growing guidance document.

[21] One example of the materials developed by Trane: "Indoor Agriculture: HVAC System Design Considerations." *Engineer's Newsletter* 48-3 (2019). https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/airside-design/admapn071en-082019.pdf.

[22] State of Missouri Public Service Commission, File No. EO-2018-0211, "Order Approving Stipulation and Agreement." September 23, 2021: "HVAC-related equipment incentivized through the business program for indoor agriculture facilities will use an HVAC end-use load shape for purposes of the PY 2021 evaluation. Opinion Dynamics will develop additional PY 2021 evaluation plans to assess the net-to-gross of this emerging business segment."

Site ID: 9203 (New Construction)

Project Description

This project involves the renovation of a portion of a 100,000 sq ft space within an existing 600,000 sq ft warehouse building into a new indoor cannabis growing facility. The project is only the first phase of renovation and covers about 30,000 sq ft of the 100,000 sq ft that this facility will eventually occupy. This first phase of the project is about 30% grow rooms and 70% other support areas. Energy efficiency measures include use of an advanced HVAC system type serving the grow rooms and LED lighting for the entire space (grow rooms and other support areas). The majority of LED lighting is located in grow areas that are not currently covered by energy code minimum lighting power density (LPD) requirements (LPD-exempt) and assume high-pressure sodium (HPS) or T5 high-output (T5HO) linear fluorescent fixtures as the baseline. For usage areas are subject to new construction codes, IECC 2018 LPD requirements are the baseline. HVAC energy savings based on IECC 2018 baselines are achieved through improved efficiency of the HVAC equipment plus the indirect reduced cooling load from LED lighting, and by using a variable refrigerant flow (VRF) plus dedicated outdoor air system (DOAS) HVAC system instead of a more conventional packaged rooftop system for the grow rooms.

The first table below describes the energy efficiency measures and ex ante gross savings claimed for this project. The second table provides a savings subtotal for the lighting measures which account for 55% of project savings, with the majority of those savings (96%) from the grow room lighting.

Ex Ante Savings Summary

Measure Name	End Use Category	Ex Ante Gross	
		kWh	kW
HVAC	HVAC	887,706	394.13
Flower 1-4	Lighting	541,157	102.80
Clone	Lighting	15,768	3.00
VEG	Lighting	274,363	52.12
MOTHER	Lighting	192,054	36.48
LPD-Based Lighting	Lighting	39,714	7.54
Total		**1,950,762**	**596.07**

Ex Ante Lighting Savings Subtotal

Measure Name	End Use Category	Ex Ante Gross	
		kWh	kW
Grow Area Lighting	Lighting	1,023,342	194.40
LPD-Based Lighting	Lighting	39,714	7.54
Total	**Lighting**	**1,063,056**	**201.94**

Data Collection

The evaluation team conducted a desk review of all project documentation. Key observations and findings are summarized below.

General Notes

- A "Project Narrative" document was not provided for this project so the evaluation team had to compile project overview information from a variety of other documents. The project narratives typically provide a high-level overview of the project, individual end use elements (like HVAC and lighting systems) and other relevant general information that is needed to understand the scope of the project, the measures implemented, and how they save energy.

- There were floor area discrepancies throughout the documentation, not just total floor area but the grow and non-grow floor areas, and the latter is a primary parameter for the LPD calculations. The building simulation project summary report listed total floor area as 30,169 sq ft with 100% of that conditioned. The project application contained multiple conflicting floor areas: 1) The project description states the initial build-out for the project as 50,000 sq ft with grow rooms at 14,000 sq ft and non-grow, support areas at 36,000 sq ft. The Whole Building Performance tab shows the floor area as 32,400 sq ft and conditioned floor area as 30,170 sq ft (93%). The LPD-based lighting calculation uses a floor area of 20,620 sq ft which represents the non-grow, support areas and is about 68% of the total floor area (30,170 sq ft). And finally, an LPD compliance form found on the electrical plans showed a total floor area of 24,480 sq ft, a grow room area of 11,193 sq ft (46%) and support area of 13,287 sq ft (54%). There is no reference source provided or cited for any of these values. Two site plans were provided with the project documentation - one for the first phase and another for the full build out – which may have also added to the confusion.

- The project files were not organized like most other projects into content-relevant subdirectories (e.g., invoices, spec sheets, plans, etc.). The files were all in a single directory except for the building simulation model reports which were in their own subdirectory. The evaluation team reviewed and reorganized the files for our review.

HVAC Notes

- The two invoices provided for HVAC equipment could not be used for equipment verification. Instead of an itemized list of HVAC unit make/model numbers delivered to the site, there was only a generic statement about installation per the mechanical schedules.

- The total operating hours tab in the Final Application was blank, though operating hours are available indirectly from the annual hours of operation (HOU) values for lighting measures.

- The final application, Whole Building Performance tab shows IECC 2018 as the baseline but had floor area discrepancies, stating the total floor area as 32,400 sq ft and conditioned floor area as 30,170 sq ft. It also shows energy use for the baseline case as 3,678, 374 kW and efficient case as 1,767,325 kWh for an overall savings of 52%, far above the top incentive category of "30% energy savings and above" noted on the form. The annual energy use values and the resultant savings are consistent with the claimed values and with the building simulation results.

- The code baseline for the project is IECC 2018, which applies to human-comfort HVAC systems and non-grow area lighting. For the process HVAC-D[23] (-D=dehumidification) equipment serving the grow rooms, the project documentation describes the approach as using a least or lessor efficient system versus a higher efficient system but does not provide the specifics of these assumptions. From the evaluation team's project document review, it appears the most significant HVAC difference between baseline and efficient cases is for the grow areas where conventional rooftop systems were used for the baseline and variable refrigerant flow heat pumps with DOAS are used for the efficient system. However, these two systems are so completely different that a more valid comparison would have been a lower-efficiency VRF system. This baseline assumption is likely the primary driver of the large ex ante HVAC savings.

- The project documentation included as *SavingsSummary.xlsx* workbook that appears to be the primary source of final ex ante savings calculations. There are eight tabs that contain HVAC runs and lighting calculations that appear to represent the history and multiple revisions of the savings for this project. The most recent tab (labeled 9-15-2021) contains HVAC and lighting savings values that are consistent with the ex ante savings. The lighting savings shown is only for the grow areas and it appears that the building simulation model also only included grow area lighting, although grow lighting is 94% of the . It also shows a total cooling tons value of 183 tons as "Total from model" but does not cite a specific building simulation report nor show a tabulation of individual unit capacities that total to this value.

Lighting Notes

- For LPD-exempt lighting, the ex ante analysis appeared to correctly use the *Ameren Ag Lighting Equivalent Quantity* workbook[24] to calculate the baseline equivalent quantity values, though as explained below at least one fixture deviated from the normal baseline fixtures used in the workbook. The evaluation team reviewed the invoice and specification documents and all of the ex ante fixtures were listed, but also provided additional fixture detail and revealed an apparent discrepancy that was addressed by the ex post analysis:

    - For the Clone Room fixtures, the application and ex ante calculation details indicated these were RAZR3 fixtures and 180 W per fixture. However, the manufacturers specification sheet shows the RAZR3 fixture as just one possible configuration of the "RAZR Array" specification. The RAZR3 fixture appears to use seven 90W LED modules per array. The RAZR Array specification also included this note about the RAZR3 configuration: "Number of Fixtures 7 (minimum 2), PPF 1400 µmols, Input Power 632W (minimum 180W)".

    - The invoice description of this fixture was "Fluence 7 RAZR3 Module" where the "7" appears to reflect the previously mentioned array of seven RAZR3 fixtures. At 632 W and a PPF of 1400 µmol/s, this array would be more comparable to a standard 1000 W HPS lamp, whereas the ex ante calculation assumed a two-fixture 180W array and a baseline fixture type of 150W HPS (fixture input watts of 165W with ballast) which is not typical and not a current option in the Ameren Ag Lighting Equivalent Quantity workbook. An ex ante baseline equivalent quantity factor of 2.0 was assumed though a source for that calculation was not provided. A quick check

[23] Acronym mentioned here: "Committee Blog: An Introduction to HVACD for Indoor Plant Environments – Why We Should Include a "D" for Dehumidification (2021) (National Cannabis Industry Association)", https://thecannabisindustry.org/committee-blog-an-introduction-to-hvacd-for-indoor-plant-environments-why-we-should-include-a-d-for-dehumidification/

[24] "Ameren Ag Lighting Equivalent Quantity 7-21-21 rev.xlsx" uses a PPFD-based approach to determine the equivalent number of HPS 1000W or T5HO baseline fixtures needed to produce an amount of lighting equivalent to that of the LED lamps.

of other similar projects evaluated for PY2021 confirmed that higher wattage fixtures are generally used for this room type.

- Even the electrical designer may have been confused by this fixture since the electrical drawing shows this as a RAZR3 fixture with a 90W input fixture wattage.

- The LPD-based lighting ex ante calculation uses 20,620 sq ft and the baseline is IECC 2018 and uses a Building Area Type of Manufacturing Facility with a 0.90 LPD. Annual hours of use is 4,380 hours and there are 15 different lighting fixtures used in the non-grow support areas. The evaluation team reviewed the specification sheets for every fixture, reviewed invoices to ensure the listed fixtures were actually purchased, evaluated the LPD building type choice by reviewing the site floor plan and found the following issues and discrepancies:

  - On the invoices, six of the 15 (40%) fixture types that account for 69 total fixtures (22%) are shown as ordered but not yet shipped. Although the evaluation team could not positively confirm delivery and receipt from the invoices or other documentation, we assumed that all had been received and installed and the final invoices were just missing from the project documentation.

  - Using the specification document provided with the project documentation, fixture wattage values were corrected for 10 of 15 (66%) fixtures with wattage changes ranging from 0.04 to 71.9 W (ex ante used the lumen per watt value instead of fixture input watts).

  - Scanning a floor plan of the site labeled with descriptions of the space types (e.g. Corridors, Lockers, Restrooms, Storage, Shipping and Receiving, Security, Dry Room, QA/QC Lab Offices) it is apparent that the majority of the spaces are hallways and storage type areas. A Warehouse LPD (0.48) might be a better match for these support areas versus the current Manufacturing Facility LPD (0.9). The evaluation team also found an LPD compliance form on the site plans which used the Space-by-Space method and showed 59% of the support areas as Hallway and had an overall baseline LPD of 0.62. In lieu of creating a detailed tabulation of floor areas by activity area type from the site plan, the evaluation team visually estimated the support area as about 60% of the total area. Based on a total floor area of 30,170 sq ft the estimated support area is about 18,000 sq ft which was determined to be close enough to validate the existing ex ante value.

HVAC System Notes

- From the project application, total cooling capacity is listed 183 tons and the same value is used for the baseline and efficient scenarios, as shown in the figure below. There is no reference to a source and this value, and the baseline value should be larger than the efficient value if the baseline system was sized to meet the larger baseline lighting load.

Project Type	Measure Type	Equip. Use	Base Equipment Detail	Quantity	Annual kWh/Unit	New Equipment Detail	Quantity	Annual kWh/Unit
New/Replace Failed Equip.	Packaged / Rooftop Unit (Incremental)	HVAC	Baseline Equipment	183	7,830	HE HVAC	183	2,979
			Qty = Tons Installed			Qty = Tons Installed		

- **HVAC System Types.** The program documentation was severely insufficient in describing and documenting the key HVAC system configurations and performance, including the baseline versus efficient scenario assumptions. However, by extensively combing through the documents that were

provided, the evaluation team was able to assemble the following partial information about the three primary HVAC system types serving the distinct areas of the facility:

The grow rooms (Flower, Veg, Clone) appear to be served by an HVAC-D (-D=dehumidification) variable refrigerant flow (VRF) system plus dedicated outdoor air system (DOAS). The significant corridor area and other larger support areas are served by conventional rooftop/package AC units with gas heating. The remaining support areas are served by smaller ductless mini-split units. A high-level summary of the equipment inventory and key characteristics created by the evaluation team is presented in the table below. As shown, based on IECC 2018 and/or current Federal equipment standards, the installed equipment efficiencies range from just meeting to significantly exceeding (54%) the minimum efficiencies. However, the grow area equipment is considered a process application and is therefore not subject to IECC 2018 requirements. For this project the VRF system design itself is also considered high-efficiency versus a baseline rooftop HVAC system. The tally must also be missing some equipment though because the total cooling capacity of 159.5 tons is less than the 183 tons reported on the application (a difference of 23.5 tons).

Summary of HVAC System Types, Areas Served, Cooling Capacities and Efficiencies

HVAC(D) System Type	Areas Served	Quantity of Units	Size Range (tons)	Total Cooling Tons	Percent of Total Tons	Efficiency Range	Capacity-Wtd Average Efficiency	Average Percent Above Code
VRF System HP	Grow Rooms	8	6 to 20	112	70%	11.6-14 EER	12.2 EER	14%
Rooftop/Package DX/GF	Support	7	3 to 8.5	28.5	18%	14 SEER	14 SEER	0%
Mini-split/ductless HP	Support	9	1 to 3	19	12%	19.1-22.8 SEER	21.6 SEER	54%
TOTALS		**36**	–	**159.5**	**100%**	–	–	**100%**

- The evaluation team also reviewed the building simulation reports. We reviewed and tabulated the information from the 42 page *System Component Summary* building simulation report to try to determine the modeled differences between the baseline and efficient cases. This report contains information on the individual HVAC system capacities and floor areas for the rooms they serve but does not show rated cooling efficiencies, nor could they be found on other reports. Although system labels used for the baseline and efficient models differed, we were able to successfully match systems and spaces for the two scenarios. The evaluation team tabulated a total capacity of 295 tons for the baseline case and 142 tons for the efficient case, both of which differ from the 183 tons reported on the application. This review also shows that a majority of the HVAC savings result from sizing of the baseline system which is twice as large as the efficient system due to the large HPS lighting loads. Ex ante savings are also the result of baseline equipment efficiency assumptions for each modeled system, but those values were not available in the project documentation. Our review also showed the baseline configuration for the grow rooms as rooftop AC/electric resistance heating units, whereas the typical baseline would be gas furnace heating. It is also unclear where dehumidification equipment is modeled and where that energy use would appear in the simulation.

Overall, the project HVAC assumptions are insufficiently documented, HVAC equipment specification sheets were missing, there are discrepancies in the accounting of floor areas related to phasing of the project, and

there were significant discrepancies with the ex ante values used for both grow room and support area lighting fixtures.

Analysis

The evaluation team's ex post analysis approach is discussed below for each of the three project measures: HVAC, LPD-exempt (grow room) lighting, and LPD-based lighting.

HVAC Savings. Ex ante savings were estimated using the TRACE™ 3D Plus 3.20.18 building simulation software with an IECC 2018 baseline according to the project application. The project summary documentation shows the total floor area as 30,169 sq ft and it is 100% conditioned. The ex ante savings reported in the application agrees with the values from the TRACE project summary document, with the minor exception that LPD-based lighting does not appear to have been incorporated into the model. Since the LPD-based floor area is roughly 70% of the total floor area, we are unsure how this was handled in the building simulation model, but lighting wattage for this area is only about 4% of the total lighting and the total HVAC cooling capacity for the support areas is only about 20% of the total per the evaluation team's HVAC summary table above.

The evaluation team was also unable to completely validate the underlying HVAC system configurations and efficiency assumptions, nor confirm the IECC 2018 baseline was used, although this baseline is not relevant for the process HVAC-D system serving the grow rooms. In addition, the claimed percent total savings (50.0%) seems excessive compared to real-world expectations for efficiency projects. The HVAC system assumptions for the grow area (70% of total cooling tons) are the biggest drivers for savings. One assumption is the use of a baseline rooftop/package HVAC system that is completely different from the installed VRF heat pump system. Another assumption is the use of electric resistance heating in the baseline system whereas gas eating is more typical, as seen for the rooftop/package systems used for this project in the support areas. Another minor but contributing component could be the baseline efficiency assumptions, but the evaluation team was unable find those in the project documentation. Due to these challenges, the evaluation could not estimate ex post savings for the HVAC system. However, the evaluation team applied an adjustment to ex ante HVAC savings to account for the HVAC interactive effects associated with the ex post lighting adjustments. Ideally the building simulation model should be rerun with the adjusted lighting loads but adjusting the HVAC savings proportionally to lighting changes should serve as a sufficient approximation of the expected impact.

LPD-Exempt Lighting Savings. The evaluation team found only one issue with ex ante grow room lighting calculations. For the Clone room measures, the ex ante fixture type and wattage, and the associated equivalent baseline quantity factor appeared to be incorrect. The ex ante calculations showed twelve RAZR3 fixtures with a 180 W fixture wattage and a 150W HPS baseline (165 W with ballast) instead of the typical 1000W HPS baseline. However, as discussed under Data Collection, the invoice showed this fixture as a "7 RAZR3 Module" where the "7" implies an array of seven RAZR3 modules with a fixture wattage of 632 W and an efficacy (PPF) of 1400 µmol/s which is more comparable to the standard 1000 W HPS lamp. The evaluation team used this information for the ex post analysis, and also revised the baseline assumption to use a 1000W HPS. The recalculated baseline equivalent quantity factor using the ex post assumptions and the Ameren Ag Lighting Equivalent Quantity workbook is shown in the table below.

Clone Room Baseline Lighting Fixture Equivalent Quantity Factor Calculation

Scenario	Fixture	Watt	PPFD	Equivalent Quantity Factor	PPF	Equivalent Watts
Baseline	HPS DE	1060	944	0.82	1700	873
Efficient LED	7 RAZR3	632		1.00	1400	632

The table below compares the final ex post input values versus the ex ante values and the revised savings estimate for the Clone Room lighting. Annual savings increased by about 68% however the impact on overall project savings is insignificant compared to grow area lighting and HVAC savings.

Ex Ante Parameters for LPD-Exempt Lighting Measures

	Baseline Case			Efficient Case			Annual	
Analysis Case	Fixture Type	Fixture Quantity	Input Watts	Fixture Type	Fixture Quantity	Input Watts	HOU	Savings (kWh)
Ex Ante	HPS - 150 W	24	165	Fluence RAZR3	12	180	8,760	15,768
Ex Post	HPS - 1000 W	10	1,060	Fluence 7 RAZR3	12	632	8760	26,420

LPD-Based Lighting Savings. For the ex post analysis, a Building Area Type Warehouse LPD of 0.48 was used instead of the ex ante assumed Manufacturing Facility LPD of 0.9, which significantly reduced the savings. As previously discussed, using a Space-by-Space type approach could more accurately reflect the lighting requirements for this facility, but current program guidance is to use the Building Area Type approach. In addition, significant ex post changes were made to some of the lighting fixture wattages. The evaluation team reviewed invoices and specification sheets and corrected a number of incorrect wattage values.

We were also unable to confirm the delivery of six fixture types from our invoice review, but rather than zeroing those out we assumed the invoices were missing. A summary of the ex post invoice review and fixture wattage updates are summarized in the table below. These fixtures all use an HOU of 4,380 hours which resulted in an ex post savings increase of 7%.

Summary of Fixtures Missing from Invoices and Ex Post Wattage Changes

Fixture Type	Fixture Quantity	Not on Invoice	Ex Ante Fixture Watts	Ex Post Fixture Watts	Fixture Watt Difference
A 2GTL 4 48L GZ10 LP835	77		35.79	35.79	0
A3 2TLX4 60L FW A12 GZ10 LP840	4	X	118.9	47	-71.9
A3E 2TLX4 60L FW A12 GZ10 EL14L LP840	3		118.9	47	-71.9
AE 2GTL 4 48L GZ10 EL14L LP835	37		34.1	34.1	0
ESX LZ S 1 R EL N SDA CC	3	X	4	4	0
EX LQM S W 3 R 120/277 EL N M6	23	X	3	0.7	-2.3
R6 LDN6 35/10 LO6AR LSS MVOLT GZ10	38		10.44	12.8	2.4
R6E LDN6 35/10 LO6AR LSS MVOLT GZ10 EL	10		10.44	10.4	0.0
S2 LBL4 4000LM 80CRI 35K MIN10 GZT MVOLT	58		32	32.4	0.4

S2E LBL4 4000LM 80CRI 35K MIN10 GZT MVOLT EL14L	10		32	32.4	0.4
SA DSXW1 LED 10C 700 40K T2M MVOLT ELCW DDBXD	6	X	46	26	-20.0
SL ZL1N L48 3000LM FST MVOLT 35K 80CRI WH	15	X	25	25	0
SLE ZL1N L48 3000LM FST MVOLT 35K 80CRI E7W WH LED Strip, Nominal 30000LMs, 7W	18	X	25	25	0
SLX HXPFL4-40-U-35K	13		46	44	-2.0
SLXE HXPFL4-40-U-35K-EM	4		46	44	-2.0

Lighting Savings Summary Totals. Ex post versus ex ante energy savings results for both grow area and LPD-based lighting measures are presented in the table below. The ex post change to the Clone room lighting had minimal impact (101% RR) on total grow area lighting savings because it is a small fraction of the total grow area lighting connected load. The LPD-based lighting changes were much higher (11% RR) but had only a small impact on total site-level savings (98% RR) because the grow area lighting is 96% of lighting energy use.

Evaluation Savings Results for Lighting Measures

Measure Name	Annual Energy (kWh)		
	Ex Ante Gross	Ex Post Gross	RR
Grow Area Lighting	1,023,342	1,033,995	101%
LPD-Based Lighting	39,714	4,382	11%
All Lighting	**1,063,056**	**1,038,377**	**98%**

Results

The table below shows the final ex post evaluated savings and realization rates. The 98% realization rate is primarily due to adjustments made to the lighting measures and the proportional adjustment of HVAC savings to account for lighting/HVAC interaction.

Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
HVAC	887,706	867,098	98%	394.13	384.98	98%
Flower 1-4	541,157	541,158	100%	102.80	102.80	100%
Clone	15,768	26,420	168%	3.00	5.02	168%
VEG	274,363	274,363	100%	52.12	52.12	100%
MOTHER	192,054	192,054	100%	36.48	36.48	100%
LPD-Based Lighting	39,714	4,382	11%	7.54	0.83	11%
Total	**1,950,762**	**1,905,475**	**98%**	**596.07**	**582.23**	**98%**

Reasons for Discrepancies

Ex post made the following adjustments to key ex ante parameters:

- LPD-Exempt lighting: For the Clone Room lighting measure both the baseline and installed fixture parameters were adjusted based on information from the invoice and lighting manufacturer specification sheets.
- LPD-Based Lighting: Fixture wattages were revised for 6 of the 15 fixtures due to incorrect values, including use of a lumens per watt value instead of fixture input watts for one fixture. The Building Area Type which determines the LPD was changed from Manufacturing Facility (0.9) to Warehouse (0.48).
- HVAC savings could not be evaluated due to insufficient HVAC system project documentation. To account for lighting/HVAC system interaction, the ex post analysis applied the overall lighting energy realization rate (98%) to the ex ante HVAC savings.

Other Findings and Recommendations

Overarching/General

- **Provide a Project Narrative summary document for every site.** A project narrative that provides a high-level description of the site and associated measures – including key baseline and high-efficiency parameter assumptions – should be provided for every site. These high-level descriptions of the site, equipment, and other relevant information can be very useful. This site did not have A Project Narrative document but other New Construction sites did.
- **Provide more targeted organization and/or curation of project documentation.** An immense amount of project documentation is typically stored and available for project review and evaluation, but identifying the documents most critical and applicable to the measure assumptions and calculations is currently very difficult. It would be helpful for both implementation and evaluation to either put all the most relevant documents that support the final calculations into a single directory or provide a curated list of the key documents. This would also avoid major omissions of files.
- **Provide a summary of the site activity types and associated floor areas.** A correct and consistent floor area inventory should be provided for every site. Floor areas are needed for LPD calculations, building simulation models, and even the application (total floor area). This summary is especially critical for the non-grow areas to determine the predominant activity type for selecting an appropriate LPD value to use. As a minimum, estimates for total site floor area, grow area total floor area, and non-grow (or support) area total floor area should be developed so they can be used consistently throughout the project documentation.

Lighting

- **Include the Ameren Ag Lighting Equivalent Quantity workbook with all indoor agricultural projects.** This workbook is used by the program implementer to determine the equivalent number of equivalent HPS or T5HO fixtures for grow area LED fixtures. A copy of the workbook should be included with each project, and the assumptions and calculations for each project fixture clearly identified, along with the file name containing the LED fixture performance specifications used in the calculations, with a date on the specification sheet if possible as LED products are constantly being improved. In addition, while the basic approach used in the workbook appears sound, the reference sources and basic assumptions for the lighting performance metrics – especially the HPS and T5 HO baseline fixtures – need to be better documented by including the references report in this workbook.

- **Project documentation for LED grow room lighting should include and clearly identify the manufacturer specification sheets used for every ex ante lighting fixture.** For grow room LED lighting, the relevant specification sheets should be clearly identified, and a full list of the relevant performance specifications used for the ex ante calculations (manufacturer, model number, fixture input watts, PPF, and PPFD) should be summarized to avoid discrepancies. This information could be stored in a project-specific version of the Ag Lighting Equivalent Quantity workbook. For some projects, instead of spec sheets for the fixtures used in the project, a full manufacturer product line catalog was provided. Other projects had manufacturer-proposals for the project-specific fixtures which is ideal. The evaluation team found lighting discrepancies in the several of the PY2021 indoor agricultural projects reviewed, and also found that the manufacturers offerings (and product specs for the same model) are also changing over time. We also saw evidence of custom versions of some fixtures that use the same basic model number but have different performance specifications. It is essential that the exact specifications for each project fixture be clearly identified.
- **Use the Space-by-Space approach for LPD-based calculations.** For indoor agricultural facilities, the LPD approach is typically only applied to part of the building, and usually a relatively small portion. As such, a space-by-space type approach versus the current default Building Area Type approach - which has limited LPD options and is best suited for use on a whole-building level - can provide a more accurate baseline estimate. This will also help ensure that quality control is done on all floor areas used in the project application and analyses. The Ameren New Construction guide already allows for the use of a space-by-space type approach, however, only the Building Area Type tables are provided in the guide, and the program application Excel workbook only allows the Building Area Type approach to be used.
- **Use IECC 2018 for lighting LPD assumptions regardless of local code presence.** There have been so many advances in lighting that impact baseline lighting energy use that using an IECC 2009 baseline under any circumstances will not accurately reflect the lighting market. Lighting equipment is Federally regulated not driven by energy codes, and energy code LPDs are essentially designed to reflect the market to a certain extent. As such, the New Construction program guide should be changed to use IECC 2018 lighting power densities which should better reflect the current new construction lighting market.

HVAC

- **Provide a summary of HVAC systems and baseline and efficient scenario assumptions.** To facilitate a more complete evaluation of the site and provide a general overview of HVAC conditioning, the project documentation should include a summarized overview of all HVAC systems at the site, the areas they serve, and most importantly a comparison summary of the key building simulation parameters used for the baseline and efficient scenarios so they can be checked and evaluated against the actual models, mechanical schedules, spec sheets, and other project documentation. Such a summary would likely have been needed to create the building simulation models so it should be readily available or can possibly be generated as a report from the building simulation tool.
- **Do not use human comfort-based HVAC codes to estimate savings for Indoor agricultural HVAC systems.** These HVAC systems are serving process loads and more similar to an industrial or manufacturing environment, so it is not appropriate to use IECC or ASHRAE standards to set baseline equipment efficiencies. It is especially not applicable to custom-built HVAC systems not registered with AHRI for which equipment performance may not be independently validated. The baseline efficiency levels and standard system features would need to be developed via an industry standard practice (ISP) study or customer standard practice if they own multiple facilities. The ISP baseline values would need to be determined from local market studies and/or surveys (participant, trade

allies, contractors, etc.), other similar projects, or secondary research in other jurisdictions, and could be documented in the TRM or program manuals.

- **The baseline HVAC system type for grow rooms should be the same as the installed system type.** The HVAC and dehumidification conditioning for grow spaces is accepted as process conditioning, not human comfort conditioning. Similar to many other process measures, efficiency should reflect a change in performance not a change in system type, unless a different system type and associated performance characteristics can be established via industry standard practice (ISP) research or guidance, or shown to be a customer's current practice for other similar, existing facilities. For example for grow rooms, the efficient configuration of a system would be one that uses an integrated design and control scheme versus one assembled from completely separate elements with their own separate control systems, and reacting independently to space conditions.
- **Incorporate LPD-based lighting into the building simulation models.** LPD-based lighting loads are not currently included in the building simulation models, likely because they are relatively small compared to the predominant LED grow area lighting loads. However, the evaluation team found the HVAC systems for the non-grow support areas are typically also included in the building simulation models, in which case the LPD-based lighting loads should also be included.

Create Guidelines/Standards for Indoor Cannabis Growing Facilities

- **Develop or adopt indoor cannabis growing facility baseline requirement guidelines.** The lighting and HVAC systems, baseline assumptions, and system operations are unique for these facility types, as recognized by the development of code minimum requirements in many other jurisdictions. If these facilities will continue to participate in energy efficiency efforts, it is highly recommended that a comprehensive guidance document be developed for consistency across these projects and to ensure claimed savings are appropriate. There is existing recent research and multiple resources from other jurisdictions that can be leveraged. Trane TRACE has also done extensive development of materials for modeling these complex HVAC systems that can also be leveraged.[25]
- **Develop Process HVAC system peak demand factors for Indoor Cannabis Growing HVAC systems.** Conventional TRM HVAC demand value factors are currently being used for these HVAC systems per the stipulation agreement last year.[26] However, these HVAC systems are serving process loads no human comfort, and HVAC loads for these facilities are also much flatter and less peaky than conventional HVAC conditioning, so it makes sense to develop a new factor. Existing building simulation runs for all of the projects in the program could be used to develop the new factors.
- **Detailed monitoring/metering of grow area custom-designed systems may be a more appropriate evaluation method.** The HVAC systems serving the grow rooms are highly engineered and controlled systems that cool/dehumidify, humidify, heat and reheat to meet design conditions for agricultural products on multiple and variable growing cycles. A more rigorous evaluation of these systems would require at least short-term monitoring and metering of key system elements, or a much more extensive review of data from the onsite energy management system.

[25] One example of the materials developed by Trane: "Indoor Agriculture: HVAC System Design Considerations", https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/airside-design/admapn071en-082019.pdf

[26] State of Missouri Public Service Commission, File No. EO-2018-0211, "Order Approving Stipulation and Agreement", September 23, 2021: "HVAC-related equipment incentivized through the business program for indoor agriculture facilities will use an HVAC end-use load shape for purposes of the PY 2021 evaluation. Opinion Dynamics will develop additional PY 2021 evaluation plans to assess the net-to-gross of this emerging business segment."

- **Conduct a post-occupancy evaluation to validate the building simulation modeled annual energy use against actual consumption.** This would have to be conducted as a special study or under evaluation for future years since at least a year of 100% operational energy use would be needed. However, if the building simulation results are a true reflection of actual operation and the energy use is relatively flat year-round, only several months or a complete growing season may be sufficient for the assessment. Results from this analysis could also be used to provide benchmarking of future projects and integrated into an indoor cannabis growing guidance document.

Appendix G. Desk Review and Onsite Reports: Retro-Commissioning Program

The evaluation of RCx projects included desk reviews and onsite visits for a sample of four projects. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Summary of New Construction Project Reviews

Site ID	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
		Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
9100	Desk review with onsite visit	226,353	226,354	100%	100.50	100.50	100%
9101	Desk review with onsite visit	1,120,776	1,120,776	100%	813.45	774.09	95%
9102	Desk review with onsite visit	1,030,972	1,030,972	100%	615.28	615.28	100%
9103	Desk review with onsite visit	157,037	153,533	98%	69.72	68.17	98%

Site ID: 9100 (RCx)

Project Description

Following a retro-commissioning (RCx) study, this project implemented multiple upgrades at a high school to optimize the ability of the Building Automation System (BAS) to increase the building's efficiency and decrease energy waste. Upgrades included optimization of the airside AHU supply air temperature (SAT) and duct static pressure (DSP) resets as well as sequence of operations, time of day scheduling, and room ventilation schedule (RVS) programming. Energy savings are achieved by the improved efficiency of the heating, ventilation and air conditioning (HVAC) systems.

The table below shows the estimated energy and demand savings for this project.

Site 9100 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
AHU SAT & DSP Resets	HVAC	99,333	44.10
Sequence of Operation, Time of Day, and RVS Programming	HVAC	127,020	56.39
	Total	**226,354**	**100.50**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope and the basis for estimated energy savings, including the baseline and proposed equipment and conditions. The project documentation included a RCx Implementation report, dated December 2021, which provides post-implementation data demonstrating the performance of the RCx measures. The evaluation team conducted a detailed analysis of the implementer's project study report to develop an onsite verification plan.

The field engineer conducted an onsite visit on February 9, 2022, with an engineer from the RCx agent and the building superintendent. The field engineer collected screen shots and logged data to corroborate the data provided in the post-implementation study. While on site, the field engineer captured representative photos of the corresponding equipment size and make and model numbers and verified the schools' hours of operation on the BAS. These hours were consistent with those used in the implementer's documentation (7:00 a.m. to 6:00 p.m.).

Per the implementer and the building superintendent, the measures came completely online at the end of 2021, so only about one month of full post-implementation data was available at the time of the onsite inspection. The building engineer said they have had no problems with new BAS controls and noted that the system is in a learning/optimization phase. The control system is designed to learn with building runtimes, setpoints, and comfort, and the site contact expects the system to further optimize based on this learning phase, potentially further increasing energy savings. The site contact confirmed that there have been no substantive operational changes due to COVID-19 since the project measures were implemented.

Analysis

The ex ante project savings were estimated using simulation modeling for a package of RCx measures, and then allocated the combined, interactive whole facility savings across the distinct RCx energy efficiency measures. The total modeled ex ante energy savings for all RCx EEMs are about 13% of the facility's baseline electricity consumption, and the EEMs selected for this project represent 5% of the facility baseline consumption.

The evaluation team compared the proposed measures defined in the project energy study, the data provided in the post-installation study, and evaluation findings and confirmed that the evaluation findings are consistent with project materials and key savings assumptions. We collected billing data for the facility, but were not able to discern post-installation savings due to the limited time period between project completion (December 2021) and the evaluation period.

Based on the evaluation review of ex ante savings, confirmation of EEM measure implementation, and onsite findings, the evaluation team accepted the ex ante energy savings estimate.

Results

The table below shows the ex ante and ex post savings and overall realization rates for this RCx project. Since the evaluation activities verified the project was implemented as proposed, the evaluation team the ex ante savings, and the project realization rate is 100%.

Site 9100 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
AHU SAT & DSP Resets	99,333	99,333	100%	44.10	44.10	100%
Sequence of Operation, Time of Day, and RVS Programming	127,020	127,020	100%	56.39	56.39	100%
Total	**226,353**	**226,354**	**100%**	**100.50**	**100.50**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- The project completion form was signed December 20, 2021, and final invoice was dated December 28, 2021, and the project materials included a post-installation study conducted in December 2021. The site contact described that the project measures were not fully implemented until January 2022, and additional savings are expected from the learning and optimization controls installed with the BAS upgrade. Based on the findings of this review, it is recommended to assess this site again with six months to one year of data available (including a cooling season) to assess the realized savings of the project and persistence of controls measures.

Site ID: 9101 (RCx)

Following an energy audit completed in Summer 2020, this retro-commissioning (RCx) project implemented six RCx measures at a 24/7 municipal facility to reduce equipment runtimes, reduce cooling loads and associated cooling energy, and improve controls for various HVAC equipment.

The table below describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9101 Ex Ante Savings Summary

Measure Name	End use Category	Ex Ante Gross	
		kWh	kW
EEM-1 Sixth Floor AHUs	HVAC	83,534	37.09
EEM-2 Cooling Savings for Sixth Floor AHUs, AHU 0-3, Econ	Cooling	210,532	191.73
EEM-3 Condenser Water Relief and Chiller Optimization	Cooling	381,898	347.79
EEM-4 Reduce Fan Speed for Nine FTUs	HVAC	256,298	113.79
EEM-5 HW Pump Control	HVAC	104,190	46.26
EEM-6 Controls for Dishwasher Exhaust Fan	Cooling	84,324	76.79
	Total	**1,120,776**	**813.45**

Data Collection

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

The evaluation team conducted an onsite visit on February 1, 2022, with a member of the maintenance staff and the retro-commissioning agent, who helped navigate the Building Management System (BMS). In addition, the field engineer observed the relevant onsite HVAC equipment, including chillers, pumps, and newly installed VFDs in the mechanical space. The field engineer collected photos of the equipment and nameplate information as well as screenshots to document setpoints and schedules. Due to the nature of the facility access to the FTUs, AHUs and the exhaust fan were not possible.

The table below describes, for each EEM, the percentage of ex ante savings associated with the EEM and the verification activities and findings during the site visit.

Site 9101 Verification Findings by EEM

Measure Name	% Ex Ante kWh Savings	Verification Findings
EEM-1 and EEM-2	7%	The AHUs were programed to fully optimize the economizer. During favorable conditions, the economizer damper can handle up to 100% of the cooling load. During cold temperatures, the unit will economize to maintain cooling supply air temperatures. The evaluation team observed the set points in the BMS and VFDs in operation.
EEM-3	19%	The evaluation team reviewed the BMS and documented the chiller set points. Although

Measure Name	% Ex Ante kWh Savings	Verification Findings
		the evaluation period occurred in the winter, the OA temperature reached a point during the site visit that the chiller turned on. When the chiller was operating, the evaluation team observed the operation of the VFDs on the Condenser Water and Chiller Water pumps.
EEM-4	34%	The nine FTUs are programed so they run, in a default mode, at low speed, unless the space temperature setpoint moves out of range. The evaluation team observed the BMS and confirmed that the FTUs were set to operate at low speed.
EEM-5	23%	The pumps operate automatically, where the control the speed of the pumps is based on a set return temperature or temperature difference between the supply and return hot water temperatures. Due to security issues and BMS access challenges, the evaluation team was unable to verify the equipment or operational setting in the BMS.
EEM-6	9%	The project installed a current-transducer (CT) sensor on the dishwasher and connected to the exhaust fan such that the exhaust fan will turn on when the CT sensor detects that the dishwasher has been turned on. The evaluation team observed the VFD in auto mode but was unable to collect any trend data on the fan operation from the BMS.

Although the evaluation team did not observe discrepancies, due to the evaluation timing, we were unable to conduct measurement and verification for many cooling-related measures. For example, we were unable to confirm the cooling mode setpoints for the FTU's and AHU. Similarly, due to the late completion of the project (completion form signed in December 2021), the project has not performed through a cooling season, and the evaluation had limited post-installation whole facility consumption data.

Analysis

Ex ante savings were estimated using separate spreadsheet-based engineering calculation workbooks for each EEM. The retro-commissioning agent provided estimates and analysis of the saving and provide an M&V report. The total estimated ex ante savings are about 25% of 2020 baseline annual electricity consumption.

The evaluation team reviewed the calculations and did not find any errors in the calculation approach or assumptions. The evaluation team reviewed the energy study and data provided by the retro-commissioning agent and compared them to what we observed on site from the BMS and what we could see and observe in the mechanical room, and we found them to be consistent.

Based on the evaluation team's review of the project documentation and onsite findings, the evaluation team accepted the ex ante energy savings. It is worth noting, however, that many of the measures are cooling-related, and due to the time of the project completion (December 2021) and evaluation period (Winter 21/22), the evaluation team was unable to observe cooling operations, performance, and energy savings.

The evaluation team made one change to the enduse classification for the Dishwasher Exhaust fan measure, changing the classification from Cooling (ex ante) to HVAC (ex post).

Results

The table below shows the ex ante and ex post savings and overall realization rates for this RCx project. Since the evaluation activities verified the project was implemented as proposed, the evaluation accepted the ex ante savings, and the project realization rate is 100%.

Site 9101 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1 Sixth Floor AHUs	83,534	83,534	100%	37.09	37.09	100%
EEM-2 Cooling Savings for Sixth Floor AHUs, AHU 0-3, Econ	210,532	210,532	100%	191.73	191.73	100%
EEM-3 Condenser Water Relief and Chiller Optimization	381,898	381,898	100%	347.79	347.79	100%
EEM-4 Reduce Fan Speed for Nine FTUs	256,298	256,298	100%	113.79	113.79	100%
EEM-5 HW Pump Control	104,190	104,190	100%	46.26	46.26	100%
EEM-6 Controls for Dishwasher Exhaust Fan	84,324	84,324	100%	76.79	37.44	49%
Total	**1,120,776**	**1,120,776**	**100%**	**813.45**	**774.09**	**95%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- The late completion (December 2021) of this project combined with the evaluation timeframe made it difficult for the evaluation team to verify the performance of cooling-season measures. Similarly, the RCx agent's report states: "Definitive data that show the proper staging of the three chillers will be demonstrated in the 2022 cooling season."
- During the site visit, the evaluation team noted the BMS was connected to a very slow network connection which limited our ability to collect the data and took significant time to navigate due to slow refresh screens. Also, the site contact had limited ability to access and navigate the BMS. BMS management is an important aspect of efficient HVAC operations, including fault detection and identifying opportunities for further energy efficiency upgrades. To ensure the persistence of HVAC-related controls measures, the evaluation team recommends the Ameren Missouri program support BAS upgrades and consider minimum BAS performance standards when existing BAS will support new energy efficiency controls and RCx measures.

Site ID: 9102 (RCx)

Project Description

Following the completion of an energy study conducted in January 2020, the Ameren Missouri Business program supported retro-commissioning (RCx) and Custom HVAC projects at this 24/7 municipal facility with natural gas heating. This RCx project included sequence of operations (SOO) improvements to the facility fan terminal units (FTUs) and optimization of the facility cooling tower fan. The associated custom HVAC project implemented VFDs on the chilled water pumps, economizer controls, and reductions to exhaust fan schedules and was evaluated as a separate project. Energy savings are achieved for the RCx energy efficiency measures through improved overall efficiency of the HVAC system.

The table below describes the RCx energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Site 9102 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Fan Terminal Unit SOO (HVAC savings)	HVAC	622,807	276.52
EEM-2 Fan Terminal Unit SOO (Cooling Savings)	Cooling	337,575	307.42
EEM-3 Cooling Tower Fan Optimization	HVAC	70,590	31.34
	Total	**1,030,972**	**615.28**

Data Collection

The evaluation team reviewed all available project documentation to understand the scope of the project and the basis for estimated energy savings, including the baseline and proposed equipment and conditions. The desk review included the original energy study, project application materials, project invoices, and savings calculation workbooks for each EEM.

The evaluation team visited the site on February 1, 2022, with the building engineer and the retro-commissioning agent. We logged on to the facility building management system (BMS) and collected screenshots and data of the FTUs and Cooling Tower equipment and control settings. During our review of the BMS, we verified the set points for the FTUs and the cooling tower. We then walked portions of the building to observe the occupancy sensors in the larger spaces and to verify the temperatures and conditions in those spaces using the local thermostat.

Key findings from the site visit include the following:

- The project reduced the minimum primary airflow to the constant volume FTUs. This airflow reduction saves energy by reducing building AHU speed, eliminating unnecessary subcooling and reheat, and reducing the overall AHU cooling loads.
- We confirmed the FTUs were scheduled OFF and operate with a night setback temperature in spaces that are unoccupied outside normal business.

- We confirmed occupancy control was added to large areas with 24/7 occupancy that that are not always occupied, allowed for demand controlled ventilation.
- The cooling tower fan was programmed to limit the fan speed to 60%.

The evaluation team also collected and reviewed the RCx agent's post-installation measurement and verification study. The study included data confirming the post-installation EEM performance and was consistent with the evaluation team observed onsite and through the facility BMS.

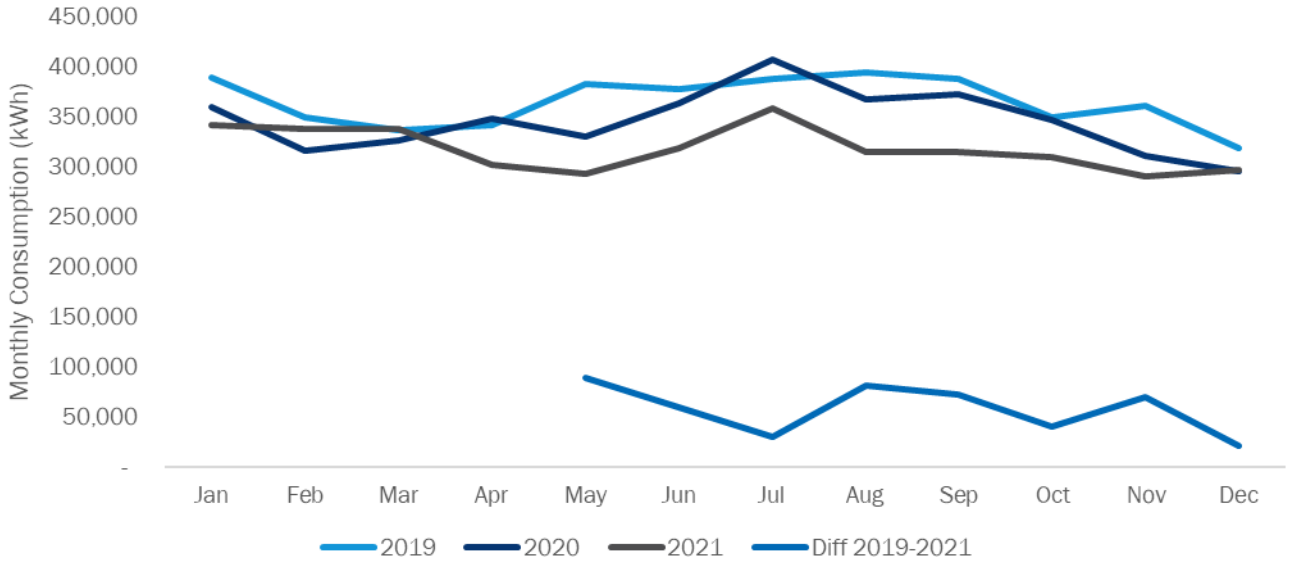
Analysis

The ex ante project savings were estimated through engineering calculations, comparing baseline and proposed equipment operation, and energy consumption. The evaluation team reviewed the calculations and key parameter assumptions and determined the total savings presented were reasonable.

When compared with annual consumption data for the years prior to the RCx implementation, the estimated project savings for the RCx project measures are about 25% of 2020 baseline whole facility electricity consumption. Combined with the ex ante savings for the additional Custom HVAC project, the total RCx and Custom HVAC estimated savings are 32% of 2020 baseline whole facility electricity consumption.

The evaluation team reviewed billing data for the period from January 2019 through December 2021. The project completion form was signed in April 2021, so the evaluation team had almost eight months of post-installation data. We learned through the site visit that the project was not fully completed until November 2021, however, with some additional system commissioning work continuing to address comfort issues.

The figure below shows the monthly facility consumption data for 2019, 2020, and 2021 and shows the monthly difference in energy consumption between 2019 and 2021 as proxy for savings. The observed reduction in whole facility consumption is consistent with the estimated energy savings, so the evaluation accepted the ex ante energy savings estimate.



Results

The table below shows the ex ante and ex post savings and overall realization rates for this RCx project. Since the evaluation activities verified the project was implemented as proposed, the evaluation team accepted the ex ante savings, and the project realization rate is 100%.

Site 9102 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
EEM-1 Fan Terminal Unit SOO (HVAC savings)	622,807	622,807	100%	276.52	276.52	100%
EEM-2 Fan Terminal Unit SOO (Cooling Savings)	337,575	337,575	100%	307.42	307.42	100%
EEM-3 Cooling Tower Fan Optimization	70,590	70,590	100%	31.34	31.34	100%
Total	**1,030,972**	**1,030,972**	**100%**	**615.28**	**615.28**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- During the site visit, the evaluation team observed one area where the space temperature was higher than the setpoint, and space occupants noting this was an ongoing problem. We discussed with the site contact that this discomfort could be a configuration issue or could be due to a stuck damper. Since the space does not have regular occupants, the site contact described solving the problem by keeping the doors open. Building comfort and equipment operation are ongoing challenges that facility teams must monitor and address to maintain optimized operation. The evaluation team recommends the facility review the damper settings and consider a Testing and Balancing (TAB) report to verify air flow matches design conditions. This was not part of the RCx program but could resolve building comfort issues.

Site ID: 9103 (RCx)

Project Description

This project upgraded the building management system (BMS) to optimize performance of controlling multiple installed HVAC systems at a 60,000 square foot elementary school with electric heating. The upgrades, or energy efficiency measures (EEMs), included reducing the hours of operation from 12 hours per day to 10 hours a day for 31 of the RTUs and from 24/7 to 12 hours per day for one additional RTU (32 RTUs total). The project also replaced failed sensors and controllers along with reduced operating hours for an additional RTU. Energy savings are primarily achieved through the reduction of RTU operating hours.

The table below describes the EEMs and ex ante gross savings claimed for this project.

Site 9103 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
HVAC Controls/EMS Building Optimization	HVAC	157,037	69.72
	Total	**157,037**	**69.72**

Data Collection

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

The evaluation team conducted an onsite visit with the school's facilities manager on January 31, 2022. During the site visit, the field engineer data accessed the BMS to capture screenshots of current conditions and of available trend data. Site data was collected by walking the site to assess the location, and condition of installed equipment. Anecdotal data was gathered by discussing the project's implementation and operations with the site's facilities manager.

The field engineer verified the reduced hours of by reviewing the BMS and confirmed that 31 of the RTUs now operate at 10 hours per day. One unit now operates at 12 hours per day. The field engineer also verified that the systems were set to auto with setback and operating temperatures within normal parameters for a building of this type and usage.

Unit Number	Baseline Schedule (Existing)	Ex Ante Schedule (Recommended)	Ex Ante Schedule (Calculations)	Ex Post Schedule (Verified in BMS)
RTU-3	Monday–Friday 6:00 a.m.–6:00 p.m. (12 hours)	Monday–Friday 5:00 a.m.–1:00 p.m. (8 hours)	Monday–Friday 5:00 a.m.–3:00 p.m. (10 hours)	Monday–Friday 6:00 a.m.–4:00 p.m. (10 hours)
RTU-32	Monday–Sunday 24/7 (24 hours)	Monday–Friday 8:30 a.m.–5:00 p.m. (8.5 hours)	Monday–Friday 8:00 a.m.–5:00 p.m. (9 hours)	Monday–Friday 6:00 a.m.–6:00 p.m. (12 hours)
RTU-2, RTUs 6-31, RTUs 33-36 (31 total)	Monday–Friday 6:00 a.m.–6:00 p.m. (12 hours)	Monday–Friday 8:30 a.m.–5:00 p.m. (8.5 hours)	Monday–Friday 8:00 a.m.–5:00 p.m. (9 hours)	Monday–Friday 6:00 a.m.–4:00 p.m. (10 hours)

The facilities manager noted there were minimal disruptions to the HVAC schedule due to COVID-19. The outside air minimums were increased from 10% to 15%–20% during occupied hours due to COVID-19 protocols. The facility manager confirmed there are no plans to revert to the 10% ventilation levels. The outside air was not modeled, and we could not adjust the analysis for this. Since these are minimum air requirements during normal occupancy, however, these would not create substantial differences in energy use.

Analysis

Ex ante savings were estimated using spreadsheet-based bin analysis, calculating savings separately for each recommend EEM. The total ex ante savings are 17% of 2020 baseline annual electricity consumption.

Ideally, the ex ante savings approach would compare historical (i.e., pre-optimization) usage data to post-optimization usage data. No pre-optimization trend data were available; however, it can be observed over the course of implementation that setpoints have become more economical and there has been a general reduction in system run-times. The limited trend data available from the BMS did show that the system was learning and adjusting start times to reflect the system characteristics.

The implementation of optimization has resulted in savings for the school district. Although the scheduled hours of operation recommended in the study were different from the observed hours by a half-hour, the total operating hours were the same. The evaluation team adjusted the ex ante savings calculations with the shifted schedule and confirmed this change had no real material impact on the savings calculation. This was due to the energy model and the implemented system reflecting the same total hours of operation.

The evaluation team reviewing the facility electricity consumption data for February 2019 through January 2022. This review confirmed there we no substantive changes to energy consumption at the facility, but the evaluation had limited post-installation data to inspect for savings.

Based on the evaluation team's review of the ex ante calculation methods, review of project documentation, and communications with the site contact during the onsite visit, the evaluation team found only one small transcription error with the ex ante calculations and found no discrepancies to warrant a savings adjustment. Therefore, the evaluation accepted the ex ante savings.

Results

The table below shows the ex ante and ex post savings and overall realization rates for this RCx project. Since the evaluation activities verified the project was implemented as proposed, the evaluation accepted the ex ante savings, resulting in a project realization rate of 100%.

Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	Realization Rate	Ex Ante Gross	Ex Post Gross	Realization Rate
HVAC Controls/EMS Building Optimization	157,037	153,533	98%	69.72	68.17	98%
Total	**157,037**	**153,533**	**98%**	**69.72**	**68.17**	**98%**

Reasons for Discrepancies

- Ex post corrected an error in the transcription of efficient kWh and savings kWh from calculation workbook to project application form.

Other Findings and Recommendations

- This project's completion form is dated April 30, 2021; however, the site contact confirmed that the project was still being implemented in January 2022. Ameren Missouri should review its program policies and practices regarding the final post-inspection and approval of energy efficiency projects so projects are not considered complete when activities required to achieve energy savings have not been fully implemented.

Appendix H. Data Collection Instruments

Data collection instruments used in the PY2020 evaluation of the BizSavers Program are embedded below.

Standard & Custom Participant Survey

PY2021 Ameren MO_Standard & Custc

New Construction Participant Interview Guide

PY2021 Ameren MO NC Program Participa

Retro-Commissioning Participant Interview Guide

PY2021 Ameren MO RCx Program Particip

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