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Ameren Missouri Program Year 2022 Annual EM&V Report

Volume 3: Business Portfolio Appendices

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Opinion Dynamics

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Appendix A. 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 1 shows a summary of the number of sampled measures by measure type.

Table 1. Sampled Standard HVAC Measures by Measure Type

Measure Type	Number of Projects	Quantity of Measures	Ex Ante kWh	% of Sampled Ex Ante kWh
Demand Control Ventilation	5	1,041.4 [A]	968,323	60%
Packaged DX	8	62	575,028	36%
ASHP	5	10	45,624	3%
Water Chiller	1	1	11,928	1%
		Total	**1,600,903**	**100%**

[A] Units in 1,000 square feet of conditioned space

Table 2 summarizes the sampled projects, by measure group, including their ex ante and ex post savings and estimated realization rates.

Table 2. Summary of Standard HVAC Project Reviews

Site ID	Measure Group	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
			Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
9300	Demand Control Ventilation	Desk Review and Onsite Verification	89,484	15,105	17%	81.49	13.76	17%
	Packaged DX	Desk Review and Onsite Verification	130,270	91,445	70%	118.63	83.28	70%
9301	ASHP	Desk Review	3,257	5,336	164%	1.45	1.56	108%
9302	Packaged DX	Desk Review	104,229	324,260	311%	94.92	294.19	310%
9303	ASHP	Desk Review and Email Verification	12,591	13,461	107%	5.59	8.60	154%
9304	ASHP	Desk Review and Phone Verification	1,095	2,464	225%	0.49	2.24	461%
9305	Packaged DX	Desk Review	125,241	88,034	70%	114.05	80.17	70%
9306	ASHP	Desk Review	27,792	29,027	104%	12.34	23.46	190%
9307	Water Chiller	Desk Review	11,928	5,550	47%	10.86	5.05	47%
9308	ASHP	Desk Review	889	4,661	524%	0.81	2.15	265%
9309	Packaged DX	Desk Review	10,328	7,855	76%	9.41	7.15	76%

Site ID	Measure Group	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
			Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
9310	Demand Control Ventilation	Desk Review and Onsite Verification	227,400	0	0%	100.96	0	0%
	Packaged DX	Desk Review and Onsite Verification	138,740	93,934	68%	126.35	85.54	68%
9311	Packaged DX	Desk Review and Email Verification	1,902	1,781	94%	1.73	1.62	94%
9312	Demand Control Ventilation	Desk Review and Onsite Verification	111,979	46,919	42%	49.72	27.12	55%
	Packaged DX	Desk Review and Onsite Verification	36,414	15,113	42%	33.16	13.76	42%
9313	Demand Control Ventilation	Desk Review	526,468	329,600	63%	411.52	250.59	61%
9314	Packaged DX	Desk Review	27,904	19,190	69%	25.41	17.48	69%
	Demand Control Ventilation	Desk Review	12,992	6,643	51%	11.83	6.05	51%

Data Collection

Desk Review

For each sampled Standard HVAC project, the evaluation team 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 (which is the TRM-recommended method when actual input data is available). 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 high saving projects that installed packaged DX units and demand-controlled ventilation (46% of total sampled ex ante energy savings). The purpose of these site visits was physical verification of key equipment and parameters, including the square footage of the area controlled

by the demand-controlled ventilation system and the type of equipment used to heat the area controlled by the demand-controlled ventilation system. The onsite engineer also verified that the nameplate of the installed packaged DX units matched project documentation.

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:

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

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

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

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

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

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

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

$$\Delta kWh_{heat} = (kBtu/hr_{heat})/3.412 * [(1/COP_{base}) - (1/COP_{ee})] * EFLH_{heat}$$

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

Table 3. 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	Desk review of project documentation and local energy codes

Parameter	Description	Source	Verification Method
$SEER_{ee}$	Seasonal Energy Efficiency Ratio of the energy efficient equipment	Spec Sheet / Invoice	Desk review of project documentation
$IEER_{base}$	Integrated Energy Efficiency Ratio of the baseline equipment	Energy Code	Desk review of project documentation and local energy codes
$IEER_{ee}$	Integrated 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	Desk review of project documentation
$HSPF_{base}$	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
COP_{base}	Coefficient of performance of the baseline equipment	Energy Code	Desk review of project documentation and local energy codes
COP_{ee}	Coefficient of performance 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	Desk review of project documentation
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor	TRM Appendix H, based on Enduse	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 4. Unitary Air Conditioner – 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

Parameter	Description	Source	Verification Method
$SEER_{base}$	Seasonal Energy Efficiency Ratio of the baseline equipment	TRM Appendix H	Desk review of project documentation and local energy codes
$SEER_{ee}$	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	Desk review of project documentation and local energy codes
$IEER_{ee}$	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 Enduse	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.

For facilities heated by natural gas, cooling savings are:

$$\Delta kWh = SQFTcond / 1000 * SFcooling$$

For facilities heated by heat pumps, heating and cooling savings are:

$$\Delta kWh = SQFTcond / 1000 * SFcooling + SQFTcond / 1000 * SFHeat\ HP$$

For facilities heated by electric resistance heating and cooling savings are:

$$\Delta kWh = SQFTcond / 1000 * SFcooling + SQFTcond / 1000 * SFHeat\ ER$$

Table 5. 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 OR Onsite Verification
$SF_{cooling}$	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 OR Onsite Verification
SF_{HeatHP}	Heating Savings factor for facilities heated by Heat Pump (HP)	TRM Appendix B, based on Building Type and location	Desk review of project documentation and customer interview OR Onsite Verification

Parameter	Description	Source	Verification Method
SF_{HeatER}	Heating Savings factor for facilities heated by Electric Resistance (ER)	TRM Appendix B, based on Building Type and location	Desk review of project documentation and customer interview OR Onsite Verification
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor	TRM Appendix B, based on Enduse	Desk review of project documentation

Electric Chiller

The team used the following equations to calculate ex post electric energy and demand savings of installing new high efficiency electric water chiller equipment.

$$\Delta kWh = TONS * (IPLV_{BASE} - IPLV_{EE}) * EFLH$$

$$\Delta kW = \Delta kWh * CF$$

Table 6. Electric Chiller – Gross Savings Input Parameters and Sources

Parameter	Description	Source	Verification Method
Tons	Chiller nominal cooling capacity in tons (note: 1 ton = 12,000 Btu/hr	Actual	Desk review of project documentation
$IPLV_{BASE}$	Efficiency of baseline equipment expressed as Integrated Part Load Value (kW/ton).	Energy Code	Desk review of project documentation
$IPLV_{EE}$	Efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)	Actual	Desk review of project documentation
EFLH	Equivalent Full Load Hours for Cooling	TRM Appendix H, based on Building Type	Desk review of project documentation
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor	TRM Appendix B, based on Enduse	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 7. Summary of Standard HVAC Project Results

Site ID	Measure Group	Annual Energy (kWh) RR	Demand (kW) RR	Reason(s) for Discrepancies
9300	Demand Control Ventilation	17%	17%	▪ The onsite engineer found that 9 of 12 sampled sensors were non-operational. Ex post analysis calculates savings based on operational sensors only. Ex ante savings are based on all installed sensors.

Site ID	Measure Group	Annual Energy (kWh) RR	Demand (kW) RR	Reason(s) for Discrepancies
				▪ Ex ante uses average SF_cool factor of 665 from Appendix F; ex post uses SF_cool factor of 449 from TRM table based on location and building type.
	Packaged DX	70%	70%	▪ Ex ante analysis applies baseline efficiencies from IECC 2012. Ex post savings are based on local energy code, IECC 2015. ▪ The ex post calculations are based on building type-specific EFLH (for stand-alone retail); ex ante uses the C&I Average EFLH.
9301	ASHP	164%	108%	▪ Ex post savings include heating savings as well as cooling savings; ex ante counts cooling only. ▪ Ex ante analysis applies baseline efficiencies from IECC 2012. Ex post savings are based on local energy code, IECC 2018. ▪ The ex post calculations are based on building type-specific EFLH (for small office); ex ante uses the C&I Average EFLH. ▪ Ex post calculates kW as Cooling kWh * Cooling CF; ex ante calculates kW using HVAC CF
9302	Packaged DX	311%	310%	▪ The ex post calculations are based on building type-specific EFLH (for outpatient health care and hospital); ex ante uses the C&I Average EFLH. ▪ Ex ante misclassifies one measure. For this measure, ex ante savings are based on a packaged DX air conditioner, while ex post savings are based on a heat pump. ▪ For the heat pump measure, ex post calculates kW as Cooling kWh * Cooling CF; ex ante calculates kW using HVAC CF
9303	ASHP	107%	154%	▪ Ex post savings include heating savings as well as cooling savings; ex ante counts cooling only. ▪ Ex ante analysis applies baseline efficiencies from IECC 2012. Ex post savings are based on local energy code, IECC 2018. ▪ The ex post calculations are based on building type-specific EFLH (for stand-alone retail); ex ante uses the C&I Average EFLH. ▪ Ex post calculates kW as Cooling kWh * Cooling CF; ex ante calculates kW using HVAC CF
9304	ASHP	225%	461%	▪ Ex post savings include heating savings as well as cooling savings; ex ante counts cooling only. ▪ The ex post calculations are based on building type-specific EFLH (for large hotel); ex ante uses the C&I Average EFLH. ▪ Ex post calculates kW as Cooling kWh * Cooling CF; ex ante calculates kW using HVAC CF
9305	Packaged DX	70%	70%	▪ Ex ante analysis applies baseline efficiencies from IECC 2012. Ex post savings are based on local energy code, IECC 2015. ▪ The ex post calculations are based on building type-specific EFLH (for stand-alone retail); ex ante uses the C&I Average EFLH.
9306	ASHP	104%	190%	▪ Ex post savings include heating savings as well as cooling savings; ex ante counts cooling only.

Site ID	Measure Group	Annual Energy (kWh) RR	Demand (kW) RR	Reason(s) for Discrepancies
				▪ Ex post savings apply new efficiencies and capacities that correspond to equipment specifications; ex ante applies values that do not correspond with installed equipment. ▪ Ex post calculates kW as Cooling kWh * Cooling CF; ex ante calculates kW using HVAC CF
9307	Water Chiller	47%	47%	▪ Ex ante savings apply 0.6 IPLV for baseline efficiency. Ex post savings apply baseline efficiency based on IECC 2015, Path A minimum requirement for chillers. ▪ The ex post calculations are based on building type-specific EFLH (for stand-alone retail); ex ante uses the C&I Average EFLH.
9308	ASHP	524%	265%	▪ Ex post savings include heating savings as well as cooling savings; ex ante counts cooling only. ▪ Ex ante analysis applies baseline efficiencies from IECC 2012. Ex post savings are based on local energy code, IECC 2018. ▪ The ex post calculations are based on building type-specific EFLH (for hospital); ex ante uses the C&I Average EFLH. ▪ Ex post calculates kW as Cooling kWh * Cooling CF; ex ante calculates kW using HVAC CF
9309	Packaged DX	76%	76%	▪ The ex post calculations are based on building type-specific EFLH (for secondary school); ex ante uses the C&I Average EFLH.
9310	Demand Control Ventilation	0%	0%	▪ Site is currently unoccupied. Property manager is seeking new tenants.
	Packaged DX	68%	68%	▪ Ex post adjusted the baseline efficiency from IECC 2012 to IECC 2015. ▪ The evaluation team made a slight adjustment to the capacity based on equipment specifications. ▪ The ex post calculations are based on building type-specific EFLH (for medium office); ex ante uses the C&I Average EFLH.
9311	Packaged DX	94%	94%	▪ The ex post calculations are based on building type-specific EFLH (for stand-alone retail); ex ante uses the C&I Average EFLH.
9312	Demand Control Ventilation	42%	55%	▪ Ex ante uses average SF_cool factor of 665 from Appendix F; ex post uses SF_cool factor of 504 from TRM table based on location and building type. ▪ Ex ante uses average SF_heat factor of 1230 from Appendix F; ex post uses SF_heat factor of 209 from TRM table based on location and building type.
	Packaged DX	42%	42%	▪ Ex ante analysis applies baseline efficiencies from IECC 2012. Ex post savings are based on local energy code, IECC 2015. ▪ The ex post calculations are based on building type-specific EFLH (for medium office); ex ante uses the C&I Average EFLH.
9313	Demand Control Ventilation	63%	61%	▪ Ex ante uses average SF_cool factor of 665 from Appendix F; ex post uses SF_cool factors of 384 and 397 from TRM table based on location and building type.

Site ID	Measure Group	Annual Energy (kWh) RR	Demand (kW) RR	Reason(s) for Discrepancies
				▪ For the facility with electric heating, Ex ante uses average SF_heat factor of 410 from Appendix F; ex post uses SF_heat factor of 402 from TRM table based on location and building type.
9314	Packaged DX	69%	69%	▪ The ex post calculations are based on building type-specific EFLH (for secondary school); ex ante uses the C&I Average EFLH. ▪ Ex post savings applies new capacities that correspond to equipment specifications; ex ante applies capacities that do not correspond to installed equipment.
	Demand Control Ventilation	51%	51%	▪ Ex ante uses average SF_cool factor of 665 from Appendix F; ex post uses SF_cool factors of from TRM table based on location and building type.

Appendix B. Additional Information: Standard Motors

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

The evaluation of Standard motors projects included desk reviews and onsite visits for a sample of six projects. Table 8 shows a summary of the number of sampled measures by measure type.

Table 8. Sampled Standard Motors Measures by Measure Type

Measure Type	Number of Projects	Quantity of Measures	Ex Ante kWh	% of Sampled Ex Ante kWh
HVAC VFD	2	28	280,971	16%
Pump/Fan VFD	2	17	1,353,588	76%
ECM/Fridge Motor	2	10	143,718	8%
		Total	**1,778,277**	**100%**

Table 9 summarizes the sampled projects, by measure group, including their ex ante and ex post savings and estimated realization rates.

Table 9. Summary of Standard Motors Project Reviews

Site ID	Measure Group	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
			Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
9200	Pump/Fan VFD	Desk review and site visit	1,276,212	2,260,308	177%	1,135.38	2,026.94	179%
9201	HVAC VFD	Desk review	14,096	-	0%	6.26	-	0%
9202	ECM/Fridge Motor	Desk review	16,908	16,908	100%	2.33	2.33	100%
9203	HVAC VFD	Desk review	266,875	349,889	131%	118.50	155.35	131%
9204	Pump/Fan VFD	Desk review	77,376	53,209	69%	70.47	48.46	69%
9205	ECM/Fridge Motor	Desk review	126,810	-	0%	17.49	-	0%

Data Collection

Desk Review

For each sampled Standard Motors project, the evaluation team 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 default and average values from the TRM Appendix H document rather than the algorithms, input parameter definitions, and measure-specific input information.

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.

Site Visits

We also conducted one onsite visit to perform a physical verification of key equipment and parameters, including the quantity of installed VFDs, 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.

HVAC VFD

The team used the following equations to calculate ex post electric energy and demand savings for HVAC VFDs.

$\Delta kWh_{fan} = kWh_{Base} - kWh_{Retrofit}$

$\Delta kWh_{total} = \Delta kWh_{fan} * (1 + E_{energy})$

$kWh_{Base} = 0.746 * HP * \frac{LF}{\eta moto}) * RHRS_{Base} \sum_{0.0\%}^{100\%} (\%FF * PLR_{Base})$

$kWh_{Retrofit} = 0.746 * HP * \frac{LF}{\eta moto}) * RHRS_{Retrofit} \sum_{30\%}^{100\%} (\%FF * PLR_{Retrofit})$

$\Delta kW = \Delta kWh * CF$

Table 10. HVAC VFD – Gross Savings Input Parameters and Sources

Parameter	Description	Source	Verification Method
HP	Nominal horsepower of controlled motor	Spec Sheet / TRM Appendix H	Desk review of project documentation
LF	Load Factor; Motor Load at Fan Design CFM (Default = 65%). Used to convert HP to BHP.	Spec Sheet / TRM Appendix H	Desk review of project documentation
ηmotor	Installed nominal/nameplate motor efficiency. If unknown, perform lookup in the NEMA Premium Efficiency Motors Default Efficiencies table in TRM Appendix H.	Spec Sheet / TRM Appendix H	Desk review of project documentation

Parameter	Description	Source	Verification Method
RHRS	Annual operating hours for fan motor based on Building Type.	Spec Sheet / TRM Appendix H	Desk review of project documentation
%FF	Percent of time at flow fraction. Values in TRM table.	TRM Appendix H, based on Control Type	Desk review of project documentation
PLR	Part load ratio for a given flow fraction range based on the flow control type. Values in TRM table.	TRM Appendix H, based on Control Type	Desk review of project documentation
E_{energy}	HVAC interactive effects factor for energy (default = 15.7%).	TRM Appendix H	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

Pump and Fan VFD

The team used the following equations to calculate ex post electric energy and demand savings for pump and fan VFDs.

ΔkWh = BHP /EFFi * Hours * ESF

ΔkW = ΔkWh * CF

Table 11. Pump and Fan VFD – Gross Savings Input Parameters and Sources

Parameter	Description	Source	Verification Method
BHP	System Brake Horsepower. Use actual or if unknown apply 65% to nominal motor horsepower.	Spec Sheet / TRM Appendix H	Desk review of project documentation and onsite visit
EFFi	Motor efficiency, installed. Actual motor efficiency shall be used to calculate kW. If not known, a default value of 93% is an appropriate assumption.	Spec Sheet / TRM Appendix H	Desk review of project documentation and onsite visit
Hours	Seasonal Energy Efficiency Ratio of the baseline equipment.	Project files / TRM Appendix H	Desk review of project documentation and onsite visit
ESF	Energy savings factor varies by VFD application. Units are kW/HP.	TRM Appendix H, based on Enduse	Desk review of project documentation
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor.	TRM Appendix H, based on Enduse	Desk review of project documentation

ECM / Fridge Motor

The team used the following equations to calculate ex post electric energy and demand savings for Electronically Commutated Motors.

ΔkWh = Savings per motor * Number of motors

$\Delta kW = \Delta kWh * CF$

Table 12. Pump and Fan VFD– Gross Savings Input Parameters and Sources

Parameter	Description	Source	Verification Method
Savings per motor	Based on the motor rating of the ECM. The TRM provides a table that lists annual kWh savings per motor by the fan motor rating (either Watts or HP).	Spec Sheet / TRM Appendix H	Desk review of project documentation
Number of motors	Number of fan motors replaced	Spec Sheet / TRM Appendix H	Desk review of project documentation
CF	Summer peak coincidence demand (kW) to annual energy (kWh) factor	TRM Appendix H, based on Enduse	Desk review of project documentation

Gross Impact Analysis Results

The table below presents the results of the Standard Motors 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 13. Summary of Standard Motors Project Results

Site ID	Measure Group	Annual Energy (kWh) RR	Demand (kW) RR	Reason(s) for Discrepancies
9200	Pump/Fan VFD	177%	179%	▪ Ex ante calculations used 15 HP, but ex post calculations used 125 HP. ▪ Ex ante calculations used a default motor efficiency value of 77% for all measures. Ex post calculations applied a motor efficiency value based on actual motor characteristics or nameplate values when available (as specified by the TRM) or used the TRM default value of 93% if the information was not available. ▪ Ex ante savings used 8,760 annual operation hours (applicable to hospitals & healthcare facilities in the TRM) but ex post calculations adjusted this to 6,385 hours for a "Large Office" building type. ▪ Ex ante savings calculations neglected to use the quantity of VFDs/motors, but the quantities were used for ex post savings calculations. There are three separate chillers at this site and three of each VFD measure. ▪ Ex ante calculations were performed using the nominal HP values a TRM default load factor of 65%. Ex post savings used the BHP when available as specified by the TRM.
9201	HVAC VFD	0%	0%	▪ Ex ante calculates VFD savings for the two new RTU rooftop units installed. Those units are Trane YHD300G, as indicated in the spec sheet provided.

Site ID	Measure Group	Annual Energy (kWh) RR	Demand (kW) RR	Reason(s) for Discrepancies
				▪ Verified savings does not qualify these VFD savings because the spec sheet for the Trane unit indicates that the VFD is internal to the unit and because IECC 2015 code section C403.4.1.1 indicates that any new direct expansion units greater than 65,000 Btu/h must have a modulating fan control.
9202	ECM/Fridge Motor	100%	100%	▪ Ex ante savings calculations were verified as correct.
9203	HVAC VFD	131%	131%	▪ Ex ante applied the default or average TRM values for two of the primary inputs used to calculate savings for the HVAC Supply/Return Fan VFD TRM measure (Section 2.8.6). ▪ Ex ante used the default 93% motor efficiency for the Pump/Fan VFD TRM measure instead of using motor efficiency based on actual motor enclosure type, horsepower, and speed (RPM). ▪ Ex ante applied the Nonresidential Average value of 6,773 hrs. This was updated to reflect the project building type of Hospital at 8,760 hrs.
9204	Pump/Fan VFD	69%	69%	▪ Ex ante applied a motor efficiency value of 98% which could not be validated, so ex post savings used the Appendix H TRM default value of 93%. ▪ Ex ante savings also did not use a load factor to calculate motor brake HP from the nominal HP. Ex post savings applied the TRM default load factor of 65%.
9205	ECM/Fridge Motor	0%	0%	▪ This project is new construction and included installation of refrigerator ECMs. ▪ The ex post analysis calculated zero savings because this measure type is only valid if installed in retrofit projects, new construction applications are not valid according to the Ameren MO TRM, Appendix H. The Code of Federal Regulations section § 431.66, "Energy conservation standards and their effective dates," effectively requires ECMs in order to meet the maximum daily energy consumption requirements.

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

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

Table 14. Summary of Custom Lighting Project Reviews

Site ID	Evaluation Approach	Annual Energy (kWh)			Demand (kW) RR		
		Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
9520	Desk review	294,722	283,990	96%	55.99	53.95	96%
9521	Desk review	87,297	90,430	104%	16.583	17.18	104%
9522	Desk review	13,953	14,930	107%	2.651	2.84	107%
9523	Desk review with Onsite Verification	629,585	436,189	69%	119.60	82.86	69%
9524	Desk review	98,664	56,184	57%	18.74	10.67	57%
9525	Desk review	883	844	96%	0.17	0.21	123%
9526	Desk review	10,317	10,992	107%	1.96	2.09	107%
9527	Desk review with Onsite Verification	740,743	806,381	109%	140.71	153.18	109%

Site 9520 (Custom Lighting)

Project Description

This project involves a major renovation to an existing jail, including a 50,000 square-foot detention center and 6,000 square-foot 911 dispatch center. Energy savings are achieved by reducing the lighting power density (LPD) below the interior lighting power allowance specified by the local energy code. Additional energy savings are achieved through lowered cooling requirements. The building has electric cooling and electric resistance heat. Table 15 describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Table 15. Site 9520 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 New Space Additions	Lighting	294,722	55.99
	Total	**294,722**	**55.99**

Data Collection

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

Analysis

The implementation team's savings estimates are calculated through standard lighting savings algorithms using estimated lighting system hours of use (HOU). These calculations use existing conditions as a baseline, assuming the annual HOU for the lighting system to be 8,760 hours per year.

$$kWh_{Ex\ Post\ Gross} = kWh_{savings(Whf)} - kWh_{electric\ heat\ penalty(IF)}$$

$$kWh_{savings(Whf)} = \left((LPD_{base} - LPD_{eff}) x Area_{sqft} x HOU_{annual}\right) x (WHF_{Cool} - IF_{kWh}) \ x \ \frac{1\ kWh}{1{,}000\ Wh}$$

$$kW_{peak\ coincident} = \left(((LPD_{base} - LPD_{eff}) x Area_{sqft} x HOU_{annual}) x \frac{1\ kWh}{1{,}000\ Wh}\right) x \ CF$$

The evaluation team calculated energy and demand savings using the above standard lighting algorithms, updated with parameter values either verified through evaluation activities or based on current TRM specifications. The evaluation team calculated kW savings using the kW factor for the lighting enduse (KW Factor: 0.0001899635).

Table 16 compares the ex ante and verified ex post values for key parameters in the calculation.

Table 16. Site 9520 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verified Source
EEM-1 New Space Additions	Baseline LPD	0.77 W/ft^2	0.77 W/ft^2	IECC 2018
	EE LPD	0.47 W/ft^2	0.43 W/ft^2	Invoices and Spec Sheets
	HOU	8,760	8,760	Implementation documented HOU
	HVAC WHF	N/A	1.09	Missouri TRM
	Electric heat interaction factor	N/A	0.24	Missouri TRM
	Coincidence Factor	0.0001899635 kW/kWh	0.0001899635 kW/kWh	Missouri TRM

Results

The evaluation team estimated savings of 283,990 kWh across all the measures implemented as part of this project, or 96% of the ex ante estimates of annual energy savings of 294,722 kWh. Demand savings of 53.95 kW represent a 96% realization rate.

Table 17. Site 9520 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 New Space Additions	294,722	283,990	96%	55.99	53.95	96%
Total	**294,722**	**283,990**	**96%**	**55.99**	**53.95**	**96%**

Reasons for Discrepancies

- The evaluation team applied an electric heat interaction factor of 0.24 for the facility to calculate the electric heating penalty. The implementation team did not include the electric heat penalty, which decreased energy savings.
- The evaluation team updated watts per unit of installed equipment based on specification sheets, resulting in increased electric energy savings.
- The evaluation team used the average WHF of 1.09 for the facility. This increased the energy savings associated with a reduced need to cool the facility.
- Ex ante reported quantities, and the quantities in the supporting invoices, do not match for eight fixture types, nor does the data clearly show where the fixtures are installed. Ex post used the lowest total quantity for each fixture between the reported and invoiced quantity.

Other Findings and Recommendations

- N/A

Site 9521 (Custom Lighting)

This project involves a two-story addition to a middle school with electric cooling and natural gas heat. Reducing the lighting power density (LPD) below the interior lighting power allowance specified by the local energy code achieves energy savings; lowering the cooling requirements of the building achieves additional energy savings. Table 18 describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Table 18. Site 9521 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 New Two-Story Addition	Lighting	87,297	16.58
	Total	**87,297**	**16.58**

Data Collection

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

Analysis

The implementation team's savings estimates are calculated using standard lighting savings algorithms using estimated lighting system hours of use (HOU). These calculations use existing conditions as a baseline, assuming the annual HOU for the lighting system to be 3,600 hours per year.

$$kWh_{Ex\ Post\ Gross} = kWh_{savings(Whf)} - kWh_{electric\ heat\ penalty(IF)}$$

$$kWh_{savings(Whf)} = \left((LPD_{base} - LPD_{eff}) x Area_{sqft} x HOU_{annual}\right) x (WHF_{Cool} - IF_{kWh}) \ x \ \frac{1\ kWh}{1{,}000\ Wh}$$

$$kW_{peak\ coincident} = \left(((LPD_{base} - LPD_{eff}) x Area_{sqft} x HOU_{annual}) x \frac{1\ kWh}{1{,}000\ Wh}\right) x \ CF$$

The evaluation team calculated energy and demand savings using the above 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 (KW Factor: 0.0001899635).

Table 19 compares the ex ante and verified ex post values for key parameters used in the calculation.

Table 19. Site 9521 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verified Source
EEM-1 New 2-Story Addition	Baseline LPD	0.87 W/ft^2	0.87 W/ft^2	IECC 2015
	EE LPD	0.50 W/ft^2	0.50 W/ft^2	Invoices and spec sheets
	HOU	3,600	3,466	Missouri TRM
	HVAC WH	N/A	1.08	Missouri TRM

Results

The evaluation team estimated savings of 90,430 kWh across all measures implemented as part of this project, or 104% of the ex ante estimates of annual energy savings of 87,297 kWh. Demand savings of 17.18 kW represent a 104% realization rate.

Table 20. 9521 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 New 2-Story Addition	87,297	90,430	104%	16.58	17.18	104%
Total	**87,297**	**90,430**	**104%**	**16.58**	**17.18**	**104%**

Reasons for Discrepancies

- The evaluation team used the average WHF of 1.08 for the facility. This increased the energy and demand savings associated with a reduced need to cool the facility.
- The evaluation team updated annual hours of use from 3,600 to 3,446 based on the standard hours in the Missouri TRM.

Other Findings and Recommendations

- Invoices and some specification sheets were missing from the project documentation. The evaluation team attempted to contact the customer to verify the missing information; however, outreach was unsuccessful. Given that there was some corroborating information, the evaluation team applied ex ante quantities.

Site 9522 (Custom Lighting)

Project Description

This is a new construction project that involves renovating an existing building to house retail, food service, and meat processing spaces. Energy savings are achieved by reducing the lighting power density (LPD) below the interior lighting power allowance specified by the local energy code. Additional energy savings are achieved through lowered cooling requirements. The building has electric cooling and natural gas heat. Table 21 describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Table 21. Site 9522 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 New Space Additions	Lighting	13,953	2.65
	Total	**13,953**	**2.65**

Data Collection

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

Analysis

The implementation team's savings estimates are calculated through standard lighting savings algorithms using estimated lighting system HOU. These calculations use existing conditions as the baseline, assuming the annual HOU for the lighting system to be 4,031 hours per year.

$$kWh_{Ex\ Post\ Gross} = kWh_{savings(Whf)} - kWh_{electric\ heat\ penalty(IF)}$$

$$kWh_{savings(Whf)} = \left((LPD_{base} - LPD_{eff}) x Area_{sqft} x HOU_{annual}\right) x (WHF_{Cool} - IF_{kWh}) \ x \ \frac{1\ kWh}{1{,}000\ Wh}$$

$$kW_{peak\ coincident} = \left(((LPD_{base} - LPD_{eff}) x Area_{sqft} x HOU_{annual}) x \frac{1\ kWh}{1{,}000\ Wh}\right) x \ CF$$

The evaluation team calculated energy and demand savings using the above 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 (KW Factor: 0.0001899635).

Table 22 compares the ex ante and verified ex post values for key parameters in the calculation.

Table 22. Site 9522 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verified Source
EEM-1 New Space Additions	Baseline LPD	1.17 W/ft^2	1.17 W/ft^2	IECC 2015
	EE LPD	0.63 W/ft^2	0.63 W/ft^2	Spec sheets
	HOU	4031	4031	Accepted ex ante value
	HVAC WHF	N/A	1.07	Missouri TRM

Results

The evaluation team estimated savings of 14,930 kWh across all the measures implemented as part of this project, or 107% of the ex ante estimates of annual energy savings of 13,953 kWh. Demand savings of 2.84 kW represent a 107% realization rate.

Table 23. Site 9522 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 New Space Additions	13,953	14,930	107%	2.65	2.84	107%
Total	**13,953**	**14,930**	**107%**	**2.65**	**2.84**	**107%**

Reasons for Discrepancies

- The evaluation team used the average WHF of 1.07 for the facility. This increased the energy and demand savings associated with a reduced need to cool the facility.

Other Findings and Recommendations

- Invoices and some specification sheets were missing from the Project Documentation. The evaluation team attempted to contact the customer to verify the missing information; however, outreach was unsuccessful. Given that there was some corroborating information, the evaluation team applied ex ante quantities and hours of use.

Site 9523 (Custom Lighting)

This project includes lighting installations in a new construction 547,000 square-foot warehouse. The difference in lighting power density (LPD) associated with efficient conditions compared to the baseline LPD accrues savings. According to the program tracking data, the heating source is natural gas, and there is no air conditioning; as a result, energy savings are only achieved through the improved efficiency of the lighting equipment. For this project, the IECC 2015 baseline was used.

Table 24 describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Table 24. Site 9523 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM 1 - Warehouse	Lighting	629,585	119.60
	Total	**629,585**	**119.60**

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 conducted a site visit to confirm building type, the installed lighting systems, operating schedule, annual hours of use (HOU), and lamp counts. The building square footage. was verified using Google Maps. The site houses two different tenants with different HOU. The evaluation team assumed each tenant is occupying 50% of the space. For one tenant, we received a verified HOU; for the other, we are using the implementation team's HOU assumption.

Analysis

The implementation team's savings estimates are calculated using standard lighting savings algorithms using estimated lighting system HOU. These calculations use existing conditions as baseline, assuming the annual HOU for the lighting system is 2,827 hours per year.

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

Or

$$kWh_{savings(Whf)} = \left(\left(LPD_{base} - LPD_{eff}\right) x Area_{sqft} x HOU_{annual}\right) x (WHF_{Cool} - IF_{kWh})\ x\ \frac{1\ kWh}{1{,}000\ Wh}$$

$$kW_{savings} = kWh_{savings} x\ KW\ Factor$$

The evaluation team calculated energy and demand savings using the above standard lighting algorithms, which were 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 (KW Factor: 0.0001899635).

Table 25 compares the ex ante and verified ex post values for key parameters in the calculation.

Table 25. Site 9523 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verified Source
EEM- Tenant 1- High Bay	Efficient LPD (W/Ft^2)	0.25	0.25	Spec sheet
	Baseline LPD (W/Ft^2)	0.65	0.65	IECC 2015- Warehouse LDP
	HOU	2827	2148.52	Ex ante assumption from application, with 76% factor to account for occupancy sensors (based on TRM deemed saving value)
EEM- Tenant 2- High Bay	Efficient LPD (W/Ft^2)	0.25	0.25	Spec sheet
	Baseline LPD (W/Ft^2)	0.65	0.65	IECC 2015- Warehouse LDP
	HOU	2827	1742.36	Confirmed HOU based on site verification, with 76% factor to account for occupancy sensors (based on TRM deemed saving value)
EEM- Tenant 1 and 2- Exit Lamps	Watt- base/unit	N/A	5	Ex Ante used the same LPD and HOU regardless of the lamp type; Ex post is using IECC 2015 for the baseline wattage and Spec Sheet for efficient wattage
	Weighted watt- efficient/unit	N/A	1.43	
	HOU	2827	8760	

Results

The evaluation team estimated savings of 436,189 kWh across all the measures implemented as part of this project, or 69% of the ex ante estimates of annual energy savings of 629,585 kWh.

Table 26. Site 9523 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM- Warehouse	629,585	436,189	69%	119.60	82.86	69%
Total	**629,585**	**436,189**	**69%**	**119.60**	**82.86**	**69%**

Reasons for Discrepancies

- The evaluation team updated the facility annual HOU after onsite verification. The evaluation team reported two different space types with different HOUs. Both spaces use occupancy sensors. The HOU for exit lamps have been updated to 8760.

Other Findings and Recommendations

- N/A

Site 9524 (Custom Lighting)

Project Description

This project replaces existing Halogen fixtures with efficient LED fixtures at a cathedral in Saint Louis, Missouri. Energy savings are achieved through the improved efficiency of the lighting equipment. Additional energy savings are achieved through lowered cooling requirements. This is the first phase of a larger project to upgrade thousands of lights throughout the cathedral and to add controls to boost energy efficiency. The building has electric cooling and natural gas heat. Table 27 describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Table 27. Site 9524 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Halogen Fixture Replacements	Lighting	67,110	12.75
EEM-2 Halogen Fixture Replacements	Lighting	31,554	5.99
	Total	**98,664**	**18.74**

Data Collection

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

Analysis

The implementation team's savings estimates are calculated through standard lighting savings algorithms using estimated lighting system hours of use (HOU). These calculations use existing conditions as the baseline, assuming the annual HOU for the lighting system to be 2,000 hours per year.

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

$$kW_{peak\ coincident} = kWh_{savings} x\ \ CF$$

The evaluation team calculated energy and demand savings using the above 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 (KW Factor: 0.0001899635).

Table 28 compares the ex ante and verified ex post values for key parameters in the calculation.

Table 28. Site 9524 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verified Source
EEM-1 Halogen Fixture Replacements	Baseline fixture quantity/watts	70/500W	70/500W	Application
	Energy efficiency fixture quantity/watts	26/140W	26/140W	Invoices and spec sheets
	HOU	2,000	1,118	Email Verification
	HVAC waste heat factor (WHF)	1.07	1.09	Missouri TRM
EEM-2 Halogen Fixture Replacements	Baseline fixture quantity/watts	34/500W	34/500W	Application
	EE fixture quantity/watts	11/205W	11/205W	Invoices and spec sheets
	HOU	2000	1,118	Email verification
	HVAC WHF	1.07	1.09	Missouri TRM

Results

The evaluation team estimated savings of 56,184 kWh across all the measures implemented as part of this project, or 57% of the ex ante estimates of annual energy savings of 98,665 kWh. Demand savings of 10.67 kW represent a 57% realization rate.

Table 29. Site 9524 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Halogen Fixture Replacements	67,110	38,216	57%	12.75	7.26	57%
EEM-2 Halogen Fixture Replacements	31,554	17,969	57%	5.99	3.41	57%
Total	**98,664**	**56,184**	**57%**	**18.74**	**10.67**	**57%**

Reasons for Discrepancies

- The evaluation team updated the facility annual HOU based on communications with facility staff. This resulted in a reduction of HOU from 2,000 hours to 1,118 hours. The reduction in hours results in a commensurate reduction in energy and demand savings.
- The evaluation team used the average WHF of 1.09 for the facility. This increased the energy and demand savings associated with a reduced need to cool the facility.

Other Findings and Recommendations

- N/A

Site 9525 (Custom Lighting)

This project replaced incandescent screw-in globe lamps with equivalent LED lamps in bathrooms within an automotive facility. The facility is air conditioned and electrically heated. Energy savings are achieved through the improved efficiency of the lighting equipment and a reduction in required cooling energy due to the lower heat output of LED fixtures.

Table 30. Site 9525 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Incandescent Lamp Replacements	Lighting	883	0.17
	Total	**883**	**0.17**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The evaluation team contacted the customer in November 2022 to confirm the lamp installation details and the hours of operation for the lamps, including control by existing occupancy sensors.

Analysis

The ex ante project savings are calculated using a standard lighting savings algorithm shown below with estimated lamp HOU, an HVAC waste heat factor (WHF) of 1.07, and an HVAC interactive factor (IF) of 0.

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

The ex ante calculations use existing conditions as a baseline with an estimated hours of use (HOU) of 2,500 hours per year. The ex post analysis reviewed and adopted the ex ante savings calculation method but updated the following parameters:

- HOU reduced from 2,500 hours per year to 1,948 hours per year based on existing occupancy sensors
- Baseline lamp wattage increased from 28W to 40W, the nominal wattage of the existing lamps
- WHF changed from 1.07 to 1.09, corresponding to the deemed Commercial and Industrial (C&I) Average WHF
- IF changed from 0 to 0.24, corresponding to the deemed value for electric heating

Table 31. Site 9525 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline lamp quantity	15	15	Application, customer verification
EEM-1	Efficient lamp quantity	15	15	Application, customer verification
EEM-1	Baseline wattage	28	40	Application, customer verification
EEM-1	Efficient wattage	6	6	Specification sheet

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	HOU	2,500	1,948	Customer verification of HOU and existing occupancy sensors; 24% HOU reduction per TRM
EEM-1	HVAC WHF	1.07	1.09	C&I Average WHF per TRM
EEM-1	HVAC IF	0	0.24	Electric heating value per TRM

Results

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

Table 32. Site 9525 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Incandescent Lamp Replacements	883	844	96%	0.1677	0.1604	96%
Total	**883**	**844**	**96%**	**0.1677**	**0.1604**	**96%**

Reasons for Discrepancies

- The ex ante HOU estimate did not account for the presence of occupancy sensors controlling the lighting in the bathrooms, which are estimated to reduce the HOU by 24 percent per the AMO TRM. This reduction in savings is offset by the higher ex post baseline wattage.

Other Findings and Recommendations

- The ex ante baseline wattage is equal to 28W, 30 percent lower than the nominal wattage of 40W for incandescent G25 lamps. The 30 percent reduction was presumably applied to account for Energy Independence and Security Act (EISA) requirements for the efficacy of screw-in lamps. However, globe lamps were exempt from EISA until the Department of Energy May 2022 Direct Final Rule for General Service Lamps, which expanded the definition of general service lamps to include globes and other formerly exempt lamp types. The Completion Form for this project was signed in February 2022 before this regulation took effect.

Site 9526 (Custom Lighting)

Project Description

This project replaced existing CFL lighting with LED lighting at a bank in Saint Louis County. Energy savings are achieved through the improved efficiency of the lighting equipment, and additional energy savings are achieved through lowered cooling requirements. The building has electric cooling and natural gas heat. Table 33 describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Table 33. Site 9526 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 CFL Screw-in Replacements	Lighting	278	0.05
EEM-2 CFL Screw-in Replacements	Lighting	10,039	1.91
	Total	**10,317**	**1.96**

Data Collection

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

Analysis

The implementation team's savings estimates are calculated through standard lighting savings algorithms using estimated lighting system HOU. These calculations use existing conditions as the baseline, assuming the annual HOU for the lighting system to be 2,548 and 8760 hours per year for EEM-1 and EEM2, respectively.

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

$$kW_{peak\ coincident} = kWh_{savings} x\ \ CF$$

The evaluation team calculated energy and demand savings using the above 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 a (KW Factor: 0.0001899635)

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

Table 34. Site 9526 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verified Source
EEM-1 CFL Screw-in Replacements	Baseline fixture quantity/watts	6/23W	6/23W	Assumed Ex ante
	EE fixture quantity/watts	6/6W	6/6W	Invoices and Spec Sheets
	HOU	2,548	2,548	Assumed Ex ante
	HVAC WHF	1.07	1.14	Missouri TRM
EEM-2 CFL Screw-in Replacements	Baseline fixture quantity/watts	63/23W	63/23W	Assumed Ex ante
	EE fixture quantity/watts	63/6W	63/6W	Invoices and Spec Sheets
	HOU	8,760	8,760	Assumed Ex ante
	HVAC waste heat factor	1.07	1.14	Missouri TRM

Results

The evaluation team estimated savings of 10,992 kWh across all the measures implemented as part of this project, or 107% of the ex ante estimates of annual energy savings of 10,317 kWh. Demand savings of 2.09 kW represent a 107% realization rate.

Table 35. Site 9526 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 CFL Screw-in Replacements	278	296	107%	0.05	0.06	107%
EEM-2 CFL Screw-in Replacements	10,039	10,695	107%	1.91	2.03	107%
Total	**10,317**	**10,992**	**107%**	**1.96**	**2.09**	**107%**

Reasons for Discrepancies

- The evaluation team used the average WHF of 1.14 for the facility. This increased the energy and demand savings associated with a reduced need to cool the facility.

Other Findings and Recommendations

- N/A

Site 9527 (Custom Lighting)

Project Description

This project involved a major renovation, including lighting upgrades, to an industrial manufacturing facility in Randolph County. Energy savings are achieved by reducing the lighting power density (LPD) below the interior lighting power allowance specified by the local energy code. Additional energy savings are achieved through lowered cooling requirements. The building has electric cooling with natural gas heat. Table 36 describes the energy efficiency measures (EEMs) and ex ante gross savings claimed for this project.

Table 36. Site 9527 Evaluation Savings Results

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 New Construction/Major Renovation	Lighting	740,743	140.71
	Total	**740,743**	**140.71**

Data Collection

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

Analysis

The implementation team's savings estimates are calculated using standard lighting savings algorithms using estimated lighting system HOU. These calculations use existing conditions as the baseline, assuming the annual HOU for the lighting system to be 8760 hours per year.

$$kWh_{Ex\ Post\ Gross} = kWh_{savings(Whf)} - kWh_{electric\ heat\ penalty(IF)}$$

$$kWh_{savings(Whf)} = \left((LPD_{base} - LPD_{eff}) x Area_{sqft} x HOU_{annual}\right) x (WHF_{Cool} - IF_{kWh}) \ x \ \frac{1\ kWh}{1{,}000\ Wh}$$

$$kW_{peak\ coincident} = kWhsavings\ x\ CF$$

The evaluation team calculated energy and demand savings using the above 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 (KW Factor: 0.0001899635)

Table 37 compares the ex ante and verified ex post values for key parameters in the calculation.

Table 37. Site 9527 Verification of Key Parameters

Measure	Parameter	Ex Ante Value	Ex Post Value	Verified Source
EEM-1 New Addition	Baseline LPD	1.3 W/ft^2	1.3 W/ft^2	IECC 2012
	EE LPD	0.6 W/ft^2	0.6 W/ft^2	Invoices and spec sheets
	HOU	8760	8760	Verified by customer
	HVAC WHF	N/A	1.09	Missouri TRM
	Coincidence Factor	0.0001899635 kW/kWh	0.0001899635 kW/kWh	Missouri TRM

Results

The evaluation team estimated savings of 806,381 kWh across all measures implemented as part of this project, or 109% of the ex ante estimates of annual energy savings of 740,743 kWh. Demand savings of 153.18 kW represent a 109% realization rate.

Table 38. Site 9527 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 New Addition	740,743	806,381	109%	140.71	153.18	109%
Total	**740,743**	**806,381**	**109%**	**140.71**	**153.18**	**109%**

Reasons for Discrepancies

- The evaluation team used the average WHF of 1.09 for the facility. This increased the energy savings associated with a reduced need to cool the facility.
- The evaluation team adjusted the watts per unit of some installed lighting based on equipment specifications. This resulted in a slight decrease in energy and demand savings.

Other Findings and Recommendations

- N/A

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

The evaluation of Custom HVAC projects included desk reviews and onsite visits for a sample of 19 projects. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Table 39. 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
9112	Desk review with Onsite Verification	60,317	53,164	88%	54.93	48.42	88%
9113	Desk review with Onsite Verification	256,285	121,010	47%	233.39	110.20	47%
9114	Desk review with Onsite Verification	1,316,312	879,901	67%	1,198.74	801.31	67%
9115	Desk review	3,850	3,511	91%	3.51	3.20	91%
9116	Desk review with remote verification	3,186	959	30%	2.90	0.87	30%
9117	Desk review with remote verification	123,870	145,494	117%	55.00	64.60	117%
9118	Desk review	411,375	411,375	100%	374.63	374.63	100%
9119	Desk review	55,873	52,467	94%	32.49	31.09	96%
9120	Desk review	6,362	8,046	126%	2.82	5.69	202%
9121	Desk review with remote verification	18,722	11,999	64%	17.05	10.93	64%
9122	Desk review	98,055	77,875	79%	89.30	70.92	79%
9123	Desk review	389,335	389,335	100%	195.53	195.53	100%
9124	Desk review	459,233	430,149	94%	418.22	391.73	94%
9126	Desk review	34,342	23,141	67%	31.27	21.07	67%
9128	Desk review	1,065,299	151,190	14%	472.97	67.13	14%
9129	Desk review with Onsite Verification	2,469,698	240,739	10%	2,249.11	219.24	10%
9130	Desk review	406,454	406,454	100%	370.15	370.15	100%
9132	Desk review with Onsite Verification	1,991,964	1,864,500	94%	1,814.05	1,697.97	94%
9133	Desk review with Onsite Verification	561,463	561,350	100%	362.54	511.21	141%

Site 9112 (Custom HVAC)

This site is a new construction project including the installation of efficient air-conditioning rooftop units with gas heating in an industrial facility. The county in which the facility is located has not adopted an energy code, so the energy savings are evaluated relative to the minimum requirements in IECC 2012, the default energy code that Opinion Dynamics is using for counties that have not adopted energy codes.

Table 40 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 40. Site 9112 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 RTU-1	Cooling	16,710	15.22
EEM-2 RTU-2	Cooling	12,106	11.02
EEM-3 RTU-3	Cooling	2,552	2.32
EEM-4 RTU-4	Cooling	11,097	10.11
EEM-5 RTU-5	Cooling	5,136	4.68
EEM-6 RTU-6	Cooling	1,326	1.21
EEM-7 RTU-7	Cooling	2,552	2.32
EEM-8 RTU-8	Cooling	8,071	7.35
EEM-9 RTU-9	Cooling	767	0.70
	Total	**60,317**	**54.93**

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 January 2023 to collect information on installed equipment and review operating schedules and setpoints on the facility building automation system (BAS); however, the zone temperature set points were unable to be verified. The installed equipment differed from the ex ante equipment in all cases, as shown in Table 41 Evaluation collected the rated capacities and efficiencies of the verified equipment from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory.

Table 41. Site 9112 Ex Ante versus Verified Makes and Models

RTU	Ex Ante Make/Model	Verified Make/Model	Verified Source
RTU-1	Trane Intellipack 40-ton	Johnson Controls GVC2G2B5JA2A60AD2	Site visit
RTU-2	Trane YCD360B4	Johnson Controls JV30S3CG4K1CMPA7E1	Site visit
RTU-3	Trane YHC102F4RHA	Johnson Controls J08ZJS18R4D6KCA6E2	Site visit
RTU-4	Trane YCD330B4	Johnson Controls AD28T3DQ4M1CTP17E1	Site visit
RTU-5	Trane YHD180G4RVB	Johnson Controls AD15T3DQ4M1CTP17E1	Site visit
RTU-6	Trane YHC067E4RLA	Johnson Controls J06ZJS12R4D6CCA6E2	Site visit
RTU-7	Trane YHC102F4RLA	Johnson Controls J08ZJS12R4D6KCA6E2	Site visit

RTU	Ex Ante Make/Model	Verified Make/Model	Verified Source
RTU-8	Trane YHD240G4RVB	Johnson Controls AD20T3DQ4M1CTP17E1	Site visit
RTU-9	Trane 0ABD036A4	York JR0A036A1A4D	Site visit

Analysis

The ex ante project savings were estimated through a cooling degree days calculation, not accounting for economizer operation. Ex post savings were estimated through a bin analysis with TMY3 weather data, factoring in economizer "free cooling" savings and verified equipment capacities and efficiencies.

Table 42. Site 9112 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	RTU-1 capacity and efficiency	40 tons, 14.2 EER [A]	38.3 tons, 16 IEER [B]	AHRI Certification
EEM-2	RTU-2 capacity and efficiency	30 tons, 14 EER	27.5 tons, 14 IEER	AHRI Certification
EEM-3	RTU-3 capacity and efficiency	8.5 tons, 14.7 EER	8.5 tons, 13.8 IEER	AHRI Certification
EEM-4	RTU-4 capacity and efficiency	27.5 tons, 14 EER	26.7 tons, 14.2 IEER	AHRI Certification
EEM-5	RTU-5 capacity and efficiency	15 tons, 15 EER	14.5 tons, 14.6 IEER	AHRI Certification
EEM-6	RTU-6 capacity and efficiency	5 tons, 17.2 EER	6.2 tons, 14.6 IEER	AHRI Certification
EEM-7	RTU-7 capacity and efficiency	8.5 tons, 14.7 EER	8 tons, 13.8 IEER	AHRI Certification
EEM-8	RTU-8 capacity and efficiency	20 tons, 14 EER	19.5 tons, 14.2 IEER	AHRI Certification
EEM-9	RTU-9 capacity and efficiency	3 tons, 17 EER	3 tons, 13 SEER	Manufacturer specifications, SEER value assumed (not rated)
EEM 1-8	Economizer operation	Not included	Comparative enthalpy control	Assumed based on code requirements and equipment specifications

[A] Energy Efficiency Ratio (EER) in the context of unitary air-conditioner ratings means full load efficiency; however, the ex ante calculations treated the EER values as equivalent to IEER values.

[B] Integrated Energy Efficiency Ratio (IEER). Ex post calculations use IEER because IEER more accurately reflects the average efficiency of an air-conditioner over the range of outdoor air conditions experienced in a full cooling season than EER, which reflects full-load efficiency.

Results

The table below shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 43. Site 9112 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 RTU-1	16,710	18,529	111%	15.22	16.87	111%
EEM-2 RTU-2	12,106	10,210	84%	11.02	9.30	84%
EEM-3 RTU-3	2,552	1,795	70%	2.32	1.63	70%
EEM-4 RTU-4	11,097	10,238	92%	10.11	9.32	92%
EEM-5 RTU-5	5,136	4,080	79%	4.68	3.72	79%
EEM-6 RTU-6	1,326	1,609	121%	1.21	1.47	121%
EEM-7 RTU-7	2,552	1,689	66%	2.32	1.54	66%
EEM-8 RTU-8	8,071	5,014	62%	7.35	4.57	62%
EEM-9 RTU-9	767	0	0%	0.70	0.00	0%
Total	**60,317**	**53,164**	**88%**	**54.93**	**48.42**	**88%**

Reasons for Discrepancies

- The verified make and model of the installed equipment differed from the ex ante make and model. Ex post savings reflect rated capacities and efficiencies of installed equipment.
- In some cases, ex ante applied baseline efficiencies that did not align with the local energy code. Verified savings applied baseline efficiencies from IECC 2012.
- No ex post savings awarded for RTU-9 because equipment is assumed to be minimum efficiency.

Other Findings and Recommendations

- We were unable to verify zone temperature set points at the site visit; therefore, 72 °F and 50% relative humidity is assumed.
- Although not reflected in the ex ante calculations, RTU-9 included an energy recovery ventilator (ERV) according to the project application. Onsite verification concluded that no ERV was installed.

Site 9113 (Custom HVAC)

This project involves retrofitting a variable speed drive (VSD) and controls package to a 600-ton water-cooled centrifugal chiller to convert operation from constant speed to variable speed. The chiller serves two office buildings totaling 400,000 square feet. Energy savings are realized from increased part-load efficiency.

Table 44. Site 9113 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Retrofit VSD to Water-cooled Centrifugal Chiller	Cooling	256,285	233.39
	Total	**256,285**	**233.39**

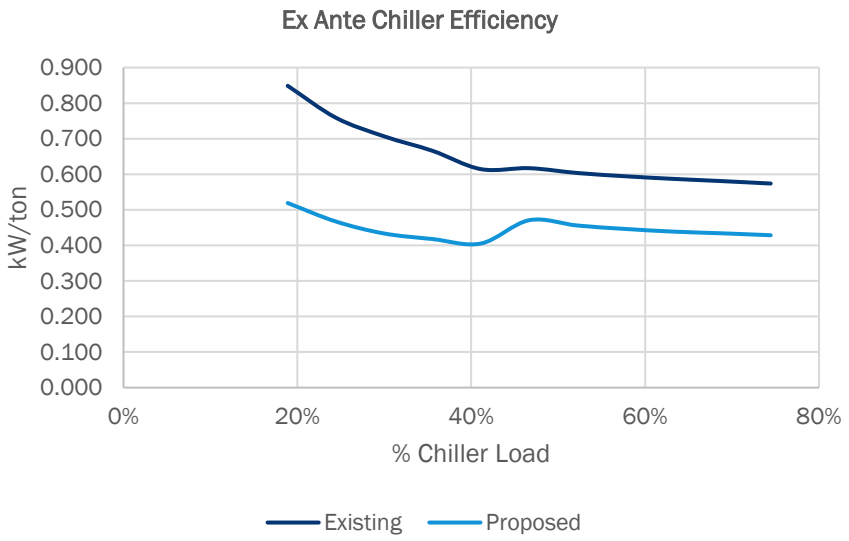
Data Collection

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 invoice confirms that one VSD and controls package was purchased and installed at the site location. Onsite review also confirmed the installation.

Analysis

The ex ante savings are predicated on unreferenced, pre- and post- chiller efficiency data as a function of chiller load, as illustrated in Figure 1. The efficiency data was included in a weather bin analysis to calculate annual energy savings. The evaluation team requested a reference for the efficiency curves from the implementer and was eventually provided manufacturer data; however, we were unable to reconcile it with the ex ante efficiency data, nor were we able to verify the ex ante data from published studies on centrifugal chillers. We further attempted to verify the energy savings through a consumption analysis, but there was not enough post-project data available for energy savings verification, nor was the facility's building automation system (BAS) set up to store trend data.

Figure 1. Ex ante existing and proposed efficiency curves



Although the efficiency data was not verified, converting a constant speed chiller serving variable HVAC loads to variable speed operation is likely to produce energy savings. Therefore, the ex post savings assumes a conservative 15% savings from baseline usage, on par with the low end of the savings range (15%–35%) asserted by the manufacturer in sales literature.

Table 45. Site 9113 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Existing chiller efficiency curve	See Figure 1	N/A	Could not verify
EEM-1	Proposed chiller efficiency curve	See Figure 1	N/A	

Results

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

Table 46. Site 9117 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Retrofit VSD to Water-cooled Centrifugal Chiller	256,285	121,010	47%	233.39	110.20	47%
Total	**256,285**	**121,010**	**47%**	**233.39**	**110.20**	**47%**

Reasons for Discrepancies

- Because the ex ante efficiency curve data could not be verified, the ex ante savings of 31% was reduced to a conservative assumption of 15%, equal to the low end of the range quoted by the manufacturer.

Other Findings and Recommendations

- Calculation workbooks used as the basis for Custom incentive offers should include references for all primary input assumptions.

Site 9114 (Custom HVAC)

This project replaced three chillers with new water-cooled centrifugal chillers with a total capacity of 3,000 tons in a central plant serving state-owned office and public assembly buildings. Energy savings are achieved by the improved efficiency of the new high-efficiency chillers compared to new equipment that only meets the minimum efficiency requirements allowed by ASHRAE 90.1-2019. In addition, the new equipment includes a water-side economizer that provides "free cooling" at outdoor air temperatures below 50°F.

Table 47. Site 9114 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Water-Cooled Centrifugal Chillers	Cooling	1,316,312	1,198.74
	Total	**1,316,312**	**1,198.74**

Data Collection

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

The Project Completion form indicates the project was completed in June 2022, and the invoice details the chiller replacement. An onsite visit was also arranged in January 2023 to verify the equipment installation and operation.

Analysis

The ex ante project savings were estimated through spreadsheet calculations using a weather bin analysis that compared the baseline and proposed equipment operation and energy consumption. The baseline part-load efficiency was assumed to be 0.5390 kW/ton, and the proposed equipment part-load efficiency was assumed to be 0.3289 kW/ton per the equipment submittal.

The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the input parameters as described in Table 48. The major changes are summarized below:

- Baseline efficiency changed from 0.5390 kW/ton to 0.5217 kW/ton based on code requirements.
- Occupied hours changed from 8,760 hours per year to 2,531 hours per year based on published building hours online.
- Water-side economizer switchover temperature changed from 45°F to 50°F based on BAS data.

Table 48. Site 9114 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Total cooling capacity	3,000 tons	3,000 tons	Submittal
EEM-1	Chiller type	Water-cooled	Water-cooled centrifugal	Project bid specifications, onsite verification
EEM-1	Applicable energy code	IECC 2009	ASHRAE 90.1-2019	Missouri 10 CSR 140-7

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline part-load efficiency (kW/ton)	0.5390	0.5217	ASHRAE 90.1-2019, adjusted for differences between design conditions and AHRI test conditions
EEM-1	Proposed part-load efficiency (kW/ton)	0.3289	0.3289	Submittal, value at design conditions
EEM-1	Occupied hours per year	8760	2531	Online building hours
EEM-1	Water-side economizer switchover temperature	45°F	50°F	BAS data captured during site visit

Results

The table below shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 49. Site 9114 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Water-Cooled Centrifugal Chillers	1,316,312	879,901	67%	1,198.74	801.31	67%
Total	**1,316,312**	**879,901**	**67%**	**1,198.74**	**801.31**	**67%**

Reasons for Discrepancies

- The primary reason for the lower verified savings is the ex ante calculations did not include unoccupied mode operation when the cooling load was lower due to temperature setups. Also, the verified baseline efficiency was slightly lower than the ex ante value.

Other Findings and Recommendations

- A cell reference error in the ex ante calculations led to the water-side economizer savings not being included.
- Ex ante savings calculations assumed IECC 2009 as the applicable energy code. Per 10 CSR 140-7, state-owned building construction and major renovations are subject to the most recent version of ASHRAE 90.1, which was ASHRAE 90.1-2019[1] for this project. Since the path for the chiller design was unknown, Path A efficiency requirements for the project chillers were assumed per TRM guidance for water-cooled chillers.
- Ex ante calculations also did not adjust chiller baseline efficiency requirements for differences in design conditions versus standard AHRI test conditions. ASHRAE 90.1 prescribes a method for doing so for water-cooled centrifugal chillers (see also IECC 2021 C403.3.2.1), which was adopted in ex post calculations.

[1] Because ASHRAE 90.1-2019 is not freely available, the evaluation team referenced IECC 2021 as a proxy. Each version of IECC adopts most of the requirements from the most recent update of 90.1.

- The installed equipment appears to qualify for an exemption from a required economizer based on its energy efficiency (see IECC 2021 C403.5). Therefore, the verified savings include savings resulting from economizer operation.
- The verified savings calculation used TMY3 weather data for Jefferson City instead of St. Louis based on project location.

Site 9115 (Custom HVAC)

This project involved the installation of a control device to modify the operation of existing RTU air conditioners. The "HVAC-CHIP" purports to cycle the compressor off for three to five minutes every half hour of runtime while the blower fan continues to run. The manufacturer's energy savings claims are based on reduced compressor usage. Table 50 describes the EEMs and ex ante gross savings claimed for this project.

Table 50. Site 9115 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC-CHIP on RTU-1	Cooling	1,736	1.58
EEM-2 HVAC-CHIP on RTU-2	Cooling	2,114	1.93
	Total	**3,850**	**3.51**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The team also collected manufacturer equipment specifications for each RTU available online. The invoice confirms that two HVAC-CHIPs have been purchased and installed at the site location.

Analysis

The ex ante project savings were estimated from a bin analysis using equipment specifications and engineering assumptions. The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- Assumed compressor motor efficiency increased from 80% to 100% because the compressor rated load amperage (RLA), used to calculate the compressor input power, already takes into account the motor efficiency
- Compressor motor runtime reduction changed from 15.0% to 13.3% based on project documentation citing a range of 3 to 5 minutes for every 30 minutes, an average of 13.3%
- RTU-1 compressor RLA increased from 13.5 to 16 in the ex post analysis based on equipment specifications
- RTU-2 condenser fan horsepower (HP) decreased from 0.375 hp to 0.25 hp based on equipment specifications
- Total cooling hours per year increased from 1,840 to 1,940 based on business hours posted online

Table 51. Site 9115 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
All	Compressor motor efficiency	80%	100%	Engineering judgement
All	Compressor runtime reduction	15%	13.3%	Project documentation
All	Total cooling hours	1,847	1,940	Bin analysis using verified business hours

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	RTU-1 compressor RLA	13.5	16	Equipment specifications
EEM-1	RTU-1 condenser fan HP	0.33	0.33	Equipment specifications
EEM-2	RTU-2 compressor RLA	17.5	17.5	Equipment specifications
EEM-2	RTU-2 condenser fan HP	0.375	0.25	Equipment specifications

Results

Table 52 shows the evaluated energy and demand savings for this project and the resulting realization rates.

Table 52. Site 9115 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC-CHIP on RTU-1	1,736	1,698	98%	1.58	1.55	98%
EEM-2 HVAC-CHIP on RTU-2	2,114	1,814	86%	1.93	1.65	86%
Total	**3,850**	**3,511**	**91%**	**3.51**	**3.20**	**91%**

Reasons for Discrepancies

- Ex ante applied 80% for the compressor motor efficiency. Verified analysis applied 100% because the motor efficiency is accounted for in the RLA. This change decreased the savings.
- Ex ante assumed that the HVAC-CHIP reduces compressor runtime by 15%. Project documentation indicated that the HVAC-CHIP would shut off the compressor fan for about 3 to 5 minutes for every 30 minutes of runtime. The evaluation team assumed that the compressor would shut off for four minutes every half hour, a reduction of 13.3%, which reduced savings.

Other Findings and Recommendations

- We recommend the implementation team seek field testing results to verify the energy savings claims of the HVAC-CHIP device and other new technologies before offering Custom incentives.
- Ex ante savings claimed for this project do not align with ex ante calculations.

Table 53. Site 9115 Discrepancies Between Ex Ante Calculations and

Measure Name	Ex Ante Calculation Files			Ex Ante Claimed Savings		
	Baseline	Proposed	Savings	Baseline	Proposed	Savings
EEM-1 HVAC-CHIP on RTU-1	10,479	8,723	1,756	10,479	8,743	1,736
EEM-2 HVAC-CHIP on RTU-2	13,464	11,208	1,756	12,614	10,500	2,114
Total	**23,943**	**19,931**	**3,512**	**23,093**	**19,243**	**3,850**

Site 9116 (Custom HVAC)

This project involved the installation of a control device to modify the operation of existing RTU air-conditioners. The "HVAC-CHIP" purports to cycle off the compressor for 3 to 5 minutes for every 30 minutes of runtime while the blower fan continues to run. The manufacturer's energy savings claims are based on reduced compressor usage. Table 54 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 54. Site 9116 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC-CHIP on RTU-1	Cooling	1,204	1.10
EEM-2 HVAC-CHIP on RTU-2	Cooling	1,982	1.80
	Total	**3,186**	**2.90**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The evaluation team also collected manufacturer equipment specifications for each RTU available online.

The evaluation team also reached out to the customer representative to arrange an onsite visit to verify the installation. While the onsite was not ultimately scheduled, the customer representative volunteered that the installation was not actually performed on RTU-2.

Analysis

The ex ante project savings were estimated from a bin analysis using equipment specifications and engineering assumptions. The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- Assumed compressor motor efficiency increased from 80% to 100% because the compressor rated load amperage (RLA), used to calculate the compressor input power, already takes into account the motor efficiency
- Compressor motor runtime reduction changed from 17% to 13.3% based on project documentation citing a range of 3--5 minutes every 30 minutes, an average of 13.3%
- RTU-1 compressor RLA decreased from 26.8 to 16 in the ex post analysis based on equipment specifications
- RTU-1 condenser fan horsepower (hp) decreased from 0.296 to 0.25 based on equipment specifications
- Total cooling hours per year increased from 1,847 to 1,940 based on business hours posted online

Table 55. Site 9116 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Compressor motor efficiency	90%	100%	Engineering judgement
EEM-1	Compressor runtime reduction	17%	13.3%	Project documentation
EEM-1	Total cooling hours	1847	1940	Bin analysis using verified business hours
EEM-1	RTU-1 compressor RLA	26.8	16	Equipment specifications
EEM-1	RTU-1 condenser fan hp	0.296	0.25	RTU-1 Specifications

Results

Table 56 shows the evaluated energy and demand savings for this project and the resulting realization rates.

Table 56. Site 9116 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC-CHIP on RTU-1	1,204	959	80%	1.10	0.87	80%
EEM-2 HVAC-CHIP on RTU-2	1,982	0	0%	1.80	0.00	0%
Total	**3,186**	**959**	**30%**	**2.90**	**0.87**	**30%**

Reasons for Discrepancies

- The primary driver of the low realization rate is the lack of installation on RTU-2.
- Ex ante RTU-1 compressor RLA reduced from 26.8 to 16 in the ex post analysis, which decreased savings
- Ex ante applied 90% for the compressor motor efficiency. Verified analysis applied 100% because the motor efficiency is accounted for in the RLA. This change decreased the savings.
- Ex ante assumed that the HVAC-CHIP reduces compressor runtime by 17%. Project documentation indicated that the HVAC-CHIP would shut off the compressor fan for about 3 to 5 minutes for every 30 minutes of runtime. The evaluation team assumed the compressor would shut off for four minutes every half hour, a reduction of 13.3%, which reduced savings.

Other Findings and Recommendations

- We recommend the implementation team seek field testing results to verify the energy savings claims of the HVAC-CHIP device and other new technologies before offering Custom incentives.

Site 9117 (Custom HVAC)

This project involves the installation of five air-handling units (AHUs) with enthalpy comparison economizer controls. Two of the AHUs were verified to have hydronic cooling coils, and the remaining three were verified to have direct expansion (DX) coils. The assumed baseline is identical equipment except with dry bulb economizer control per IECC 2012. Energy savings result because there are more economizer hours annually with the enthalpy control than dry bulb control. Table 57 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 57. Site 9117 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Enthalpy Comparison Economizer Controls	HVAC	123,870	55.00
	Total	**123,870**	**55.00**

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 sequence of operations included in the mechanical equipment drawings within the project files indicated that enthalpy comparison economizer controls were to be installed. To verify installation, the evaluation team contacted the customer in December 2022. The facility manager provided BAS screenshots indicating that the necessary control points were installed and requested, and received confirmation from the engineer who programmed the controls.

Analysis

The ex ante project savings were estimated through spreadsheet calculations using a weather bin analysis, comparing baseline and proposed equipment operation and energy consumption. An average IEER cooling efficiency was calculated for the AHUs and used in the weather bin analysis.

The ex post analysis reviewed and adopted the ex ante savings calculation methods, but updated the following parameters:

- Average cooling efficiency (IEER) changed from 19.11 to 17.43 based on equipment specifications
- Used TMY3 weather data from Kansas City instead of St. Louis (project location closer to the former)

Table 58. Site 9117 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline economizer control	Dry bulb temperature	Dry bulb temperature	2012 IECC
EEM-1	Efficient economizer control	Enthalpy comparison	Enthalpy comparison	Customer, mechanical drawings
EEM-1	AHU average IEER	19.11	17.43	Equipment specifications
EEM-1	Baseline annual economizing hours (dry bulb control)	1206	1217	Bin analysis, TMY3 weather data

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Efficient annual economizing hours (enthalpy control)	2641	2764	Bin analysis, TMY3 weather data

Results

Table 59 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 59. Site 9117 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Enthalpy Comparison Economizer Controls	123,870	145,494	117%	55.00	64.60	117%
Total	**123,870**	**145,494**	**117%**	**55.00**	**64.60**	**117%**

Reasons for Discrepancies

- The ex ante calculation erroneously applied the chiller efficiency to three of the five AHUs. The evaluation found that these AHUs are actually DX units and used the AHRI-rated IEERs, which resulted in a lower average IEER and higher ex post savings.

Other Findings and Recommendations

- N/A

Site 9118 (Custom HVAC)

At Site 9118, one of three chillers was replaced with a higher-efficiency, 500-ton water-cooled centrifugal chiller with variable-frequency drive (VFD). The project type was designated "New/Replace Failed Equipment," a designation that requires the new efficient equipment to be compared against a code-minimum baseline setup. The ex post savings evaluation used a constant speed, water-cooled centrifugal chiller to meet the minimum efficiency requirements under International Energy Conservation Code (IECC) 2018, the code version adopted in the local jurisdiction.

Table 60. Site 9118 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Chiller	Cooling	411,375	374.63
	Total	**411,375**	**374.63**

Data Collection

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

Analysis

The ex ante project savings evaluation uses energy modeling results for the existing and proposed chiller plant configuration produced by the vendor. Weather bin analyses were included for individual chillers under baseline and proposed conditions. All energy savings documentation is in PDF format, so the underlying calculations are not accessible.

The evaluation team reviewed the baseline efficiency assumptions and found the full load value (FLV) in agreement with the minimum requirement for a 500-ton water-cooled centrifugal chiller under Path A in IECC 2018. The baseline and efficient equipment part-load efficiency data are reasonable with respect to expected performance for constant speed and variable speed centrifugal chillers.

The evaluation team developed a bin analysis to verify the ex ante savings using the ex ante load curve and part-load efficiency data and found close agreement (within 10%) with the vendor's energy savings result. Since the reasons for the discrepancy were not clear and the vendor's energy modeling software is assumed to be more accurate than a bin analysis, the vendor's energy savings result was accepted for ex post savings.

Table 61. Site 9118 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Chiller type	Water-cooled	Water-cooled centrifugal	Submittal
EEM-1	Cooling capacity (tons)	500	500	Submittal
EEM-1	Baseline chiller FLV (kW/ton)	0.560	0.560	IECC 2018 Path A
EEM-1	Efficient chiller FLV (kW/ton)	0.560	0.560	Submittal
EEM-1	Baseline chiller part-load efficiency data	Vendor-provided	Vendor-provided	

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Efficient chiller part-load efficiency data	Vendor-provided	Vendor-provided	
EEM-1	Chiller plant cooling load curve	Vendor-provided	Vendor-provided	
EEM-1	Hours of operation	8710	8760	Ex ante modeling

Results

Table 62 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 62. Site 9118 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Chiller	411,375	411,375	100%	374.63	374.63	100%
Total	**411,375**	**411,375**	**100%**	**374.63**	**374.63**	**100%**

Reasons for Discrepancies

- The ex post bin analysis found slightly fewer total hours (8,710) than the ex ante analysis (8,760).

Other Findings and Recommendations

- The ex ante energy modeling information for this project was difficult to sort out and did not meet generally accepted quality controls standards for custom energy efficiency projects.

Site 9119 (Custom HVAC)

This project included the conversion of two single zone constant volume AHUs to multi-zone variable air volume (VAV) control plus a building automation system (BAS) installation in an office building. Each AHU serves one floor of the building. Prior to this project, each AHU was controlled by a single thermostat and was not scheduled. With the BAS, multiple control measures were implemented including AHU scheduling, a discharge air temperature (DAT) reset, a static pressure (SP) reset, and an economizing mode.

Table 63. Site 9119 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Controls - Fan Energy Savings	HVAC	39,414	17.50
EEM-2 HVAC Controls - Cooling Energy Savings	Cooling	16,459	14.99
	Total	**55,873**	**32.49**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The project files included trend data from the BAS, which the evaluation team used to verify some of the baseline and proposed control settings.

Analysis

The ex ante project savings were estimated through spreadsheet calculations using a weather bin analysis comparing baseline and proposed equipment operation and energy consumption. The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameter:

- Changed occupied hours to 6:00 a.m.–5:00 p.m., Monday through Friday

Table 64. Site 9119 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
All	AHU-1,2 baseline occupied hours	24/7	24/7	Ex ante calculations
All	AHU-1,2 proposed occupied hours	5:00 a.m.–6:00 p.m., Monday–Friday	6:00 a.m.–5:00 p.m., Monday–Friday	Trend data
All	AHU-1 baseline max SF speed	90%	80%	Trend data
All	AHU-1 proposed max SF speed	90%	80%	Trend data
All	AHU-2 baseline max SF speed	100%	100%	Ex ante calculations
All	AHU-2 proposed max SF speed	100%	100%	Trend data, ex ante calculations
All	AHU-1,2 baseline DAT setpoint (F)	55	55	Ex ante calculations
All	AHU-1,2 proposed DAT setpoint (f)	Reset schedule, 55-65	Reset schedule, 55-65	Ex ante calculations
All	AHU-1,2 baseline SP setpoint	Constant	Constant	Ex ante calculations

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
All	AHU-1,2 proposed SP setpoint	Reset schedule	Reset schedule	Trend data, ex ante calculations
All	AHU-1,2 baseline economizer	None	None	Ex ante calculations
All	AHU-1,2 proposed economizer	Economizer, dry bulb	Economizer, dry bulb	Ex ante calculations

Results

Table 65 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 65. Site 9119 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Controls - Fan Energy Savings	39,414	35,766	91%	17.50	15.88	91%
EEM-2 HVAC Controls - Cooling Energy Savings	16,459	16,701	101%	14.99	15.21	101%
Total	**55,873**	**52,467**	**94%**	**32.49**	**31.09**	**96%**

Reasons for Discrepancies

- The ex ante calculations state the non-winter, maximum VFD speed for AHU-1 is 90%; however, the trend data show it is actually 80%. The latter value is used in the ex post calculations for the baseline and proposed conditions.
- The BAS trend data shows 15% lower annual occupied hours than the ex ante assumption. This reduction in occupied hours from the 24/7 baseline assumption leads to greater savings, offsetting the savings reduction due to the lower VFD speed for AHU-1.

Other Findings and Recommendations

- N/A

Site 9120 (Custom HVAC)

This project involved the installation of high efficiency water source heat pumps (WSHPs) in a government building with electric heat. Savings are achieved in relation to a baseline of 2015 IECC minimum efficiency WSHPs.

Table 66 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 66. Site 9120 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Phase 1 WSHP replacements	HVAC	6,362	2.82
	Total	**6,362**	**2.82**

Data Collection

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

Analysis

The ex ante project savings were estimated through spreadsheet calculations using a weather bin analysis comparing baseline and proposed equipment operation and energy consumption. The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- Baseline EER adjusted from 13 to 11.81 to reflect design conditions
- Proposed IEER adjusted from 14.81 to 15.52 to reflect design conditions
- Cooling oversize factor of 115% assumed
- Baseline COP adjusted from 3.7 to 4.05 to reflect design conditions
- Coincident factor changed from deemed HVAC value to deemed Cooling value, with kW savings calculated from cooling kWh savings rather than total kWh savings, in accordance with the TRM.

Table 67. Site 9120 Key Parameters for Ex Ante and Ex Post Savings

Key Parameter	Ex Ante	Ex Post	Source
Baseline EER	13	11.81	IECC 2015, adjusted for design conditions
Proposed EER	14.81	15.52	Spec sheet, design conditions
Cooling Capacity (Btu/h)	144,700	144,700	Spec sheet
Cooling Oversize Factor	100%	115%	ASHRAE 90.1 Appendix G
Baseline COP	3.7	4.05	IECC 2015, adjusted for design conditions
Proposed COP	4.67	4.67	Spec sheet, design conditions
Heating Capacity (Btu/h)	171,855	171,855	Spec sheet
Operating Hours	8760	8760	24/7 operation

Key Parameter	Ex Ante	Ex Post	Source
Coincidence Factor	0.000443983 (HVAC)	0.000910684 (Cooling)	Ameren Missouri TRM

Results

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

Table 68. Site 9120 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Phase 1 WSHP Replacements	6,362	8,046	126%	2.82	5.69	202%
Total	**6,362**	**8,046**	**126%**	**2.82**	**5.69**	**202%**

Reasons for Discrepancies

- Ex ante calculations apply proposed EER and COP at AHRI rating conditions. Ex post analysis apply proposed EER and COP at design conditions, which resulted in an increase in energy savings. This was the primary driver of the realization rate.
- Ex ante savings apply a cooling oversizing factor of 100%. Verified savings account for oversizing cooling units with an oversize factor of 115%, which decreases energy savings.
- Ex ante applies baseline COPs that do not align with the energy code corresponding with the county of the site, IECC 2015. Verified savings apply baseline efficiencies that align with IECC 2015 and adjusts them for design conditions. The result decreases heating savings.
- To calculate demand savings, ex ante multiplies total kWh savings by an HVAC coincidence factor. Verified savings multiply the cooling kWh savings by the Cooling Coincidence Factor, which results in increased demand savings.

Site 9121 (Custom HVAC)

This project includes the installation of six new rooftop units (RTU) with Carrier's Humidi-MiZe(R) adaptive dehumidification system and demand-controlled ventilation (DCV). The RTUs and DCV received Standard rebates, whereas the dehumidification system qualified for a Custom rebate. The Humidi-MiZe(R) system is a variation of hot gas reheat in which hot refrigerant gas from compressor discharge is blended with warm liquid refrigerant from the condenser and routed through a reheat coil installed behind the evaporator coil. Dehumidification is accomplished by cooling the incoming air to its dewpoint and reheating it to the required supply temperature. The ex ante savings are based on the use of hot refrigerant to reheat the air leaving the evaporator coil instead of the baseline assumption of electric heating elements. Table 69 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 69. Site 9121 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Hot Gas Reheat	HVAC	18,722	17.05
	Total	**18,722**	**17.05**

Data Collection

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

The final application and RTU performance summary included within the project files indicated that a dehumidification system was installed. To verify key details of the installation including RTU make and model, occupancy schedule, and dehumidification settings, the evaluation team contacted the customer in December 2022. The project engineer provided nameplate photos and BAS screenshots showing the requested information.

Analysis

The ex ante project savings were estimated through spreadsheet calculations using a bin analysis with typical meteorological year, third generation (TMY3) weather data, comparing baseline and proposed equipment operation and energy consumption.

The ex post analysis reviewed and adopted the ex ante savings calculation methods, but updated the following parameters:

- The occupancy schedule changed from 6 a.m.–6 p.m. seven days a week to 5 a.m.–8 p.m. Monday–Friday based on BAS screenshots and customer verification.
- The change in occupancy schedule caused the hours in dehumidification mode to decrease from 374 to 240 hours per year.

Table 70. Site 9121 Key Parameters for Ex Ante and Ex Post Savings

Key Parameter	Ex Ante	Ex Post	Ex Post Source
Reheating load (BTU per year)	170,888	170,888	Calculated from equipment parameters and standard HVAC assumptions
Hours per year in dehumidification mode	374	240	Determined from weather bin analysis with verified occupancy schedule

Results

Table 71 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 71. Site 9121 Evaluation Savings Results

Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Hot Gas Reheat	18,722	11,999	64%	17.05	10.93	64%
Total	**18,722**	**11,999**	**64%**	**17.05**	**10.93**	**64%**

Reasons for Discrepancies

- The evaluation team used the same bin analysis savings calculation method as the ex ante calculations but developed a new bin hours profile using TMY3 weather data and the actual occupied schedule for the RTUs. The evaluation team calculated outdoor dewpoint temperatures using psychometric data and standard equations from the 2017 ASHRAE Handbook - Fundamentals. The resulting ex post hours in dehumidification mode were approximately 240 versus the ex ante value of 374. This result accounts for the realization rate of 64 percent.

Other Findings and Recommendations

- The evaluation team investigated whether electric reheat was a valid baseline assumption. The validity was confirmed by the project engineer, who stated that electric reheat was an option with the selected equipment. The evaluation team also noted the equipment engineering manual lists electric accessory heaters as a field-installed option; therefore, electric reheat was accepted as a valid baseline assumption.

Site 9122 (Custom HVAC)

This project installed multiple HVAC system improvements at a university building with natural gas heat. The energy efficiency measures include an air-cooled variable refrigerant flow (VRF) system with four outdoor units. The baseline system is the same system design but uses the least efficient equipment allowed under the federal standards for air-cooled VRF multi-split heat pumps, 10 CFR 431.97. The proposed system exceeds the minimum energy efficiency requirements allowed per the federal standard, which will achieve energy savings. There are no requirements specific to VRF systems in IECC 2012, the default building energy code for the project location. Table 72 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 72. Site 9122 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 VRF System	Cooling	98,055	89.30
	Total	**98,055**	**89.30**

Data Collection

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

The invoices and equipment specification sheets included within the project files indicated the air-cooled VRF system was installed. To verify site occupancy hours, the evaluation team attempted to contact the customer in December 2022 and January 2023, but the customer could not be reached. In absence of customer confirmation, the evaluation team found the building's business hours online.

Analysis

The implementation team estimated project savings through spreadsheet calculations using a weather bin analysis, which compared baseline and proposed equipment operation and energy consumption. An average IEER cooling efficiency was calculated for the VRF system and used in the weather bin analysis.

The evaluation team analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- Average baseline cooling efficiency (IEER) changed from 9.71 to 9.81 based on equipment specifications and federal standards
- Average new cooling efficiency (IEER) changed from 18.44 to 17.92 based on equipment specifications
- Occupancy hours changed from 5 a.m.–6 p.m., Monday through Friday, and 8 a.m.–6 p.m., Saturday and Sunday, to 5 a.m.–12 a.m., Monday through Friday, and 8 a.m.–12 a.m., Saturday and Sunday, based on the building operation schedule
- Used TMY3 weather data from Kirksville instead of Saint Louis (the project location is closer to the former)

Table 73. Site 9122 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline average IEER	9.71	9.81	Equipment specifications, Federal standards
EEM-1	Efficient average IEER	18.44	17.92	Equipment specifications
EEM-1	Cooling capacity (tons)	88.21	88.21	Equipment specifications
EEM-1	Cooling oversize factor	100%	115%	ASHRAE 90.1 Appendix G
EEM-1	Annual operating hours	4,424	6,979	Bin analysis, TMY3 weather data

Results

Table 74 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 74. Site 9122 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 VRF System	98,055	77,875	79%	89.30	70.92	79%
Total	**98,055**	**77,875**	**79%**	**89.30**	**70.92**	**79%**

Reasons for Discrepancies

- The implementation team's calculation assumes no oversizing. The ex post analysis assumes an 115% oversizing factor consistent with ASHRAE 90.1 Appendix G, which decreases savings.
- The verified analysis corrects some proposed equipment efficiencies per the spec sheets, which decreases the average efficiency.
- The verified analysis uses slightly higher baseline efficiencies per the minimum requirements for VRF multi-split heat pumps in 10 CF 431.97.
- These impacts are partially offset by an increase in occupied hours in the verified analysis based on the building's business hours posted online in January 2022.

Other Findings and Recommendations

- Verified analysis uses bin hours for the geographically closer weather station.

Site 9123 (Custom HVAC)

This project involved the installation of new HVAC equipment and a building automation system (BAS), plus implementation of controls measures including scheduling, constant volume (CV) to variable air volume (VAV) conversion, static pressure reset, and economizer adjustments. Demand-controlled ventilation was also implemented but qualified for a Standard incentive. Only the Custom control measures are included in this evaluation. Energy savings are generated by optimizing equipment operation relative to existing operation.

Table 75. Site 9123 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Control Measures - Fan Energy Savings	HVAC	340,752	151.29
EEM-2 HVAC Control Measures - Cooling Energy Savings	Cooling	48,583	44.24
	Total	**389,335**	**195.53**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The information reviewed spanned ex ante calculation workbooks, BAS trend data, mechanical plans, and project invoices.

Analysis

The ex ante project savings are estimated through bin analyses. Numerous discrepancies were identified between the ex ante calculations and mechanical plans with regard to key equipment parameters such as outdoor airflow, supply airflow, and fan horsepower listed in Table 76. Furthermore, the equipment identification in the calculation workbook often did not match the filename. We noted the discrepancies to the implementer, who confirmed that the correct files had been uploaded to the project tracking system. The ex post analysis reviewed and adopted the ex ante calculation workbooks but changed key parameters to align with the mechanical plans, as noted.

Table 76. Site 9123 Key Parameter Discrepancies for Ex Ante and Ex Post Savings

Equip. ID	Key Parameter	Ex Ante	Ex Post	Ex Post Source
RTU-1	Outdoor airflow (CFM)	140	320	Rooftop AHU schedule
RTU-3	Outdoor airflow (CFM)	140	320	Rooftop AHU schedule
RTU-5	Outdoor airflow (CFM)	674	850	Rooftop AHU schedule
RTU-6	Outdoor airflow (CFM)	221	145	Rooftop AHU schedule
RTU-6	Supply airflow (CFM)	2,205	2,000	Rooftop AHU schedule
RTU-6	Supply fan horsepower	3	2	Rooftop AHU schedule
RTU-7	Outdoor airflow (CFM)	221	350	Rooftop AHU schedule
RTU-8	Outdoor airflow (CFM)	380	1,400	Rooftop AHU schedule
RTU-8	Supply airflow (CFM)	3,800	4,545	Rooftop AHU schedule
RTU-9	Outdoor airflow (CFM)	380	1,000	Rooftop AHU schedule

Equip. ID	Key Parameter	Ex Ante	Ex Post	Ex Post Source
RTU-10	Outdoor airflow (CFM)	420	220	Rooftop AHU schedule
RTU-10	Supply airflow (CFM)	3,200	1,815	Rooftop AHU schedule
RTU-10	Supply fan horsepower	7.5	2	Rooftop AHU schedule
RTU-11	Outdoor airflow (CFM)	420	500	Rooftop AHU schedule
RTU-12	Outdoor airflow (CFM)	420	500	Rooftop AHU schedule
RTU-13-17	Outdoor airflow (CFM)	80	0	Rooftop AHU schedule
RTU-18	Outdoor airflow (CFM)	120	0	Rooftop AHU schedule
RTU-18	Supply airflow (CFM)	1,200	800	Rooftop AHU schedule
RTU-19	Outdoor airflow (CFM)	120	275	Rooftop AHU schedule
DOAS-20	Supply, outdoor airflow (CFM)	4,300	5,500	Dedicated outside AHU schedule
DOAS-22	Exhaust fan hp	3	2	Dedicated outside AHU schedule

Results

Table 77 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 77. Site 9123 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Control Measures - Fan Energy Savings	340,752	340,752	100%	151.29	151.29	100%
EEM-2 HVAC Control Measures - Cooling Energy Savings	48,583	48,583	100%	44.24	44.24	100%
Total	**389,335**	**389,335**	**100%**	**195.53**	**195.53**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- The sum of the ex ante savings calculations does not match the ex ante savings.
- Of 23 ex ante calculation workbooks that could be verified from the mechanical plans, 19 have discrepancies with respect to equipment parameters as defined in the mechanical plans. The evaluation team recalculated the savings using parameters from the mechanical plans and determined realization rates of 106% and 109% for kWh savings and kW savings, respectively. However, because some equipment could not be verified from the mechanical plans, the evaluation team is not confident that the inputs are correct in the corresponding workbooks given the numerous discrepancies described above. Therefore, ex post kWh and kW realization rates were reduced to 100%.

Site 9124 (Custom HVAC)

A hospital totaling 240,000 square feet made major upgrades to their chiller plant and system. The existing system contained the following components:

- (1) 400-ton centrifugal chiller with a compressor VFD and (1) 350-ton screw chiller
  - Both chillers operate at constant flow and need to run simultaneously to meet cooling loads
  - Only (1) chiller is needed in the winter months
- (2) cooling towers with 30hp motors with VFDs serve the chillers
- (2) 20 hp chilled water pumps, which operate at constant flow
- (2) 25 hp condenser water pumps, which also operate at constant flow. Both chilled water pumps and condenser water pumps must operate when both chillers are operating
- (6) secondary constant volume chilled water pumps, which serve multiple AHUs
  - These pumps are being removed in the new system

The hospital installed (1) 750-ton centrifugal chiller with VFD in addition to the (2) existing chillers, for a total cooling capacity of 1,500 tons. The new chiller is the lead chiller accompanied by one other chiller; the third chiller is the lag. The (2) existing cooling towers were replaced with (3) 50hp VFD-controlled cooling towers; (3) new 60hp chilled water pumps with VFDs replaced the (2) existing primary pumps, and (3) new 60hp condenser pumps replaced the (2) existing pumps. The new chilled water and condenser pumps operate with (2) pumps running simultaneously as the lead and the third acting as the lag. In addition, chilled water reset controls were installed to replace the existing fixed temperature control.

The new chillers and controls were qualified for Custom incentives and are the subject of this desk review. The pump and fan VFDs also qualified for Custom incentives but are not included in this review.

The new chiller configuration is more energy efficient than the old system. The chilled water reset control saves energy by increasing the chilled water supply temperature setpoint during non-summer months when the demand for cooling is lower, thus reducing the chiller cooling load.

Table 78. Site 9124 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Chillers	HVAC	390,322	355.46
EEM-2 Chilled Water Controls	HVAC	68,911	62.76
	Total	**459,233**	**418.22**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the eQuest building energy modeling (BEM) input and report files, to determine the baseline and proposed equipment and conditions, and to understand the basis for estimated energy savings.

Analysis

The evaluation team reproduced the building energy model (BEM) analysis and verified the baseline and proposed equipment and conditions. The ex post analysis reviewed and adopted the ex ante modeling parameters but updated the following input data: weather data updated from older TMY2 to TMY3 data.

Table 79. Site 9124 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Chiller 1 (existing) capacity, control, efficiency	350 tons, CV 0.646 kW/ton	350 tons, CV, 0.646 kW/ton	Modeling inputs, Energy Study. Chiller ratings adjusted for design conditions in simulation.
EEM-1	Chiller 2 (existing) capacity, control, efficiency	400 tons, VFD, 0.627 kW/ton	400 tons, VFD, 0.627 kW/ton	Modeling inputs, Energy Study. Chiller ratings adjusted for design conditions in simulation.
EEM-1	Chiller 3 (new) capacity, control, efficiency	750 tons, VFD, 0.569 kW/ton	750 tons, VFD, 0.569 kW/ton	Modeling inputs, equipment specifications. Chiller ratings adjusted for design conditions in simulation.
EEM-2	Chiller 3 CHW temperature reset (°F)	44 (fixed)	44-48 based on OAT 95-65	Modeling inputs, Energy Study

Results

Table 80 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 80. Site 9124 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Chillers	390,322	378,483	97%	355.46	344.68	97%
EEM-2 Chilled Water Controls	68,911	51,666	75%	62.76	47.05	75%
Total	**459,233**	**430,149**	**94%**	**418.22**	**391.73**	**94%**

Reasons for Discrepancies

- The ex ante simulations used older TMY2 weather data instead of TMY3.

Other Findings and Recommendations

- eQuest only allows modeling of (2) chillers per building, but the proposed building scenario has (3) chillers. The implementer chose to model the new 750-ton chiller and the 350-ton existing chiller, because only two chillers will operate at a given time. However, they chose the smaller of the two existing chillers. Alternatively, they could have used the average of the existing chillers specifications, or the more efficient chiller, because the building operator would likely make the same decision for maximum efficiency. Evaluation tested to see the impact of using the 400-ton chiller, with results

decreasing savings. Since it is the decision of the energy manager to select the most efficient HVAC setup, evaluation accepted the use of the 350-ton chiller in the ex post calculations.

Site 9126 (Custom HVAC)

This project encompassed high efficiency split system air-conditioners and heat pumps, a rooftop unit, and a dedicated outdoor air system (DOAS) installed in a new multifamily building for transplant recipients. The building has gas heating. The equipment is more energy efficient than required by the energy code adopted by the local jurisdiction, IECC 2018.

Table 81. Site 9126 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 HVAC Equipment	Cooling	34,342	31.27
	Total	34,342	31.27

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The installed equipment makes, models, and performance data were corroborated through the construction plans and submittals included with the project files.

Analysis

The ex ante project savings were estimated through spreadsheet calculations using a weather bin analysis comparing baseline and proposed equipment operation and energy consumption. The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- Total cooling capacity changed from 74.9 tons to 74.2 tons based on submittal data
- An assumed oversize factor of 115% was applied
- Heat pump baseline efficiency changed from 13 to 14 SEER based on IECC 2018 requirements

Table 82. Site 9126 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Total cooling capacity (tons)	74.9	74.2	Submittals, net cooling capacity (RTUs and DOAS) and rated cooling capacity (other equipment)
EEM-1	Oversizing factor	100%	115%	ASHRAE 90.1 Appendix G
EEM-1	Average baseline and proposed efficiency	12.8/15.9	13.3/15.9	IECC 2018, submittals
EEM-1	Annual occupied hours	8,760	8,760	Ex ante assumption

Results

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

Table 83. Site 9126 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 HVAC Equipment	34,342	23,141	67%	31.27	21.07	67%
Total	**34,342**	**23,141**	**67%**	**31.27**	**21.07**	**67%**

Reasons for Discrepancies

- Ex ante calculations assume a baseline of SEER 13 for 23 heat pump units. According to IECC 2018, these units have a minimum requirement of SEER 14. This reduces the overall energy and demand savings.
- Ex post assumes a 115% oversizing factor in alignment with ASHRAE 90.1 Appendix G. Ex post also uses the net cooling capacity of the RTUs and DOAS as well as the rated capacity of the split systems, which differ slightly from the ex ante capacities. These differences in net capacity reduce energy and demand savings.

Other Findings and Recommendations

- The project application lists the baseline and proposed tons of cooling as 77; however, the ex ante calculations actually use 75 tons.

Site 9128 (Custom HVAC)

This project is a new construction project. The project involved the construction of a two-story 70,000 square-foot hospital. The Custom measures evaluated here include two (2) 150-ton RTUs with DX cooling and gas heating. The RTUs have VAV control, though the zones are a mix of variable volume and constant volume. The terminal boxes have electric reheat. Although the application designated IECC 2015 as a baseline, the local jurisdiction has adopted IECC 2009. The as-designed HVAC system uses less cooling, reheat, and fan energy than a baseline system meeting minimum code requirements including constant volume zones where VAV is not required by code and minimum efficiency RTUs.

Table 84. Site 9128 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 (2) 150 Ton RTUs	HVAC	1,065,299	472.97
	Total	**1,065,299**	**472.97**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. Customer invoices documented the purchase of two 150-ton RTUs for the facility, and mechanical plans provided details on the RTUs and terminal boxes.

Analysis

The ex ante project savings were estimated through BEM using Trane TRACE® 3D Plus. The ex post analysis reviewed and adopted the ex ante modeling with the following changes:

- In the ex ante baseline design, both RTUs were set up as CV systems. However, most zones were required to be VAV under IECC 2009. These zones were changed to VAV in the ex post baseline model.
- In the ex ante efficient design, both RTUs were set up as VAV systems. However, some zones are actually CV according to the mechanical plans. Therefore, these zones were changed to CV in the ex post efficient design.
- The ex ante baseline and efficient designs did not include economizers. However, the mechanical plans indicated that both RTUs include economizers. Since economizers are required for the RTUs under IECC 2009, economizers were added in the ex post baseline and efficient designs.
- The ex post energy modeling used TMY3 weather data from Cape Girardeau instead of Saint Louis (the project location is closer to the former).

Table 85. Site 9128 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	RTU-1,2 baseline EER	9.5	9.5	IECC 2009
EEM-1	RTU-1,2 efficient EER	10	10	RTU submittal

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline supply air control	CV	VAV except exempt zones and as-designed CV zones	IECC 2009, mechanical plans
EEM-1	Efficient supply air control	VAV	VAV except as-designed CV zones	Mechanical plans
EEM-1	Reheat type	Electric	Electric	Mechanical plans

Results

Table 86 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 86. Site 9128 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 (2) 150-ton RTUs	1,065,299	151,190	14%	472.97	67.13	14%
Total	**1,065,299**	**151,190**	**14%**	**472.97**	**67.13**	**14%**

Reasons for Discrepancies

- The ex ante modeling designated all zones in the baseline design as CV and all zones in the efficient design as VAV. However, IECC 2009 503.4.5 requires supply air systems serving multiple zones to be VAV systems, with certain exceptions including zones with a peak supply airflow of 300 cfm or less and where the flow rate is less than 10% of the total fan system supply airflow rate. The ex post modeling, therefore, modified the baseline design to switch zones that do not qualify for this exception to VAV. In addition, zones that are CV in the mechanical plans were changed to CV in the efficient design (they were already CV in the baseline design). Collectively, the zone changes accounted for the majority of the savings discrepancy by reducing the cooling, fan, and reheat energy savings.
- The ex ante models did not include economizers, which are in the mechanical plans. Economizers are required by IECC 2009 503.4.1 for each RTU so were added to both baseline and efficient designs in the ex post analysis. This change further decreased the cooling savings.
- Ex post analysis weather data changed to Cape Girardeau, slightly increasing total savings.

Other Findings and Recommendations

- We were unable to precisely recreate the ex ante savings: rerun of the simulation file resulted in 10% more savings than claimed.

Site 9129 (Custom HVAC)

This large new construction project included efficient rooftop units (RTU), a variable refrigerant flow (VRF) system, and heat pump split systems. The installed RTUs and heat pumps exceed the minimum efficiency requirements in IECC 2018, the energy code adopted by the local jurisdiction. In addition, the VRF equipment exceeds the minimum requirements in the federal standards for VRF systems in 10 CFR 431.97.

Table 87. Site 9129 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 RTUs and Make-up Air Unit (MAU)	Cooling	2,022,424	1,841.79
EEM-2 VRF System	Cooling	376,994	343.32
EEM-3 Heat Pump Split Systems	Cooling	70,280	64.00
	Total	**2,469,698**	**2,249.11**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope and the basis for estimated energy savings. This included a review of the project baseline and proposed conditions. The evaluation team also arranged for an onsite visit to verify a sample of the installed equipment.

Analysis

The ex ante project savings were estimated through spreadsheet calculations using a weather bin analysis that compared baseline and proposed equipment operation and energy consumption.

The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- Total capacity of RTUs and the MAU reduced from 3,788 tons to 275 tons based on equipment submittals and onsite verification
- Average baseline and proposed IEER of RTUs and the MAU changed from 11.0/13.9 to 11.3/14.3 respectively based on equipment submittals
- Total capacity of the VRF system reduced from 220 tons to 211 tons based on AHRI-certified equipment ratings
- Average baseline and proposed IEER of VRF equipment changed from 9.91/23.39 to 9.94/22.3 based on AHRI-certified equipment ratings and minimum efficiency requirements in 10 CFR 431.97
- Total cooling hours reduced from 5,441 hours per year to 2,685 hours per year in alignment with the deemed commercial and industrial average effective full load hours (EFLH) value of 1,053

Table 88. Site 9129 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	RTU and MAU total capacity (tons)	3788	275	Submittal information in ex ante calculations, verified from model numbers
EEM-1	RTU and MAU average baseline/proposed IEER	11.0/13.9	11.3/14.3	Submittal information in ex ante calculations
EEM-2	VRF system total capacity (tons)	220	211	AHRI certificates
EEM-2	VRF average baseline/proposed IEER	9.91/23.39	9.94/22.3	AHRI certificates, 10 CFR 431.97
EEM-3	Heat pump total capacity (tons)	147	147	Submittals
EEM-3	Heat pump average baseline/proposed IEER	14.0/18.1	14.0/18.1	Submittals
All	Total cooling hours	5,441	2,685	Bin analysis, equivalent to 1,053 EFLH

Results

Table 89 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 89. Site 9129 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 RTUs and MAU	2,022,424	61,397	3%	1,841.79	55.91	3%
EEM-2 VRF System	376,994	149,187	40%	343.32	135.86	40%
EEM-3 Heat Pump Split Systems	70,280	30,155	43%	64.00	27.46	43%
Total	**2,469,698**	**240,739**	**10%**	**2,249.11**	**219.24**	**10%**

Reasons for Discrepancies

- There was a large discrepancy in the calculation of the RTU and MAU total capacity: the ex ante calculations use a total capacity of 3,788 tons, whereas the verified capacity is only 275 tons.
- The ex ante calculations assume the building is occupied every hour of the year. Onsite verification found that the HVAC schedules are variable and set as needed throughout the year. Since the schedule changes, varies by HVAC system, and includes different space-types such as restaurants, bars, and retail, the ex post analysis adjusted the bin hours to align with the commercial and industrial average EFLH deemed value of 1,053 in St. Louis. This reduced total cooling hours from 5,441 to 2,685.
- The VRF capacities in the ex ante calculations differed from the AHRI-certified capacities for the same equipment. The latter values were used in the ex post calculations.
- The ex ante calculations did not account for oversizing equipment. In accordance with ASHRAE 90.1 Appendix G, an 115% oversize factor is assumed in the ex post calculations, which reduces both baseline and proposed usage, resulting in lower savings.

- The verified baseline and proposed efficiencies differed from the ex ante values for the RTUs and VRF system.

Other Findings and Recommendations

- The onsite evaluation team verified a sample of each equipment type and did not identify any discrepancies in installed equipment models. While they were not able to find some of the heat pumps, these units are assumed to be installed.

Site 9130 (Custom HVAC)

This project involved the installation of two (2) 300-ton water-cooled centrifugal chillers in a health care building. The ex ante savings were generated with a proprietary Excel-based modeling tool by comparing the proposed chillers usage to a baseline usage of two (2) new water-cooled rotary screw chillers of equivalent capacity.

Table 90. Site 9130 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Chillers	Cooling	406,454	370.15
	Total	**406,454**	**370.15**

Data Collection

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

The installed equipment was verified by the project invoices submitted with the project files. The project files also included an email from the vendor to the trade ally identifying the proposed equipment and less-efficient baseline equipment.

Analysis

The ex ante project savings were estimated through a proprietary Excel-based modeling tool, MyPLV™, by Trane. The underlying calculations for the tool are not accessible. The tool inputs include chiller and cooling tower parameters and typical cooling load profiles for different building types including hospitals. The evaluation team reviewed the ex ante savings by developing a bin analysis and comparing the results. The bin analysis savings equated to 99% of the ex ante savings, so the latter were considered validated.

Table 91. Site 9130 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline and proposed chiller capacity (tons)	300	300	Vendor performance data
EEM-1	Baseline and proposed chiller efficiency	kW/ton as a function of % of full load	kW/ton as a function of % of full load	Vendor performance data

Results

Table 92 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 92. Site 9130 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Chillers	406,454	406,454	100%	370.15	370.15	100%
Total	**406,454**	**406,454**	**100%**	**370.15**	**370.15**	**100%**

Reasons for Discrepancies

- N/A

Other Findings and Recommendations

- We recommend Ameren develop criteria for approving the use of proprietary energy modeling tools for Custom applications. Tools that are frequently used could be placed on an approved list after thorough review by the implementation and evaluation teams. Tools that are not frequently used should be evaluated on a project by project basis, with the implementation team reviewing the energy savings estimates and documenting the review in an Excel workbook.

Site 9132 (Custom HVAC)

This project included implementation of measures identified in a Retro-Commissioning (RCx) study of a health care complex. A chiller plant with seven water-cooled centrifugal chillers with a total capacity of 11,850 tons provides chilled water to air handling units (AHUs) in multiple buildings. The energy saving measures include supply air temperature (SAT) resets implemented for 36 AHUs. Prior to the RCx study, many chilled-water valves were leaking, resulting in abnormally low chilled water temperature. The leaks were identified and fixed as part of this project, resulting in increased supply air temperature and achieving large energy savings.

Table 93. Site 9132 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 SAT Reset	Cooling	1,991,964	1,814.05
	Total	**1,991,964**	**1,814.05**

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. The ex ante calculations include a detailed inventory of AHUs indicating pre- and post-supply air temperature, with the building automation system (BAS) screenshots corroborating the pre- and post-conditions. Some of the valves were counted in the ex ante savings even though they had not been repaired at the time of the application submittal because they were anticipated to be addressed soon after.

An onsite visit was arranged to verify these last repairs, the chiller plant efficiency, and the hours of operation. The leaks were verified as repaired; however, the chiller plant efficiency and hours of operation could not be verified from the onsite BAS.

Analysis

The ex ante project savings were estimated through engineering calculations using an assumed mixed air temperature, relative humidity, and AHU-specific pre- and post-supply air temperatures. The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- The mixed air conditions were adjusted to a slightly lower dry bulb temperature and relative humidity based on TMY3 weather data.

Table 94. Site 9132 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Average mixed air dry bulb temperature (°F) and relative humidity	73, 60%	70.9, 53%	TMY3 weather data assuming 20% outside air/80% return air
EEM-1	Chiller plant efficiency (kW/ton)	0.8	0.8	Ex ante assumption
EEM-1	Annual operating hours	5,928	5,928	TMY3 weather data; hours when savings occur

Results

The table below shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 95. Site 9132 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 SAT Reset	1,991,964	1,864,500	94%	1,814.05	1,697.97	94%
Total	**1,991,964**	**1,864,500**	**94%**	**1,814.05**	**1,697.97**	**94%**

Reasons for Discrepancies

- The mixed air conditions were adjusted to slightly lower dry bulb temperature and relative humidity based on TMY3 weather data.

Other Findings and Recommendations

Although the leak repairs were thoroughly documented and backed up with BAS data, no explanation or backup documentation was provided for the following key parameters:

- Chiller plant efficiency of 0.8 kW/ton
- Annual hours of operation of 5,928
- Averaged mixed air condition of 73°F and 60% relative humidity

There are seven chillers within the chiller plant, and the control sequences are unknown. The evaluation team only had access to performance data for two chillers; however, the ex ante efficiency assumption of 0.8 kW/ton appears reasonable for the chiller plant as a whole based on the vintage of the other chillers and the IECC minimum values in effect in the year of manufacture. The hours of operation also appear reasonable as savings would occur during non-winter months, approximately March through October.

While the post-inspection documentation thoroughly demonstrated the leak repairs, it is the evaluator's opinion that a thorough explanation with supporting data should have been included for each key parameter given the large savings claimed for this project.

Site 9133 (Custom HVAC)

This project consists of a gut renovation of a historic building into an entertainment center. The installed rooftop units (RTU) and air-cooled chiller qualified for Custom incentives by exceeding the minimum energy efficiency requirements in IECC 2018.

Additional Custom measures included an enthalpy economizer and demand-controlled ventilation. Enthalpy economizers save energy by using outdoor air to provide "free cooling" when the outdoor air enthalpy is less than the return air enthalpy. Demand-controlled ventilation saves energy by optimizing the volume of outdoor air that must be conditioned according to zone occupancy.

Table 96. Site 9139 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Chiller	Cooling	41,648	37.93
EEM-2 Rooftop Units	Cooling	201,032	183.08
EEM-3 Enthalpy Economizer	HVAC	185,533	82.37
EEM-4 Demand-Controlled Ventilation (DCV)	HVAC	133,250	59.16
	Total	**561,463**	**362.54**

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 the basis for estimated energy savings. Post-inspection photos provided by the implementation team confirmed most of the equipment installations. The evaluation team arranged an onsite visit to verify the economizer, DCV controls, and remaining equipment installations.

Analysis

Ex ante savings for EEM-1, EEM-2, and EEM-3 were calculated through bin analyses. Ex ante savings for EEM-4 were calculated using the Ameren Missouri TRM algorithm for DCV, which requires a site-specific input of floor area (ft^2) controlled by DCV.

The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- RTU baseline IEER updated from 11.83 to 11.26 based on IECC 2018 requirements
- RTU cooling capacity changed from 445 tons to 427.2 tons, the total net cooling capacity from the equipment submittals
- Economizer base switchover temperature changed from 60°F to 65°F based on IECC 2018 requirements for dry bulb economizers in Climate Zone 4A
- HVAC oversizing factor changed from 100% to 115%
- Peak coincidence factor for EEM-3 and EEM-4 changed from 0.0004439830, the deemed value for the HVAC enduse, to 0.0009106840, the deemed value for the Cooling enduse

Table 97. Site 9139 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Chiller Baseline/Proposed IPLV (EER)	14.00/15.64	14.00/15.64	Submittal
EEM-1	Chiller Cooling Capacity (tons)	240.3	240.3	Submittal
EEM-2	RTU Average Baseline/Proposed IEER	11.83/15.39	11.26/15.42	IECC 2018 and submittals
EEM-2	RTU Total Cooling Capacity (tons)	445.0	427.2	Submittals, net cooling capacity
EEM-3	Economizer Baseline Switchover Temperature (°F)	60	65	IECC 2018 Table C403.5.3.3
EEM-3	Economizer Proposed Control Method	Comparative enthalpy	Comparative enthalpy	Submittals
EEM-1-3	HVAC Oversizing Factor	100%	115%	ASHRAE 90.1 Appendix G
EEM-4	Demand-Controlled Ventilation Savings Factor	650 kWh/1000 SF	650 kWh/1000 SF	Ameren Missouri TRM
EEM-4	Demand-Controlled Ventilation Square Footage	205,000	205,000	Verified through onsite visit
EEM-3,4	Peak Coincidence Factor (kW/kWh)	0.0004439830	0.0009106840	Ameren Missouri TRM

Results

Table 98 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 98. Site 9139 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Chiller	41,648	40,011	96%	37.93	36.44	96%
EEM-2 Rooftop Units	201,032	227,808	113%	183.08	207.46	113%
EEM-3 Enthalpy Economizer	185,533	160,280	86%	82.37	145.96	177%
EEM-4 Demand-Controlled Ventilation	133,250	133,250	100%	59.16	121.35	205%
Total	**561,463**	**561,350**	**100%**	**362.54**	**511.21**	**141%**

Reasons for Discrepancies

- EEM-3 and EEM-4 ex ante kW savings calculations incorrectly use HVAC coincidence factors; these are changed to Cooling in ex post[2], resulting in increased demand savings.

[2] Economizers reduce mechanical cooling energy so should be considered a cooling end use. The Ameren Missouri TRM prescribes the Cooling end use for demand-controlled ventilation.

- The ex ante baseline economizer switchover temperature is 60°F; however, IECC 2018 prescribes a switchover temperature of 65°F for Climate Zone 4A. The ex post economizer kWh savings are also lower because a more accurate method of modeling the percentage of "free cooling" was used.
- Incorrect RTU baseline efficiencies were used in the ex ante calculations; savings increased in the ex post calculations when the correct baseline efficiencies were applied.

Other Findings and Recommendations

- HVAC calculations should use net cooling capacity where available instead of gross cooling capacity. Net capacity is equal to the gross capacity minus the heat from the supply fan motor. In addition, bin analyses should assume that HVAC equipment is oversized unless information is available to the contrary. ASHRAE 90.1 Appendix G prescribes a guideline of 15% oversizing for cooling equipment.
- The evaluation team reviewed whether demand-controlled ventilation is required for this facility per IECC 2018 C403.7.1. We determined it is not required because the average occupancy is likely to be below 25 people per 1,000 square feet of floor area. Therefore, no DCV was accepted as a baseline assumption for EEM-4.

Appendix E. Desk Review and Onsite Reports: Custom Incentive Program, Indoor Agriculture Projects

The evaluation of Custom indoor agriculture projects included desk reviews for a sample of 4 projects. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Table 99. Summary of Custom Indoor Agriculture 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
9400	Desk review with Onsite Verification	8,401,739	8,189,734	97%	2,659.18	2,581.87	97%
9401	Desk review	1,248,287	1,178,178	94%	554.22	162.52	29%
9402	Desk review with Onsite Verification	3,801,343	3,710,982	98%	1,147.75	621.85	54%
9403	Desk review with Onsite Verification	4,838,634	2,417,992	50%	1,842.72	396.12	21%

Site 9400 (Custom Indoor Ag)

Project Description

This gut-rehab project converted a 1-story, 45,000 square-foot warehouse/manufacturing space to an indoor cannabis-growing facility, which includes grow rooms and support areas (i.e., offices, storage, etc.). Energy efficiency savings are limited to the three grow areas and include a more efficient HVACD[3] system design and LED lighting. The grow area lighting is exempt from energy code lighting power density (LPD) requirements (LPD-exempt). Baselines are assumed to be high-pressure sodium (HPS) or T5 high-output (T5HO) fluorescent fixtures depending on the grow room type. HVAC energy savings are achieved through improved efficiency of the HVACD system design, reduced cooling capacities from the use of LEDs versus baseline technology lighting systems, and hot gas reheat (HGR) as an integrated HVACD unit dehumidification feature versus standalone, in-room, lower-efficiency dehumidification devices. A 2012 IECC baseline consistent with the location (city of Moberly in Randolph County) was assumed for the HVACD systems. The grow room HVACD systems for this facility are unique: they are computer room air conditioners (CRAC) units, normally reserved for data centers.

Table 100 summarizes the tracking data energy efficiency measures, the ex ante gross savings for each, and the total savings claimed for this project.

Table 100. Site 9400 Ex Ante Measure and Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Packaged/RTU	HVAC	4,185,314	1,858.21
EEM-2 Lighting - Flower Rooms	Lighting	2,970,779	564.34
EEM-3 Lighting - Veg Rooms	Lighting	1,134,350	215.49
EEM-4 Lighting - Mother Clone Room	Lighting	111,296	21.14
	Total	**8,401,739**	**2,659.18**

Data Collection

Data collection for this project consisted of a desk review of project documentation, building simulation input and output files, and onsite verification results.

The evaluation team reviewed all available project documents to understand the scope of the project including the final application, invoices, calculation workbooks, project communication emails, site plans, post-installation photos, HVACD and lighting equipment specification sheets, Trane TRACE® 3D Plus (TRACE) building energy modeling (BEM) input and report files, and other supporting documents to determine the baseline and proposed equipment and conditions and to understand the basis for estimated energy savings. Additional information was provided by the implementer in response to questions about discrepancies or deficiencies with the primary documentation. All this information was referenced in developing the 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:

[3] HVACD= heating, ventilation, air conditioning and dehumidification, which is an integral element of indoor agriculture space conditioning systems.

General Notes

- The evaluation team compiled and constructed a project overview from a variety of document. Every project should have a high-level overview of the project, individual end use elements (like HVAC and lighting systems), and a summary of the parameters most relevant to characterizing the measures and used to develop the savings estimates.
- Project documentation continued to be insufficient, conflicting, and not clearly organized; key project documentation was not clearly identified and some documentation was not provided.
  - This project appears to have been through multiple variations of measures and configurations, as there were many documents and multiple versions of directories, files, applications, savings workbooks, etc. This situation, combined with not having the files associated with the savings claim clearly identified, made it challenging to locate and identify which documents to use for the evaluation and create a project summary. For example, there was both a "Submittal for Payment" subdirectory and a "Model and Final Calcs" subdirectory, which both imply they could contain the supporting files.
  - Additional documentation outside the implementation team's formal tracking system was provided in five separate files, which included final application, savings calculation workbooks, building simulation files, and photos. Some of these were inconsistent with the tracking data savings.
  - In the supplemental documents provided by the implementation team, there was one ex ante calculation summary workbook (*4-14-22 Final Calcs ZR.xlsx*) that showed savings consistent with tracking data. The formal project documentation system also had a document that used building simulation results in a similar format, but the values differed from the tracking data (*Saving Summary BizSavers.xlsx*)
  - A "Spec Sheets" subdirectory did not contain the spec sheets for the grow lighting or HVACD units but instead included specs for the lighting in the support areas, circulation fans, building plan equipment schedules, and lighting fixture layouts. This may have been residual files from an earlier project iteration.
  - A "Lighting" sub-directory did not contain the spec sheets for the grow lighting but had a variety of other related documents. For example, documents labeled "cutsheets" were installation documents not spec sheets. There were, however, some useful technical lighting design plans for each room that showed fixture configurations and lighting levels for both the baseline HPS and LED technologies.
  - For grow room lighting, the effective baseline fixtures factor calculator workbook was not provided, although some of the data and the developed factors were used in the ex ante savings calculation workbook. The calculator is used to determine the number of HPS fixtures equivalent to the as-built LED fixtures based on lighting performance characteristics and is a standard tool used by the implementation team.
- There were multiple floor area inconsistencies across the application, the building plans, and the building simulation model. Consistent and accurate accounting of floor areas is important for HVAC system simulation. The floor area discrepancies are as follows:
  - The application shows a single-story building with a total site floor area of 45,000 square feet and conditioned floor area of 43,000 square feet. However, the TRACE Project Summary report lists

both the total building area and conditioned floor area as 42,294 square feet and a slightly larger roof area of 44,947 square feet.

- An analysis workbook *(square footage check for LPD.xlsx)* provided as part of a supplemental data request to the implementation team, contains a tabulation of floor areas at the individual area level and shows the total floor area as 42,296 square feet, with the grow area portion (Flower, Veg, Clone) at 28,291 sq ft (67%) and the support areas making up the balance at 14,005 square feet (33%). The source of the values in this workbook is not documented, but the values appear to be derived from the building simulation energy model, and the total floor area is consistent with that in the model.
- The building floor plan shows a total area of 45,260 square feet and a spot-check of the Flower Room floor areas versus the previously mentioned workbook shows discrepancies: The plans show only three different room sizes of 2,157, 2,232 and 2,325 square feet, whereas the detailed workbook shows 10 different values ranging from 2,168 to 2,335 square feet. These minor discrepancies are likely a result of the process of importing the building footprint into the building simulation tool.

- Invoices were available for lighting (two shipments), and the total fixture on the two invoices matched the ex ante claimed quantities. However, there were no invoices for the individual HVAC units that showed size, make, and model--only a bill for lump-sum installation services.

HVACD Notes

- The HVACD systems used at this facility to condition the Flower and Veg room grow areas are especially unusual. They are computer room air conditioning (CRAC) units, which are typically used for data center and server/computer room applications. The HVACD design includes another unique feature: two HVAC systems per room versus the more typical one unit per room, most likely for redundancy and/or variable loading of the rooms.
- CRAC units are similar to other air conditioning equipment but are typically designed to lower the temperature of a room as opposed to conventional air conditioning units that are designed to remove both heat and humidity. As such, CRAC's have their own unique efficiency rating metric: the sensible coefficient of performance (SCOP). The SCOP is defined as the net sensible cooling capacity in kW (not kBtuh) divided by the power input in kW. CRAC minimum SCOPs are set by national equipment Standards, vary by equipment type, and have not been changed since 2012 – 2013, when the minimum efficiency standards were first established.[4] The SCOP minimum efficiencies are provided in Table 101 below. With reference to this table, the CRAC units at this facility are an up flow design.

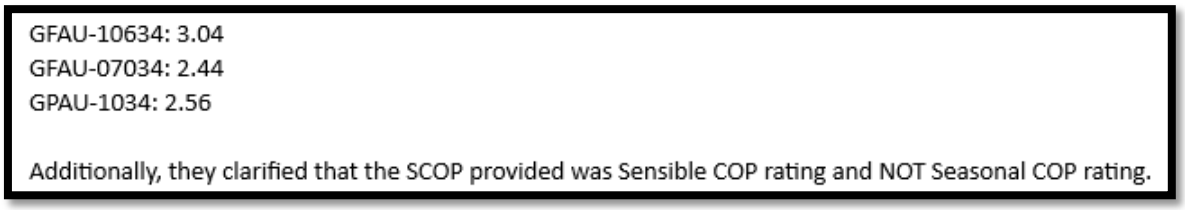
[4] See https://appliance-standards.org/product/computer-room-air-conditioners for more information.

Table 101. Site 9400 CRAC Equipment Minimum Efficiencies[5]

Equipment Class	Amended or New Federal Energy Conservation Standard	Compliance Date of Amended/New Federal Energy Conservation Standard
Computer Room Air Conditioner, air-cooled, <65,000 Btu/h	2.20 SCOP (downflow), 2.09 SCOP (upflow)	10/29/2012
Computer Room Air Conditioner, air-cooled, =65,000 Btu/h and <240,000 Btu/h	2.10 SCOP (downflow), 1.99 SCOP (upflow)	10/29/2013
Computer Room Air Conditioner, air-cooled, =240,000 Btu/h and <760,000 Btu/h	1.90 SCOP (downflow), 1.79 SCOP (upflow)	10/29/2013

- Neither SCOP nor conventional EER/IEER efficiency ratings were listed on the spec sheets for the grow room HVAC units. The project documentation contained an email chain that traced the implementers efforts to obtain equipment efficiencies from the HVAC equipment sales engineer. The COP values shown in Figure 2 were provided on 4/5/2022, but no spec sheets or other information were provided to support how value calculations. The footnote below the values refers to SCOP efficiency values (consistent with CRAC efficiency ratings), which had also been provided via email earlier in the year.

Figure 2. Site 9400 Program Application HVAC Record



- The manufacturer of the CRAC units (Data Aire) ceased operations as of December 16, 2022, and the website (https://www.dataaire.com) is now completely offline and inaccessible. As such, we were unable to validate the reported efficiencies with the manufacturer.
- The Trane TRACE® 3D Plus building energy modeling (BEM) tool was used to simulate ex ante HVACD savings. Initially, only the TRACE building simulation model *input* file was provided in the project documentation. However, because one of the output reports is the primary source of the claimed savings, we raised this point with the implementation team, and the output report files were subsequently provided.
- A table summarizing the HVACD systems key characteristics and assumptions for both the baseline and efficient scenarios was not initially available in the project documentation. Upon requesting one from the implementation team, the table below was provided which shows a very high-level summary of the HVACD and lighting system descriptions for the three grow rooms, with installed equipment COPs embedded in the HVACD description.

[5] https://www.regulations.gov/document/EERE-2011-BT-STD-0029-0038

Figure 3. Site 9400 High-Level Summary of Installed Equipment

Building Area Type	Space/ Room Type	HVACD System Type	Cooling Capacity	HVACD As-Built	LED Grow Lighting As-Built
Grow Rooms	Flower Rooms 1-11	SZ/DX CV	20 Tons Count: 2	2.44 COP, supplemental electric heat, HGR dehum	Fohse A3i 1500W Count: 55
	Veg Room	SZ/DX CV	30 Tons Count: 2	3.04 COP, supplemental electric heat, HGR dehum	Fohse F1V 600W Count: 204
	Mother/Clone Room	SZ/DX CV	10 Tons Count: 1	2.56 COP, supplemental electric heat, HGR dehum	Fohse F1V 1000W Count: 35

**all support areas were modeled as identical to baseline*

The document also explained that the HVACD systems for both the grow area and support areas are simulated in the model, and that the as-built scenario system types and parameters were taken from the building plan mechanical schedules, submittals, and other available manufacturer documentation. It did not provide the baseline HVACD efficiencies.

- The evaluation team used the TRACE BEM software to:
  - Rerun the input models and verify the HVACD claimed savings, which are derived directly from the TRACE Project Summary output report. Due to continuous updates of the TRACE tool, older models always need to be converted to the latest version of TRACE, so results can differ slightly from ex ante values. Two different TRACE input files were provided with the project documentation. After we identified the correct one, a rerun of this model using the latest TRACE version produced results consistent with ex ante claimed savings.
  - Review and validate the HVACD and lighting parameter values and areas/zones actually used in the models, with a focus on reviewing and validating the HVACD efficiency assumptions for both the installed and baseline case models. The assumed baseline system efficiencies are not documented in the project documentation and are only available via interactive review of the model within TRACE. Screen captures of the HVACD system inputs are included in the engineering analysis workbook.
  - We also noted that the model includes support areas and HVAC systems but did not review them as their contribution is insignificant compared to the grow room HVACD and lighting.
- A complete summary of the grow room HVACD system characteristics produced from our review of the project documentation and the building simulation models is provided in Table 102. Cooling efficiency values for both the Efficient and Baseline cases are included. Bold text indicates the full-load values physically entered in the model, typically a COP. Values in parentheses are the bold text values converted to EERs. The two values are presented because EER is the most typical rating used for commercial unitary packaged equipment, which would be the comparable baseline systems type. As shown, the same efficiency values were used for both the efficient and baseline scenarios. We are unsure of the reason for this approach, but it may be due to the uncertainty of the COP values, as previously discussed.

Table 102. Site 9400 HVACD System Characteristics and Ex Ante Efficiencies

Room Type	Number of Rooms	Model Number	Total Qty	Nominal Cooling Tons (kBtuh)	Ex Ante Efficient Case Efficiency	Ex Ante Baseline Case Efficiency
Flower Room	11	GFAU-07034	22 (2 per room)	20 (240)	**2.44 COP** (8.33 EER)	**2.44 COP** (8.33 EER)
Veg Room	1	GFAU-10634	2 (2 per room)	30 (360)	**3.04 COP** (10.37 EER)	**3.04 COP** (10.37 EER)
Mother Room	1	GPAU-1034	1	10 (120)	**2.56 COP** (8.73 EER)	**2.56 COP** (8.73 EER)

Lighting Notes

Only grow room lighting measures were claimed for this project.

- The LPD-exempt lighting baseline assumes HPS 1000W lamp fixture (1060W) for the Flower and Mother Rooms and T5HO 4 foot/8-lamp fixtures (432W) for the Veg Room. The ex ante analysis developed an equivalent quantity of baseline fixtures needed to provide the same lighting levels as the LED fixture. The ex ante values are presented in Table 103.

Table 103. Site 9400 Equivalent Quantity of Baseline Fixtures for A3i 1500W Fixture

Location	LED Fixture	Watts	Baseline Fixture Type	Equiv. Baseline Fixture Factor
Flower Room	Fohse A3i 1500	1500	HPS 1000W	2.47
Veg Room	Fohse F1V 600W	600	T5HO 4' 8-lamp	3.35
Clone Room	Fohse F1V 1000W	1000	HPS 1000W	1.41

- The source of the equivalent baseline fixture factors was not provided in the calculation workbook, but the values are consistent with the approach used in the KEM Ag Lighting PPF Equivalent Data.xlsx workbook and the earlier version Ameren Ag Lighting Equivalent Quantity workbook.[6] Although this workbook was not provided with the original project documentation, we obtained the workbook during last year's evaluation and used it to confirm the factors were calculated correctly.
  - The *KEM Ag Lighting PPF Equivalent Data.xlsx* workbook contains three tabs: one for Flower rooms, one for Veg rooms, and one that contains the data points used for the equivalent baseline fixture quantity calculations.
  - The equivalent baseline fixture calculation is based on the common practice of using PPFD (photosynthetic photon flux density) or PPF (photosynthetic photon flux) values for the LED lamps as determined from specification sheets versus 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.
  - The equivalent baseline fixture quantity factor for the Veg Rooms of 3.35 seems excessive and perhaps would not even be physically possible, but the factor was developed using the standard

[6] The *KEM Ag Lighting PPF equivalent data.xlsx* workbook uses a PPFD-based approach to determine the equivalent number of baseline fixtures needed. One tab is used for Flower Rooms and uses an HPS baseline , another tab is used for Veg Rooms and uses an 8-lamp T5HO fixture, and the final tab contains the HPS and T5HO PPF basis used to develop the baseline fixture factor. It is a living document that is updated and maintained by the implementer and contains a catalog of the most common LED lighting fixtures

workbook approach. In the calculator workbook, the Flower Room HPS baseline records have a maximum factor of 2.47 but for the Veg Room T5HO baseline the factor is as high as 5.80 and about 1/3 of the values are greater than 2.5.

- The project documentation included lighting design plans for the Flower Room and both the A3i and HPS baseline. The ratio of fixtures from this analysis was 2.21 (144/65) versus the 2.47 from the equivalent baseline calculator, about a 90% reduction. The ex ante value was not changed, but this does indicate that a closer look at the factors may be warranted for a future program cycle until LEDs become the baseline.

- As previously mentioned, no savings were claimed for the LPD-compliant support area lighting. Although the application contained data for the lighting fixtures in the support areas, it appears the installed lighting LPD slightly exceeded the minimum LPD for the selected building type, so this measure must have been dropped from the project.

Overall, the HVACD systems, layout, and operation of these sites is very unique and complex, and especially unique for this facility in that it uses CRAC systems that are typically used exclusively for data centers. The presence of multiple variations of files and interim versions made it difficult to evaluate. The project was also missing key information like a summary of the HVAC system baseline versus efficient parameter comparisons.

Onsite Verification Results

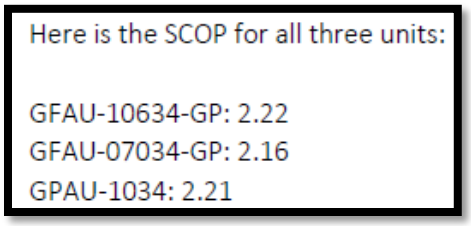
The evaluation team conducted the onsite verification on January 10, 2023. Verification staff were directed to verify as many of the verification points as possible but to prioritize the equipment and areas responsible for the largest portion of project savings. Key findings from the onsite verification include:

- Total floor area was confirmed to be about 45,000 square feet using a couple of different methods, with minor differences attributed to gross versus net.
- The building floor plan provided in the project documentation and the tracking data showed a combined Mother/Clone room as a single space, but the Mother Room and Clone Room were found to be separate spaces onsite. The separate spaces were also shown on building plans provided to the field staff while onsite. We confirmed with the site contact that this was a late-design change.
- The facility is operating at full capacity with 24/7 operation. Seasonal grow cycle operation and timing was considered proprietary and not shared with field staff, but some lighting schedule information was available. Photos were also taken of the room conditions (e.g., lighting, temperature, humidity, CO2, fan operation) on the building automation system (BAS) display in every room visited.
- The claimed quantities of grow room HVACD systems were verified. For the Flower Rooms, each room had two HVAC units, and there were a total of 11 rooms and 22 HVAC units. For the single Veg Room, the two units were present, and both units were running at the time of the visit. For the Mother Room, the single unit was also verified. Building plan HVAC Mechanical Schedules were provided onsite and the equipment specs for the three grow room HVACD units were verified to be the same as those provided in the ex ante project documentation.
- Photos were taken of several grow room HVACD outdoor units, and the indoor units of the rooms that were physically visited. However, *no nameplates or other model identification tags were observed on any of the indoor or outdoor equipment*. Only the manufacturer and product line names were observed on the units. Indoor units were identified as “gPod by dataaire.” Outdoor units were identified only as

"gForce by dataaire" and had faded paper labels attached which were not readable. Post-retrofit inspection photos included in the ex ante project documentation showed these labels were general safety warning labels.

- A copy of an email with HVACD unit efficiencies was provided to the field staff by the trade ally. Efficiencies were specified as sensible COP (SCOP) values, as shown below for the three units. These values were provided by the independent HVAC equipment company sales engineer not directly by the manufacturer Data Aire. Values are shown in Figure 4 which is a screen shot of the email.

Figure 4. Site 9400 HVACD Efficiencies Obtained by Onsite Verification



These SCOP rating values are consistent with the Federal equipment efficiency ratings for CRAC units, as previously discussed.

- Flower Room lighting control system display panels outside each room were spot-checked for several flower rooms. All indicated the use of two lighting zones with 12 hour on/off cycles (typically 12 a.m. to 12 p.m.). In addition, the lighting intensity has three levels of dimming to simulate Spring/Summer/Fall (e.g. Spring about 30%, Fall about 70%). In addition to the room-level views, a master control view showed what week of the total grow cycle each flower room was in.
- Flower Room lighting fixtures counts were confirmed by counting fixtures in two separate rooms (5 X 11 = 55 fixtures per room), but four different rooms were accessed. Fixtures were confirmed to be Fohse A3i from the fixture labels and physical configuration. The extrapolated fixture count for all 11 rooms matched the ex ante value of 605.
- For the single Veg Room, the lighting control system display panel was observed and showed the use of four separate lighting zones with 18 hour on/off cycles (6 a.m. to 12 p.m.), with the lighting intensity set to about 40% to represent a Spring setting. The lighting model number was confirmed as an F1V from the fixture label. The wattage was not on the label but confirmed by the 6-module array configuration used for a 600 W fixture. The observed lighting array was 6 fixtures wide by 16 fixtures long, and there were two tiers of lighting for a total of 192 fixtures (6X16X2). This is a slight discrepancy from the claimed value of 204, but 11 fixtures were also found in storage, bringing the total found onsite to 203. The site contact explained this discrepancy as the result of a design spacing issue during construction.
- The Mother Room lighting control display panel was checked and showed two separate lighting zones with 18 hour on/off cycles (6 a.m. to 12 p.m.), with the lighting intensity set to about 30% to represent a Spring setting. The lighting model number was confirmed as an F1V from the fixture label, and the wattage was not on the label but confirmed by the 8 module array configuration used for a 1000 W fixture. The total fixture count matched the ex ante value of 35 fixtures.
- Photos of the site, building, HVAC, and lighting equipment for several of the support areas were also collected but not used for the evaluation since there were no claimed savings for those areas.

Analysis

The evaluation analysis for this project is documented in an engineering analysis workbook. A summary of evaluation team findings is presented in this section for each measure category.

HVAC Energy Savings. The only issue to address was the use of baseline efficiency values that were the same as the efficient values. A review of the 2012 IECC Standards provided in Figure 5 presents the values that should have been used for the baseline.

Figure 5. Site 9400 2012 IECC Minimum Equipment Efficiencies[7]

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE*
				Before 6/1/2011	As of 6/1/2011	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 11.4 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 10.1 IEER	10.0 EER 10.1 IEER	
		All other	Split System and Single Package	9.8 EER 9.9 IEER	9.8 EER 9.9 IEER	

For the ex post analysis, the spec sheets indicated that all of the installed units have electric heating, so we assumed the same for the baseline systems and used the system size to determine the correct 2012 IECC efficiency values. Updated ex post baseline efficiency values are summarized in Table 104.

Table 104. Site 9400 HVACD System 2012 IECC Minimum Efficiencies

Zone/Room	Model Numbers	Quantity	Nominal Cooling tons (kBtuh)	IECC Size Category	2012 IECC Min Efficiency (Electric Heating)	Ex Post Modeled Baseline Case Efficiency
Flower Room	GFAU-07034	22	20 (240)	240-760	10.0 EER / 10.1 IEER	10 EER
Veg Room	GFAU-10634	2	30 (360)	240-760	10.0 EER / 10.1 IEER	10 EER
Mother Room	GPAU-1034	1	10 (120)	65-135	11.2 EER / 11.4 IEER	11.2 EER

Because these are CRAC units, we also compared the reported efficiencies to the CRAC minimum efficiency standards, although these values were not used for the evaluation. Those values are compared in Table 105 and confirm the installed units are more efficient than the baseline.

Table 105. Site 9400 Summary of CRAC SCOP Efficiencies

Zone/Room	Model Numbers	Quantity	Nominal Cooling tons (kBtuh)	SCOP Standards Size Range	IECC CRAC Unit Minimum Efficiencies	Project Documentation SCOP Values
Flower Room	GFAU-07034	22	20 (240)	240-760	1.79 SCOP (upflow)	2.16 SCOP

[7] Reference: 2022 TRM Appendix H, 2012 IECC Single-Package & Split System AC Minimum Efficiencies table,

Zone/Room	Model Numbers	Quantity	Nominal Cooling tons (kBtuh)	SCOP Standards Size Range	IECC CRAC Unit Minimum Efficiencies	Project Documentation SCOP Values
Veg Room	GFAU-10634	2	30 (360)	240-760	1.79 SCOP (upflow)	2.22 SCOP
Mother Room	GPAU-1034	1	10 (120)	65-240	1.99 SCOP (upflow)	2.1 SCOP

A summary of the ex ante and ex post efficiencies used for the TRACE models is provided in Table 106. Because the ex ante values were provided as COPs, both COP and EER values are listed for both. Note the installed equipment for the Flower Rooms and Mother Room is *less efficient* than the 2012 IECC minimum efficiency values for unitary package units. This may be another reason why the ex ante approach used the same value for both scenarios. For the ex post analysis though, we assumed a package unitary HVACD system was the appropriate baseline.

Table 106. Site 9400 Summary of Ex Ante and Ex Post HVACD System Efficiency Values

Room Type	Number of Rooms	Model Number	Total Qty	Nominal Cooling Tons (kBtuh)	Ex Ante Efficient and Baseline Case Efficiency	Ex Post Baseline Case Efficiency
Flower Room	11	GFAU-07034	22	20 (240)	2.44 COP (8.33 EER)	10.0 EER (2.93 COP)
Veg Room	1	GFAU-10634	2	30 (360)	3.04 COP (10.4 EER)	10.0 EER (2.93 COP)
Mother Room	1	GPAU-1034	1	10 (120)	2.56 COP (8.73 EER)	10.2 EER (3.28 COP)

For the ex post TRACE model, we used the verified ex ante installed equipment efficiencies but updated the baseline case equipment efficiencies to those shown in Table 106 We also incorporated into the model the small decrease in lighting counts in the Veg Room from the onsite verification. Results from the TRACE Project Summary output reports for ex ante and ex post models are presented in Figure 6 and Figure 7, respectively. The TRACE versions are 4.12.68 for ex ante and 5.00.123 for ex post. The Efficient and Baseline scenarios are clearly labeled in both figures, along with some short descriptions of what they represent. Note the lighting values shown in these simulations are not used for savings claims, though they will typically be very close.

Figure 6. . Site 9400 TRACE Ex Ante Project Summary Report Simulation Results

	Efficient LED Lighting GPOD HGR		Baseline HID Lighting 1.7 Dehum	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,228,693.00	773.88	6,332,125.00	1,220.31
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	119,240.60	13.61	201,122.70	22.96
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00
Heating	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	5,045,930.00	1,073.83	9,262,387.00	1,941.68
Interior Receptacles	555,890.60	65.69	555,890.60	65.69
Pumps	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	**7,949,754.20**	**1,927.01**	**16,351,525.30**	**3,250.64**

Figure 7. Site 9400 TRACE Ex Post Project Summary Report Simulation Results

	Efficient LED Lighting GPOD HGR		Baseline HID Lighting 1.7 Dehum	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,115,300.00	711.78	6,074,187.00	1,154.34
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	119,158.40	13.60	199,806.00	22.81
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00
Heating	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	4,998,625.00	1,066.63	9,148,857.00	1,924.40
Interior Receptacles	555,890.60	65.69	555,890.60	65.69
Pumps	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	**7,788,974.00**	**1,857.70**	**15,978,740.60**	**3,167.24**

The TRACE HVAC enduses for this project are only Cooling and Fans; there is no electric heating use. The difference in the Interior Lighting energy use is due to the small ex post adjustment to Veg Room fixture quantity.

End-use Energy to Coincident Peak Demand Factor. An additional analysis was performed this year to develop project-specific system peak demand coincidence factors (CF), and then using that value to determine whether an HVAC or Process CF is most appropriate for the project. CF values are applied to the annual energy savings to calculate the peak demand savings. Ex ante claims use the HVAC CF for all projects but a PY2021 recommendation was to consider using the Process CF, as it should better represent the year-round and relatively flat cooling required for an indoor agriculture facility. The Process and HVAC CFs from the Ameren Missouri TRM are presented in Table 107.[8]

Table 107. Site 9400 TRM Prescriptive Process and HVAC Coincidence Factors

Enduse	Process BUS	HVAC BUS
CF Value	0.0001379439	0.0004439830

We followed the following approach for this analysis:

- The ex post 8760 hourly building simulation HVAC enduse results for the Efficient Case is the primary data source.
- For calculating the CF, we used all of the building simulation HVAC enduses, which include Cooling, Heating, and Fans.
- To develop the project-specific CF, we applied the same general approach used for the creation of the original CF factors including use of a peak demand hour based on the single hour during the year that corresponds to the Ameren Missouri system peak: Day 203, hour 17 (July 22, Hour 17).[9]

Results are summarized in Table 108; since the project-specific CF is between the Process and HVAC CF factors but slightly closer to the HVAC CF, we retained the ex ante assumption. CF analysis details are available in the evaluation engineering analysis workbook.

Table 108. Site 9400 Peak Demand Coincidence Factor Comparison

Project-Specific Coincidence Factor	Process End Use CF	HVAC End Use CF	Process % Difference	HVAC % Difference
0.0002943867	0.0001379439	0.0004439830	51%	49%

Grow Room Lighting Savings. Lighting in the grow areas is considered exempt from new construction code lighting power density (LPD) requirements. Baselines for these lighting systems are instead based on industry standard practice (ISP), which is primarily HPS or T5HO fixtures, depending on the room type and the number of plant tiers (single or two to three tiers). Table 109 shows the key parameter values used in the estimation of energy savings for the LPD-exempt lighting measures:

Table 109. Site 9400 Ex Ante Parameters for Grow Room Lighting Measures

Space	Baseline				Efficient				
	Fixture Type	Qty	Watt/ Unit	Total kW	Fixture Type	Qty	Watt/ Unit	Total kW	HOU
Flower Rooms	HPS-1000W	1,496	1,060	1,586	Fohse A3i	605	1,500	908	4,380

[8] Appendix G TRM Volume 1, Table 2 "Commercial and Industrial End-Use Category Monthly Shapes and Coincident Peak Factors"
[9] "Ameren Missouri Coincident Peak Demand Quantification Process", January 14, 2016, illustrates and explains the approach used to develop coincidence factors from end use load shapes.

Space	Baseline				Efficient				
	Fixture Type	Qty	Watt/ Unit	Total kW	Fixture Type	Qty	Watt/ Unit	Total kW	HOU
Veg Rooms	T5 HO (4ft-8L)	683	432	295	Fohse F1V 600w	204	600	122	6,570
Mother Room	HPS-1000W	49	1,060	52	Fohse F1V 1000w	35	1,000	35	6,570

The only ex post lighting adjustments were made to the Veg Room lighting because of the onsite verification. The onsite verification found the quantity of lighting fixtures installed in the Veg Room (192) was less than the claimed value (204), and some of these fixtures were also found in storage. The ex ante and evaluation verified quantities for all fixtures are summarized in Table 110.

Table 110. Site 9400 Ex Ante Parameters for Grow Room Lighting Measures

Space	Ex Ante Qty	Onsite Verified Qty	Percent Installed
Flower Rooms	605	605	100%
Veg Rooms	204	192	94.1%
Mother Clone	35	35	100%

For reference, the full set of ex ante and ex post values are shown in Table 111, including the hours of use (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.

Table 111. Site 9400 Ex Ante & Ex Post Parameters for Grow Room Lighting Measures

Space	Efficient/Ex Ante			Verified/Ex Post			Ex Ante
	Qty	Watt/Unit	Total kW	Qty	Watt/Unit	Total kW	HOU
Flower Rooms	605	1,500	907.5	605	1,500	907.5	4,380
Veg Rooms	204	432	122.4	**192**	600	115.2	6,570
Mother Clone	35	1,060	35.0	35	1,000	35.0	6,570

The revised Veg Room quantities were also used to update both the efficient and baseline scenarios in the TRACE model. The changes made were as follows:

- Changed the efficient model quantity of LEDs from 204 to 192
- Changed the baseline model quantity of T5HO fixtures from 683 to 643 total lighting load

A complete summary of ex post changes made versus the ex ante values is provided in Table 112.

Table 112. Site 9400 Key Parameters Summary for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline efficiencies	COP varies by size, same as efficient case	10 to 10.2 EER varies by unit size	2012 IECC, Electric heating

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Peak demand Coincidence Factor	HVAC endues	Process enduse	Ex post analysis 8760 hour TRACE model data
EEM-3	Installed fixture quantity	204	192	Onsite survey
EEM-3	Baseline fixture quantity	683	643	Adjusted to match the installed fixture change

Results

Table 113 presents the ex ante and ex post energy and demand savings for this project and the resulting realization rates. In spite of what seemed like a significant change to the baseline HVACD system efficiencies, there is only a slight reduction in savings (97%) and lighting impact is also minor (94%).

Table 113. Site 9400 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Packaged / RTU	4,185,314	4,039,535	97%	1,858.21	1,793.48	97%
EEM-2 Lighting - Flower Rooms	2,970,779	2,970,779	100%	564.34	564.34	100%
EEM-3 Lighting - Veg Rooms	1,134,350	1,068,124	94%	215.49	202.90	94%
EEM-4 Lighting - Mother Room	111,296	111,296	100%	21.14	21.14	100%
Total	**8,401,739**	**8,189,734**	**97%**	**2,659.18**	**2,581.87**	**97%**

Reasons for Discrepancies

For HVACD measures, the ex ante calculation used the COP efficiency values for both the efficient and baseline scenarios. For the ex post analysis, EER values consistent with 2012 IECC were used. For the lighting measures, only the Veg Room was impacted due to a minor difference in fixture quantities found onsite versus the ex ante claim.

Other Findings and Recommendations

- **Provide documentation to support claimed HVACD efficiency values**. The COP efficiency values provided for the CRAC HVACD units used by this project were not supported by specification sheets nor calculations. For custom and non AHRI-rated equipment, project documentation must include the specification sheets and the calculations used to derive the claimed efficiency rating.
- **Project documentation continued to be insufficient, conflicting, and disorganized.** Project documentation for this project was worse than any reviewed for PY2021. The project documentation on TRC Captures was missing and/or inconsistent with the claimed savings. Multiple versions (at least two different sets) of additional project files and photos were supplied in response to our request for supplemental documents. None of the building simulation output files or reports were available in Captures, and initially only the input file was provided. Another data request was needed to obtain the TRACE output reports, which are the primary source of HVACD energy savings and should, therefore, be required and referenced for traceability.

  - A related recommendation is to firm up folder naming conventions and, as a minimum, have either (1) one folder where all the primary files used to support the ex ante savings claim are located or (2) create a list of the key documents and their locations (which might be better to avoid duplicating files). It would also be helpful to use a systematic versioning approach to track interim iterations of workbooks, building simulation files, etc.

- **Grow room lighting savings should account for dimming.** Dimming of especially high-watt LED fixtures should be reflected in the energy savings and selection of the equivalent baseline assessment if it is anticipated to be normal operation. The onsite verification of this project and the BAS installed there offered significant additional insight into the dimming operation of grow room lighting that should be reflected in the lighting savings calculations and building simulation models--maybe even in the equivalent baseline fixture factor, though it will add a significant amount of complexity to both.
- **Consider a cap on the equivalent baseline fixture factor.** The Veg Room lighting had a very large equivalent baseline fixture factor (3.5) for T5HO lamps. To use 3.5 T5HO fixtures in the physical space of 1 LED fixture seems excessive. Further research should be conducted to determine if a cap on the factor should be considered.

Site 9401 (Custom Indoor Ag)

This project involved a new construction indoor cultivation facility, with a floor area totaling about 40,700 square feet. Grow rooms make up roughly 57% of the floor area, with the remaining floor area being support areas. This project generated savings through the installation of high-efficiency HVACD[10] equipment, including enhanced control and dehumidification functions, serving the grow rooms. A 2015 IECC baseline consistent with the location (Saint Charles County) was applied to estimate savings for the HVACD systems. The grow rooms use standard HPS and T5HO lighting fixtures rather than LEDs, so there are no grow room lighting measures. This is a very unique facility. In addition to the standard grow-type rooms, it also has two research and development (R&D) rooms: a Flower R&D room and a Veg R&D room.

Table 114 summarizes the energy efficiency measures and ex ante gross energy and demand savings claimed for this project.

Table 114. Site 9401 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Packaged / Rooftop Unit	HVAC	1,248,287	554.22
	Total	**1,248,287**	**554.22**

Data Collection

Data collection for this project consisted of a desk review of project documentation. We attempted to recruit the customer for an onsite verification, but the customer did not have time to meet nor respond to questions.

The evaluation team reviewed all available project documents to understand the scope of the project and the measures and basis for estimated energy savings. The documentation review included program applications, savings calculation workbook files, invoices, site plans and equipment schedules, HVAC and lighting equipment specification sheets, Trane TRACE® 3D Plus (TRACE) building energy model (BEM) input and output report files, and other supporting documents to determine the specific baseline and proposed equipment and conditions. All this information was referenced when developing the Excel-based engineering analysis workbook used to estimate ex post savings and document our data review. Key information and project characteristics obtained from the project documentation include:

General Notes

- The evaluation team compiled and constructed a project overview from a variety of documents. Every project should have a high-level overview of the project, individual enduse elements (like HVAC and lighting systems), and a summary of the parameters most relevant to characterizing the measures and used to develop the savings estimates.
- There were issues with the implementer's project documentation system (Captures) and uploading larger energy models and photos. This was quickly remedied with a workaround to transfer the files to the evaluation team using an alternate approach, but this led to duplication and confusion about which files directly supported the savings claims.

[10] HVACD= heating, ventilation, air conditioning, and dehumidification, which is an integral element of indoor agriculture space conditioning systems.

- Building plans included COMcheck™ energy code compliance reports that confirmed the applicability of 2015 IECC for this jurisdiction. Total floor area noted on those forms was 40,703 gross square feet.
- Project documentation continued to be insufficient, conflicting, and disorganized:
  - Identifying the actual physical address for the facility was difficult. There were different site addresses (or no actual address) and different street names across the application, building plans, and other documents, as well as multiple business names for the site.
  - Equipment model numbers often conflicted across sources, and most were only partial model numbers. A more detailed discussion of the spec sheet review is provided in the HVAC Notes section.
  - A large number (73) of inspection photos were provided, but the files were not labeled nor organized. A document with a key to the tag numbers that could be seen in some of the photos (e.g,, "M=Mother Room," "F=Flower Room") was included with the photos.
- There were multiple floor area inconsistencies across the application, the building plans, and the building simulation model. Consistent and accurate accounting of floor areas is important for HVAC system simulation. The floor area discrepancies are as follows:
  - On one tab, the application shows a single-story building with a total site floor area of 40,680 square feet and about 25,000 to 30,000 square feet of grow rooms; on another tab, it shows 40,000 total square feet.
  - The building plans were used to provide an independent assessment of floor area. Total building floor area was listed as 40,703 square feet on the plans. A tabulation of the floor areas for individual rooms that was also provided on the plans yielded 38,042 square feet (a 2661 square-foot difference from the total). The total grow room floor area is 21,614 square feet (57%), and the support room total floor area is 16,428 square feet (43%).
  - The building simulation model summary report listed the total building area and conditioned floor area as 76,407 square feet and a total roof area of 39,777 square feet. The trade ally apparent discrepancy was explained as the result of an interstitial conditioned ceiling space between the grow rooms and the roof that is separately conditioned, which effectively doubled the "floor area" above the grow rooms; therefore, the roof area is a better indicator of true floor area.

HVAC Notes

- The ex ante project savings are always derived from the TRACE "Project Summary" output report (examples provided in the Analysis section). Typically, these results are copied to an Excel workbook where the savings are calculated because the project summary does not provide savings only annual energy use for each scenario. However, for this project, the values in the ex ante calculation workbook (*36142- Model Results Calculations ZR.xlsx*) were inconsistent with the TRACE Project Summary report and tracking data. When the discrepancy was pointed out, the implementation team explained that the application (and tracking data savings) was based on a significantly revised final model; the true final model was then provided to the evaluation team and verified to be consistent with the tracking data savings.
- As previously mentioned, the floor area shown in the final building simulation model was **twice** the actual floor area. There was no mention of this unique configuration in the project documentation, but

the trade ally explained there is a conditioned ceiling space above the main level that is designed to minimize the skin load on the grow rooms. It sits above the entire first floor of the building so duplicates the footprint and floor area. Because it is conditioned and served by two separate HVAC units, it needed its own zone-space in the model, which is why the floor area is doubled on the Trace 3D Project Summary report. We confirmed this space is represented in the model and served by dedicated HVAC units.

- As summarized in Table 115, the HVACD measure covers eight different grow room types, 26 units, and 7 different sizes ranging from 3 to 50 tons of DX units from AAON. This detailed tabulation is a composite of information created from the Mechanical Schedule on the building plans, the invoices, the specification sheets, other project documentation, and reconciled discrepancies found between some documents.

Table 115. Site 9401 HVACD System Summary Table

Zone/Room	Tag Number (Reference)	Model Numbers	Qty	Nominal Tons	Total Tons	Percent of Total Cooling
Flower Rooms	RTU-FX_X	RN-030-3-0	10	30	300	54%
Veg Room	RTU-V_X	RN-050-3-0	2	50	100	18%
Dry Cure Rooms	RTU-DC_X	RQ-003-3-V	4	3	12	2%
Mother Rooms	RTU-M_X	RN-030-3-0	2	30	60	11%
Flower R&D	RTU-R&DF_X	RN-020-3-0	2	20	40	7%
Veg R&D	RTU-R&DV_X	RN-009	2	9	18	3%
Clone	RTU-C_X	RN-006-3-0	2	5	10	2%
Hardening	RTU-VH	RN-011-3-0	2	10	20	4%
		Totals	**26**		**560**	

- To validate the installed equipment efficiency assumptions, we reviewed two specification sheet documents (Submittal 2 and Submittal 5):
  - Submittal 2 did not have spec sheets for all the models, the tag numbers on the spec sheets did not match the Mechanical Schedule, and the model number on the spec sheets did not match the one listed on the installed equipment in inspection nameplate photos. Two of the units were also different sizes than those listed on the Mechanical Schedule.
  - Only Submittal 5 had the complete list of all seven units, which was also confirmed by matching tag numbers on the specification sheets to model numbers shown in the nameplate photos from the post-inspection photos provided with project documentation. We were able to extract and tabulate the rated efficiencies and sizes. We also verified that all units had hot gas reheat (HGR) features and most also had VFD. All units also had back-up modulating electric reheat.

The verified installed equipment efficiencies are summarized in Table 116.

Table 116. Site 9401 HVACD Verified Installed Equipment Efficiencies

Zone/Room	Tag Number (Reference)	Model Numbers	Qty	Nominal Tons	Efficiency from Spec Sheets
Flower Rooms	RTU-FX_X	RN-030-3-0	10	30	11.0 EER \ 12.0 IEER
Veg Room	RTU-V_X	RN-050-3-0	2	50	11.0 EER \ 12.7 IEER
Dry Cure Rooms	RTU-DC_X	RQ-003-3-V	4	3	14.2 SEER \ 12.1 EER
Mother Rooms	RTU-M_X	RN-030-3-0	2	30	11.0 EER \ 12.0 IEER
Flower R&D	RTU-R&DF_X	RN-020-3-0	2	20	12.3 EER \ 14.8 IEER
Veg R&D	RTU-R&DV_X	RN-009	2	9	13.2 EER \ 16 IEER
Clone	RTU-C_X	RN-006-3-0	2	5	13.2 SEER \ 11.4 EER
Hardening	RTU-VH	RN-011-3-0	2	10	12.7 EER \ 15.4 IEER

- The evaluation team also used the TRACE BEM software to perform the following:
  - Rerun the input models and verify the HVACD claimed savings derived directly from one of the BEM output reports. Due to continuous updates of the TRACE tool, older models always need to be converted to the latest version of TRACE, so results can differ slightly from ex ante values. For this specific project, rerunning the model initially provided in the project documentation produced results that were significantly different from the claimed savings. When this discrepancy was raised with the implementation team, they confirmed it was not the final model and provided the correct model. A rerun of this model using the latest TRACE version produced results consistent with ex ante claimed savings.
  - Review and validate the HVACD and lighting parameter values and areas/zones actually used in the models, with a focus on reviewing the HVACD efficiency assumptions for both the installed and baseline case models. The assumed baseline system efficiencies are not documented in the project documentation and only available via interactive review of the model within TRACE. Screen captures of the HVACD system inputs are included in the engineering analysis workbook.
- A summary of our model review findings is provided in Table 117. Comparison with the efficiency values from the spec sheets shows the ex ante model used the correct efficiencies for the efficient case model. For SEER-rated equipment, the alternate EER rating was used because TRACE does not allow a SEER value (EER is more correct for simulation). Table 117 also shows a baseline of 9.5 EER was used for all systems regardless of their size, but no explanation for using this value was provided in the project documentation.
  - In reviewing the TRACE models, we observed that HVAC systems for the support areas are also modeled, including baseline efficiencies that were different from the efficient model. Although the savings for these areas will also be reflected in the total HVAC savings from the model, the grow room HVACD use will always predominate these facility loads, so we did not review nor revise the support area HVAC systems.

Table 117. Site 9401 HVACD System Summary Table

Zone/Room	Tag Number (Reference)	Model Numbers	Nominal Tons	Efficiency from Spec Sheets	Ex Ante Modeled Efficient Case Efficiency	Ex Ante Modeled Baseline Case Efficiency
Flower Rooms	RTU-FX_X	RN-030-3-0	30	11.0 EER\12.0 IEER	11.0 EER	9.5 EER
Veg Room	RTU-V_X	RN-050-3-0	50	11.0 EER \ 12.7 IEER	11.0 EER	9.5 EER
Dry Cure Rooms	RTU-DC_X	RQ-003-3-V	3	14.2 SEER \ 12.1 EER	12.1 EER	9.5 EER
Mother Rooms	RTU-M_X	RN-030-3-0	30	11.0 EER \ 12.0 IEER	11.0 EER	9.5 EER
Flower R&D	RTU-R&DF_X	RN-020-3-0	20	12.3 EER \ 14.8 IEER	12.3 EER	9.5 EER
Veg R&D	RTU-R&DV_X	RN-009	9	13.2 EER \ 16 IEER	13.2 EER	9.5 EER
Clone	RTU-C_X	RN-006-3-0	5	13.2 SEER \ 11.4 EER	11.4 EER	9.5 EER
Hardening	RTU-VH	RN-011-3-0	10	12.7 EER \ 15.4 IEER	12.7 EER	9.5 EER

Lighting Notes

No savings were claimed for either the LPD-exempt lighting in grow areas or LPD-compliant lighting in support areas. The application contained some data for the lighting fixtures in the support areas but likely did not result in any savings and was zeroed out. Grow rooms used the baseline HPS and T5HO lighting technologies.

Overall, the HVACD systems, layout, and operation of these sites is very unique and complex. The project was insufficiently documented, and key information was missing like a summary of the HVAC systems and baseline versus efficient parameter comparisons. However, we were able to piece together the key details needed for the evaluation.

Analysis

The evaluation analysis for this project is documented in an engineering analysis Excel workbook.

HVAC Energy Savings. The only issue to address was the flat ex ante baseline efficiency value. A review of the 2015 IECC Standards provided in Figure 8 shows the ex ante value of 9.5 EER was incorrect and appears to be the value used for the largest size category (≥ 760,000 Btu\h) and “all other” heating types (i.e., non-electric heating).

Figure 8. Site 9401 2015 IECC Minimum Equipment Efficiencies[11]

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	
				Before 1/1/2016	As of 1/1/2016
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 12.8 IEER
		All other	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 12.6 IEER
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 12.4 IEER
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 12.2 IEER
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 10.1 IEER	10.0 EER 11.6 IEER
		All other	Split System and Single Package	9.8 EER 9.9 IEER	9.8 EER 11.4 IEER
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 9.8 IEER	9.7 EER 11.2 IEER
		All other	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 11.0 IEER

For the ex post analysis, the spec sheets indicated that all installed units have electric heating, so we assumed the same for the baseline systems and used the system size to determine the correct 2015 IECC efficiency values. The updated ex post baseline efficiency values are summarized in Table 118. Note for SEER-rated equipment, we used the EER values since SEER is not an option in TRACE and for consistency with the installed equipment efficiency approach.

Table 118. Site 9401 HVACD Model Evaluation Updated Efficiencies

Zone/Room	Tag Number (Reference)	Model Numbers	Nominal Tons	Nominal Cooling kBtuh	IECC Size Category	2015 IECC Min Efficiency (Electric Heating)	Ex Post Modeled Baseline Case Efficiency
Flower Rooms	RTU-FX_X	RN-030-3-0	30	360	240-760	10 EER / 11.6 IEER	10 EER
Veg Room	RTU-V_X	RN-050-3-0	50	600	240-760	10 EER / 11.6 IEER	10 EER
Dry Cure Rooms	RTU-DC_X	RQ-003-3-V	3	36	<65	14 SEER / 11.0 EER	11.0 EER
Mother Rooms	RTU-M_X	RN-030-3-0	30	360	240-760	10 EER / 11.6 IEER	10 EER
Flower R&D	RTU-R&DF_X	RN-020-3-0	20	240	240-760	10 EER / 11.6 IEER	10 EER
Veg R&D	RTU-R&DV_X	RN-009	9	108	65-135	11.2 EER / 12.8 IEER	11.2 EER
Clone	RTU-C_X	RN-006-3-0	5	60	<65	14 SEER / 11.0 EER	11.0 EER
Hardening	RTU-VH	RN-011-3-0	10	120	65-135	11.2 EER / 12.8 IEER	11.2 EER

[11] Reference: 2022 TRM Appendix H, 2015 IECC Single-Package & Split System AC Minimum Efficiencies table,

For the ex post TRACE model, we used the verified ex ante installed equipment efficiencies but updated the baseline case equipment efficiencies to those shown in Table 118 Results from the TRACE Project Summary reports for ex ante and ex post models are presented in Figure 9 and Figure 10, respectively.

Figure 9. Site 9401 TRACE Ex Ante Project Summary Report Simulation Results

	Baseline HID Lighting		HID Lighting HE HVAC	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,333,658.00	490.77	1,157,927.00	320.13
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	239,053.60	41.82	178,301.60	28.81
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00
Heating	15,637.91	26.76	3,834.12	25.57
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	2,866,385.00	583.51	2,866,385.00	583.51
Interior Receptacles	76,563.53	11.55	76,563.53	11.55
Pumps	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	**5,531,298.04**	**1,154.41**	**4,283,011.25**	**969.57**

Figure 10. Site 9401 TRACE Ex Post Project Summary Report Simulation Results

	Baseline HID Lighting		HID Lighting HE HVAC	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,263,519.00	474.79	1,157,479.00	320.13
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	238,678.90	41.67	178,340.80	28.75
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00
Heating	15,696.61	26.52	3,896.99	24.61
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	2,862,555.00	582.18	2,862,555.00	582.18
Interior Receptacles	76,563.53	11.55	76,563.53	11.55
Pumps	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	**5,457,013.04**	**1,136.72**	**4,278,835.32**	**967.22**

As previously discussed, the TRACE HVAC enduses are Cooling, Fans, and Heating. There is also a very small difference (about 0.1%) in the Indoor Lighting energy use between ex ante and ex post, although no changes were made to lighting, so this must be due to using the updated TRACE version.

Enduse Energy to Coincident Peak Demand Factor. An additional analysis was performed this year to determine whether an HVAC or Process CF is most appropriate for the project. CF values are applied to the annual energy savings to calculate the peak demand savings. Ex ante savings calculations use the HVAC CF for all projects, but the evaluation team recommended using the Process CF in the PY2021 evaluation report as it should better represent the year-round and relatively flat cooling required for an indoor agriculture facility. The Process and HVAC CFs from the Ameren Missouri TRM are presented in Table 119.[12]

Table 119. Site 9401 TRM Prescriptive Process and HVAC Coincidence Factors

Enduse	Process BUS	HVAC BUS
CF Value	0.0001379439	0.0004439830

To determine which of these CFs is more appropriate for this project, we developed a project-specific CF. We followed the following approach for this analysis:

- The ex post 8,760 hourly building simulation HVAC enduse results for the Efficient Case is the primary data source.
- For calculating the CF, we used all the building simulation HVAC enduses which include Cooling, Heating, and Fans.
- To develop the project-specific CF, we applied the same general approach used for the creation of the original CF factors, where the peak demand is based on the single hour during the year that corresponds to the Ameren Missouri system peak: Day 203, hour 17 (July 22, Hour 17).[13]

Results are summarized in Table 120, which shows that the calculated project-specific CF is between the Process and HVAC CF factors but significantly closer to the Process CF; as a result, we applied a Process CF to estimate ex post demand savings. CF calculation details are available in the evaluation engineering analysis workbook.

Table 120. Site 9401 Peak Demand Coincidence Factor Comparison

Project-Specific Coincidence Factor	Process End Use CF	HVAC End Use CF	Process % Difference	HVAC % Difference
0.0002152778	0.0001379439	0.0004439830	25%	75%

A high-level summary of all ex post changes made versus the ex ante values is provided in Table 121.

Table 121. Site 9401 Key Parameters Summary for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline efficiencies	9.5 EER	10 to 11.2 EER varies by unit size	2015 IECC, electric heating
EEM-1	Installed efficiencies	Varies by model	No change	Manufacturer spec sheets

[12] Appendix G TRM Volume 1, Table 2 "Commercial and Industrial End-Use Category Monthly Shapes and Coincident Peak Factors"
[13] "Ameren Missouri Coincident Peak Demand Quantification Process", January 14, 2016, illustrates and explains the approach used to develop coincidence factors from enduse load shapes.

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Peak demand Coincidence Factor	HVAC endues	Process enduse	Ex post analysis 8,760-hour TRACE model data

Results

Table 122 presents the ex ante and ex post energy and demand savings for this project and the resulting realization rates. There was only a slight reduction in energy savings (94%), but demand savings were significantly impacted by the evaluation with a 29% realization rate.

Table 122. Site 9401 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Packaged / Rooftop Unit	1,248,287	1,178,178	94%	554.22	162.52	29%
Total	**1,248,287**	**1,178,178**	**94%**	**554.22**	**162.52**	**29%**

Reasons for Discrepancies

The ex post change in energy savings was due to updating the baseline efficiencies to reflect 2015 IECC minimum values - 10 to 11.2 EER depending on equipment size category—versus the ex ante value, which was a flat 9.5 EER for all equipment. The significant reduction in peak demand is due to changing the enduse CF from HVAC to Process, which aligns better with the project-specific CF developed by the evaluation.

Other Findings and Recommendations

- **Project documentation is still poorly organized and lacks a project and measure overview.** Project documentation sometimes included multiple files and multiple "final" versions. The evaluation team had to sort and sift through multiple files to determine the correct ones that supported the savings claim and application. Last year, we developed a project documentation memo and checklist. This year, we also allowed time for the implementer and trade ally to reconcile project documentation (in the Captures system) before we pulled project files down. Neither of these approaches seemed to have been adopted. Better coordination between the implementation and trade ally may be needed to ensure interim work products are not a distraction and the true, final documents that support the claimed savings are readily identified.
- **Add a summary of the key HVACD baseline and efficient case parameters.** Efficiency and performance values should be summarized in tables following the examples provided in this site report to facilitate BEM QC by both the implementation and evaluation teams. In addition, the building simulation modeler should consider including screen prints of key system parameters from the TRACE 3D model as part of the project documentation. Furthermore, if HVACD systems that serve support areas are included in the model with **differing** baseline and efficient case parameters, then these values should also be summarized since their impacts are also reflected in the model results.
- **Include and reference TRACE 3D output Project Summary reports in ex ante savings workbooks.** The TRACE 3D "Project Summary" report is always the primary source of HVACD energy savings. For ex ante savings estimates, the results are typically used in a calculation workbook, but the original project summary file is not referenced there and sometimes not even provided in the project documentation;

only the TRACE input file is provided (on the assumption that the report can just be regenerated if needed). Another TRACE output report is sometimes used to develop the total tonnage used in the Quantity field of the program application. We strongly recommend including any TRACE output reports used for ex ante calculations with the project documentation and explicitly referencing the filename in the ex ante calculation workbook.

- **Pre/Post Inspection photos and protocol.** The implementation team should establish and follow a protocol that identifies what photos are needed and how to group or label them in project documentation. A protocol will help both organize photos and clearly show how they are used to satisfy inspection requirements.
- **Consider only modeling the HVACD systems for the grow areas.** While including all grow and non-grow area and energy systems in the TRACE models gives better insight into total facility energy use, modeling just the grow areas when there aren't any measures in the support areas could help simplify the model and reduce the work needed to create the model.
- **Final documentation must include the full address of the facility.** The facility address is needed to confirm equipment shipments on invoices, view the site virtually, and for onsite verification visits. This has not typically been an issue for past projects, but because it was an issue for this project, it would be worth investigating to see if it can be avoided for future projects.

Site 9402 (Custom Indoor Ag)

Project Description

This the final phase of a three phase (Phase 3) project implemented at this indoor cannabis-growing facility. It encompasses 17,547 square feet and includes two flower rooms and one veg room. The measures for this project are LED lighting in the flower rooms and veg room grow areas, and high-performance package DX systems serving the new Phase 3 space. The grow area lighting baselines are high-pressure sodium (HPS) or T5 high-output (T5HO) fluorescent fixtures depending on the grow room type. HVAC energy savings are achieved through improved efficiency of the HVACD system design, reduced cooling capacities from the use of LEDs versus baseline technology lighting systems, and hot gas reheat (HGR) as an integrated HVACD dehumidification feature versus standalone, in-room, lower-efficiency dehumidification devices. A 2018 IECC baseline consistent with the location (St. Louis City in St. Louis City County) was applied to estimate savings for the HVACD systems. Phase 3 is not yet operational though: All the equipment is installed but not operational as it is awaiting a state license before plants can be moved in. Phases 1 and 2 are fully operational but not in scope.

The table below summarizes the tracking data energy efficiency measures, the ex ante gross savings for each, and the total savings claimed for this project.

Table 123. Site 9402 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Packaged / Rooftop Unit	HVAC	1,675,576	743.93
EEM-2 LPD Exempt Lighting	Lighting	2,125,767	403.82
	Total	**3,801,343**	**1,147.75**

Data Collection

Data collection for this project consisted of a desk review of project documentation and on-site verification. The evaluation team reviewed all available project documents to understand the scope of the project and to understand the measures and basis for estimated energy savings. The documentation review included program applications, savings calculation workbook files, invoices, site plans and equipment schedules, HVAC and lighting equipment specification sheets, Trane TRACE® 3D Plus (TRACE) building energy model (BEM) input and output report files, and other supporting documents to determine the specific baseline and proposed equipment and conditions. All of this information was referenced when developing the Excel-based engineering analysis workbook used to estimate ex post savings and document our data review. Key information and project characteristics obtained from the project documentation include the following:

General Notes

- The evaluation team compiled and constructed a project overview from a variety of documents. Every project should have a high-level overview of the project, individual enduse elements (like HVAC and lighting systems), and a summary of the parameters most relevant to characterizing the measures and used to develop the savings estimates.

- This project used a new version of the program application that combines all grow lighting into a single record in the tracking data, even though there are distinctly different fixture and operating characteristics. This reduces traceability and transparency in the tracking data and will make it more difficult to apply and interpret ex post adjustments, as well as identify where implementation and program changes may be needed.
- There are minor discrepancies in the floor areas reported in the project documentation. The application shows 17,547 square feet but the TRACE Project Summary report shows the total building area at 29,864 square feet and conditioned area at 16,330.
- Invoices were used to validate the lighting and HVAC equipment.

HVACD Notes

- The facility is unusual in that it uses multiple HVACD units (sometimes of different sizes) to serve the same room. The HVACD equipment is also unusually located in a mezzanine area above the grow rooms instead of on the roof. All of the units are Desert Aire Grow Aire™ Series Dehumidifier units.
- The ex ante project savings are always derived from the TRACE "Project Summary" output report (examples provided in the Analysis section). Typically, these results are copied to an Excel workbook where the savings are calculated because the project summary does not provide savings, only annual energy use for each scenario. However, none of the TRACE reports were included in the project documentation, only the input files. There were also two TRACE input files in the same directory, and neither was identified as the "final" model.
- The evaluation team also used the TRACE BEM software to complete the following:
  - Rerun the input models and verify the HVACD claimed savings, which are derived directly from one of the BEM output reports. Due to continuous updates of the TRACE tool, older models always need to be converted to the latest version of TRACE, so results can differ slightly from ex ante values. For this specific project, rerunning the model initially provided in the project documentation produced results that differed significantly from the claimed savings. When this discrepancy was raised with the implementation team, they confirmed it was not the final model and provided the correct model. A rerun of this model using the latest TRACE version produced results consistent with ex ante claimed savings.
  - Review and validate the HVACD and lighting parameter values and areas/zones actually used in the models, with a focus on reviewing the HVACD efficiency assumptions, for both the installed and baseline case models. The assumed baseline system efficiencies are not documented in the project documentation and only available via interactive review of the model within TRACE. Screen captures of the HVACD system inputs are included in the engineering analysis workbook.
- Spec sheets were provided for the three unique units, none of which are AHRI-rated. The bottom of each specification sheet contains "Notes" that include a statement with an EER value but the calculations supporting that EER value are not provided, or at least not clearly laid out and readily apparent:
  - Example: The title of the worksheet is "MCA\MFS Calculation Worksheet" and at the bottom of the page is this item in the "Notes" section: "**Equivalent EER Ratio:** 186,000 BTUH Cooling at 21,200 watts is equivalent to 8.8 EER" But there is no reference or direction to the source of either of these values or explanation of the calculation.
  - Note: The implementer provided the evaluation team with new information related to calculating the EER for these units and requested a revision of ex ante savings shortly before the draft report

submission. As stated in the draft report, we revisited savings for this project between submitting the draft and final reports. After further review of the additional information, we determined no changes to ex post savings were necessary.

- Table 124 provides a summary of the HVACD equipment for the three grow rooms, and the room numbers are coded into the tag numbers, for example F5=Flower Room 5. There are three models, ten units total, and a total capacity of 265 tons. This detailed tabulation is a composite of information created from the Mechanical Schedule on the building plans, the invoices, the specification sheets and other project documentation, reconciling discrepancies found between some of the documents, and for the baseline efficiency values we had to extract from the TRACE models as they were not listed anywhere else.
  - Review of the TRACE model revealed that instead of modeling the systems individually, a single composite system was created for each of the three rooms. The composite systems were totaling the cooling tons for each room and using a tons-weighted average efficiency value. This approach is represented by the last three columns in the table that show the capacity and efficiencies of the modeled composite DX systems. This approach is not described anywhere in the project documentation, but using a composite system can be an acceptable approach in some situations.
  - The Equivalent EER values used for the ex ante analysis were consistent with the values on the specification sheet. We also verified the weighted efficiency values were calculated correctly.
  - As for the baseline EER, a 9.7 EER was used for all units, but no explanation was provided for this approach. Given that these units cover three different sizes, there should be three different baseline efficiency values.

Table 124. Site 9402 HVACD System Summary Table

Tag Numbers	Model Number	Quantity	Nominal Tons	Equivalent EER from Spec Sheet	TRACE Model Composite Unit Size	Ex Ante Model Efficient Case Weighted Efficiency (EER)	Ex Ante Model Baseline Case Weighted Efficiency (EER)
DH-V3A	QV30P	1	30	9.5	60	9.5	9.7
DH-V3B	QV30P	1	30	9.5			
DH-F5A	QV30P	1	30	9.5	105	9.4	9.7
DH-F5B	QV30P	1	30	9.5			
DH-F5C	QV15P	1	15	8.8			
DH-F5D	QV30P	1	30	9.5			
DH-F6A	QV30P	1	30	9.5	100	9.41	9.7
DH-F6B	QV10P	1	10	8.6			
DH-F6C	QV30P	1	30	9.5			
DH-F6D	QV30P	1	30	9.5			
	Totals	10	265				

Lighting Notes

Only grow room lighting measures were claimed for this project.

- The single record in the tracking data actually represents three different rooms and fixture counts as show in Table 125. These details are only available on the application.

Table 125. Site 9402 Equivalent Quantity of Baseline Fixtures for A3i 1500W Fixture

Measure	Location	LED Fixture	Quantity
EEM-2A	Flower Room 5	Fluence SPYDR 2i47	338
EEM-2B	Flower Room 6	Fluence SPYDR 2i47	360
EEM-2C	Veg Room	Fluence SPYDR 2x47	249

- The LPD-exempt lighting baseline assumes HPS 1,000W lamp fixture (1,060W) for the Flower and T5HO 4 foot/8-lamp fixtures (432W) for the Veg Room. The ex ante analysis developed an equivalent quantity of baseline fixtures needed to provide the same lighting levels as the LED fixture. The ex ante values are presented in Table 126.

Table 126. Site 9402 Equivalent Quantity of Baseline Fixtures for A3i 1500W Fixture

Location	LED Fixture	Watts	Baseline Fixture Type	Equiv. Baseline Fixture Factor
Flower Room	Fluence SPYDR 2i47	644	HPS 1000W	1.00
Veg Room	Fluence SPYDR 2x47	342	T5HO 4' 8-lamp	2.00

- In reviewing the specification sheets, we found that the ex ante fixture wattages did not match the values provided on the specification sheets in the project documentation.
  - For the Fluence SPYDR 2i47, the ex ante fixture watts is 644W but the specification sheet showed 631W at 277V. For the Fluence SPYDR 2x47, the ex ante fixture watts is 342W but the specification sheet showed 348W at 277V. Most commercial lighting systems operate at 277V.
  - However, for both fixtures, the bottom of the specification sheet had a table that showed fixture wattages at various voltages. These values are presented in Table 127 and the ex ante values are provided in bold text. From this table, it appears the ex ante analysis did not use the 277V values, and instead values for two different voltage ratings were used. This was not explained anywhere in the project documentation. However, the fixture description on the invoice did contain the text "347-480V," indicating the operating voltage was definitely not 277V.

Table 127. Site 9402 Fixture Watts at Different Voltages

Fixture Type	277V	347V	400V	480V
Fluence SPYDR 2i47	631W	648W	645W	**644W**
Fluence SPYDR 2x47	348W	**342W**	341W	NA

Overall, the HVACD systems, layout, and operation of these sites is very unique and complex. The project was insufficiently documented, and key information was missing like a summary of the HVAC systems and baseline versus efficient parameter comparisons. However, we were able to piece together the key details needed for the evaluation.

Onsite Verification Results

The evaluation team conducted the onsite verification on February 6, 2023. Where needed, we prioritized verification of the equipment and areas responsible for the largest portion of project savings. Key findings from the onsite verification include:

- The three phases of the facility were confirmed. Per the site contact, Phases 1 and 2 are fully operational. For Phase 3, all equipment has been installed but the facility is awaiting a state license before plants can be moved in. The onsite report provided a tabulation of canopy area by phase.
- A value of 15,104 square feet was obtained onsite, and the discrepancy was explained as this value perhaps being the canopy square feet.
- The verification team was able to access the BAS system to record HVAC setpoints and toured the interior of the facility to count the lighting, and the HVAC equipment, located on the exterior of the building.
- The onsite verification team confirmed there were no in-room dehumidifiers present in the flower or veg rooms. These also confirmed the HVAC units are located on the mezzanine level in a space adjacent to the grow room and connected via a duct; the dehumidification units are fed by the rooftop package units.
- Duct heaters were observed on all ducts leading to the flower and veg rooms.
- The site contact confirmed there are two units per room; they operate in a lead/lag fashion; and the reason for the small third unit in the flower room was to provide redundancy and reach peak dehumidification when needed while being sensitive to the needs of the (mezzanine) space, which was small.
- The lights in Flower Room 5 and Flower Room 6 were found to be installed but off. There are no plants in either space. Flower Room 5 and Flower Room 6 use a two-tier system. Racks of plants may be compressed like library stacks to conserver space. There is no HVAC equipment in the room besides fans. All HVAC equipment is ducted in from separate rooms located on the mechanical mezzanine level.
- In Veg Room 3, they observed roughly 75 of the 249 lights on and some plants in the room. This area was also awaiting additional licenses. Veg Room 3 is in the shape of an “L” and uses a compressible stack system as well; however, the Veg Rooms have 3 tiers.
- All ex ante lighting fixture quantities in the three grow rooms were confirmed. Flower Room 5 had 2 tiers of 13X13 for a total of 338 fixtures. Flower Room 6 had 2 tiers of 12 X15 for a total of 360 fixtures. The Veg Room was an L-shaped room with three tiers of two arrays: one was a 13X5 matrix and the other was a 9X2 matrix for a total of 249 fixtures.
- Onsite verification staff were able to access the BAS and review the flower and veg room settings (i.e., temperature, humidity, floor heat, dehumidifier settings, etc.), which matched ex ante assumptions. Rooms that were not fully operational had not been completely coded into the BMS; however, the facility manager said the schedules for these rooms would mirror the setpoints for the other phases.
- Extensive photographs were taken of the lighting systems, empty spaces, and HVACD equipment including the chillers, chiller nameplates, air handlers, duct heaters, and dehumidifiers.

Analysis

The evaluation analysis for this project is documented in an engineering analysis workbook. A summary of evaluation team findings is presented in this section for each measure category.

HVAC Energy Savings. The only issue addressed by the evaluation was the flat ex ante baseline efficiency value. A review of the 2018 IECC Standards provided in Figure 11 shows the ex ante value of 9.7 EER was incorrect and appears to be the value used for the largest size category (≥ 760,000 Btu\h) and electric heating type. It also shows there will be significant variation in the minimum efficiency for the 10-, 15-, and 30-ton units at this facility.

Figure 11. Site 9401 2018 IECC Minimum Equipment Efficiencies for [14]

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 12.8 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 12.6 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER	
		All other	Split System and Single Package	10.8 EER 12.2 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER	
		All other	Split System and Single Package	9.8 EER 11.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER	
		All other	Split System and Single Package	9.5 EER 11.0 IEER	

For the ex post analysis, the specification sheets indicated that all installed units have electric heating, so we assumed the same for the baseline systems and used the system size to determine the correct 2018 IECC efficiency values. Updated ex post baseline efficiency values are summarized in Table 128.

Table 128. Site 9402 HVACD Unit Ex Post Updated Baseline Case Efficiencies

Zone/Room	Tag Number (Reference)	Model Numbers	Nominal Tons	Nominal Cooling kBtuh	IECC Size Category	2018 IECC Min Efficiency (Electric Heating)	Ex Post Modeled Baseline Case Efficiency
DH-V3A	QV30P	1	30	360	240-760	10.0 EER / 11.6 IEER	10.0 EER
DH-V3B	QV30P	1	30	360	240-760	10.0 EER / 11.6 IEER	10.0 EER
DH-F5A	QV30P	1	30	360	240-760	10.0 EER / 11.6 IEER	10.0 EER
DH-F5B	QV30P	1	30	360	240-760	10.0 EER / 11.6 IEER	10.0 EER
DH-F5C	QV15P	1	15	180	135-240	11.0 EER / 12.4 IEER	11.0 EER

[14] https://codes.iccsafe.org/content/iecc2018/chapter-4-ce-commercial-energy-efficiency#IECC2018_CE_Ch04_SecC403

Zone/Room	Tag Number (Reference)	Model Numbers	Nominal Tons	Nominal Cooling kBtuh	IECC Size Category	2018 IECC Min Efficiency (Electric Heating)	Ex Post Modeled Baseline Case Efficiency
DH-F5D	QV30P	1	30	360	240-760	10.0 EER / 11.6 IEER	10.0 EER
DH-F6A	QV30P	1	30	360	240-760	10.0 EER / 11.6 IEER	10.0 EER
DH-F6B	QV10P	1	10	120	65-135	11.2 EER/12.8 IEER	11.2 EER
DH-F6C	QV30P	1	30	360	240-760	10.0 EER / 11.6 IEER	10.0 EER
DH-F6D	QV30P	1	30	360	240-760	10.0 EER / 11.6 IEER	10.0 EER

Development of the final capacity-weighted values used for the *composite* HVACD systems modeled in TRACE are summarized in Table 129. All values in the last column are higher than the ex ante baseline value of 9.7 EER.

Table 129. Site 9402 Composite HVACD Model Evaluation Update Efficiencies

Tag Numbers	Model Number	Quantity	Nominal Tons	2018 IECC Ex Post EER	TRACE Model Composite Unit Size	Ex Post Model Baseline Case Weighted Efficiency (EER)
DH-V3A	QV30P	1	30	10.0	60	10.0
DH-V3B	QV30P	1	30	10.0		
DH-F5A	QV30P	1	30	10.0	105	10.14
DH-F5B	QV30P	1	30	10.0		
DH-F5C	QV15P	1	15	11.0		
DH-F5D	QV30P	1	30	10.0		
DH-F6A	QV30P	1	30	10.0	100	10.12
DH-F6B	QV10P	1	10	11.2		
DH-F6C	QV30P	1	30	10.0		
DH-F6D	QV30P	1	30	10.0		

A complete summary of the ex ante and ex post efficiencies used for the composite TRACE models is provided in Table 130. Note the case efficiencies are less than the 2018 IECC minimum, although the installed equipment serves an agricultural load and does not have to be AHRI rated.

Table 130. Site 9402 Summary of Ex Ante and Ex Post Composite HVACD System Efficiency Values

Grow Room	Composite Unit Size	Ex Ante & Ex Post Efficient Case Efficiency	Ex Ante Baseline Case Efficiency	Ex Post Baseline Case Efficiency
Veg Room	60	9.5 EER	9.7 EER	10.0 EER
Flower Room 5	105	9.4 EER	9.7 EER	10.14 EER
Flower Room 6	100	9.41 EER	9.7 EER	10.12 EER

For the ex post TRACE model, we used the verified ex ante installed equipment efficiencies but updated the baseline case equipment efficiencies to those shown in Table 129. We also incorporated into the model the small increase in the Flower Room LED lighting fixture wattage (described in the Grow Room Lighting Savings section). Results from the TRACE Project Summary output reports for ex ante and ex post models are presented in Figure 12 and Figure 13, respectively. Because the TRACE output reports for the ex ante simulation were not included in the project documentation, the results shown are those produced by the evaluation team's rerun of the input file and may be slightly different from ex ante. We do not know what version of TRACE was used for the ex ante calculations because we had to convert the file to run it, but the ex post version is 5.00.123. The Efficient and Baseline scenarios are clearly labeled in both figures, along with some short descriptions of what they represent. Note that the lighting values shown in these simulations are not used for savings claims, though they will typically be very close.

Figure 12. Site 9402 TRACE Ex Ante Project Summary Report Simulation Results

	Baseline		Efficient	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,703,584.00	540.83	1,127,193.00	270.44
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	124,045.70	14.83	21,221.85	3.92
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00
Heating	4,792.12	6.26	8,430.10	52.38
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	4,665,711.00	958.84	2,539,927.00	538.50
Interior Receptacles	296,762.00	34.57	296,762.00	34.57
Pumps	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	**7,794,894.82**	**1,555.34**	**3,993,533.95**	**899.81**

Figure 13. Site 9402 TRACE Ex Post Project Summary Report Simulation Results

	Baseline		Efficient	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,626,121.00	520.81	1,127,987.00	269.06
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	124,045.70	14.83	21,246.77	3.93
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00
Heating	4,792.12	6.26	8,281.26	50.80
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	4,665,711.00	958.84	2,552,156.00	541.29
Interior Receptacles	296,762.00	34.57	296,762.00	34.57
Pumps	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	**7,717,431.82**	**1,535.31**	**4,006,433.03**	**899.65**

The TRACE HVAC enduses for this project are Cooling, Fans, and Heating. The difference in the Interior Lighting energy use is due to the small ex post adjustment to the LED fixture wattage.

Enduse Energy to Coincident Peak Demand Factor. An additional analysis was performed this year to develop project-specific system peak demand CFs, and then using that value to determine whether an HVAC or Process CF is most appropriate for the project. CF values are applied to the annual energy savings to calculate the peak demand savings. Ex ante claims use the HVAC CF for all projects, but a PY2021 recommendation was to consider using the Process CF, as it should better represent the year-round and relatively flat cooling required for an indoor agriculture facility. The Process and HVAC CFs from the Ameren Missouri TRM are presented in Table 107.[15]

Table 131. Site 9402 TRM Prescriptive Process and HVAC Coincidence Factors

Enduse	Process BUS	HVAC BUS
CF Value	0.0001379439	0.0004439830

We followed the following approach for this analysis:

- The ex post 8,760 hourly building simulation HVAC enduse results for the Efficient Case is the primary data source.
- For calculating the CF, we used all building simulation HVAC enduses, which included Cooling, Heating, and Fans.

[15] Appendix G TRM Volume 1, Table 2 "Commercial and Industrial End-Use Category Monthly Shapes and Coincident Peak Factors"

- To develop the project-specific CF, we applied the same general approach used for the creation of the original CF factors including use of a peak demand hour based on the single hour during the year that corresponds to the Ameren Missouri system peak: Day 203, hour 17 (July 22, Hour 17).[16]

Results are summarized in Table 108, which shows the project-specific CF is between the Process and HVAC CF factors but much closer to the Process CF; we therefore applied a Process CF to estimate ex post demand savings. CF analysis details are available in the evaluation engineering analysis workbook.

Table 132. Site 9402 Peak Demand Coincidence Factor Comparison

Project-Specific Coincidence Factor	Process End Use CF	HVAC End Use CF	Process % Difference	HVAC % Difference
0.0001968286	0.0001379439	0.0004439830	**19%**	81%

Grow Room Lighting Savings. Lighting in the grow areas is considered exempt from new construction code LPD requirements. Baselines for these lighting systems are instead based on industry standard practice (ISP), which is primarily HPS or T5HO fixtures depending on the room type and the number of plant tiers (single or 2 to 3 tiers). Table 133 shows the key parameter values used in the estimation of energy savings for the LPD-exempt lighting measures:

Table 133. Site 9402 Ex Ante Parameters for Grow Room Lighting Measures

Measure-Room Type	Baseline				Efficient				
	Fixture Type	Qty	Watt/Unit	Total kW	Fixture Type	Qty	Watt/Unit	Total kW	HOU
EEM-2A Flower Rooms	HPS-1000W	698	1,060	740	Fluence SPYDR 2i47	698	644	450	4,380
EEM-2B Veg Rooms	T5 HO (4ft-8L)	498	432	215	Fluence SPYDR 2x47	249	342	85	6,570

The only ex post lighting adjustments were made to the flower room LED lighting watts per fixture. The watts per fixture for the flower room fixtures (SPYDR 2i47) was increased from 644W ex ante to 648W ex post. As previously discussed, we found the ex ante fixture wattages did not match the specification sheets, and this was likely due to use of non-standard voltage at the facility. Fixture wattages versus voltage are shown again in Table 134. Given the ex ante fixture wattage for the SPYDR 2x47 was 342W, which corresponds to 347V. For consistency for the ex post analysis, we used the 347V wattage for the SPYDR 2i47 fixture which is 648W.

Table 134. Site 9402 Fixture Watts at Different Voltages

Room Type	Fixture Type	277V	347V	400V	480V
Flower Room	Fluence SPYDR 2i47	631W	**648W**	645W	644W
Veg Room	Fluence SPYDR 2x47	348W	**342W**	341W	NA

A high-level summary of ex post changes made versus the ex ante values is provided in Table 135.

[16] "Ameren Missouri Coincident Peak Demand Quantification Process", January 14, 2016, illustrates and explains the approach used to develop coincidence factors from enduse load shapes.

Table 135. Site 9402 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline system efficiency	9.7 EER	Varies by size 10-11.2	2018 IECC
EEM-1	Peak demand Coincidence Factor	HVAC enduse	Process enduse	Ex post analysis 8760 hour TRACE model data
EEM-2	SPYDR 2i47 Installed fixture wattage	644W	648W	Spec sheet fixture wattage @347V

Results

The table below shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 136. Site 9402 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Packaged / Rooftop Unit	1,675,576	1,597,444	95%	743.93	220.36	30%
EEM-2 LPD Exempt Lighting	2,125,767	2,113,538	99%	403.82	401.50	99%
Total	**3,801,343**	**3,710,982**	**98%**	**1,147.75**	**621.85**	**54%**

Reasons for Discrepancies

For the HVAC system, the ex ante approach used a baseline efficiency value that did not appear to be based on size and was just the same value for all HVAC units. In addition, the peak demand coincident factor was adjusted from HVAC to Process which had a significant impact on demand. Only a very minor change was to the lighting fixture wattage that decreased the savings.

Other Findings and Recommendations

- **Consider not claiming a project until the program year that it is expected to be operational.** Phase 3 of this facility was not operational at the time of our onsite verification visit and was on hold until the license was approved. In its current state of non-operation, the project could only be partially verified and also produced no actual savings in PY2022.
- **Lighting detail by grow room should be retained in the tracking data.** The revised application results in a single record that encompasses all grow lighting areas, so the fixture and operating hour differences between the rooms is lost. This will make both tracking and evaluation more difficult, and the realization rate for the individual rooms will be lost. We recommend restoring the room-level detail in the application for more traceable accounting and attribution of lighting discrepancies.
- **Use the LED fixture wattage consistent with lighting system voltage.** LED fixture wattage can vary based on the voltage at which it is operated. Most lighting systems use 277V, and this is the typical voltage used for fixture wattages on manufacture specification sheets. If a facility lighting system voltage is different than 277V, it should be noted in the project documentation.

- **Document and explain any composite HVACD systems used for TRACE.** For all of the grow rooms, the two to four physical HVAC units were rolled into a single "composite" HVAC unit in the building simulation model. This reduction in fidelity can result in a loss of diversity of operation in the model. A brief explanation of the approach used to create the composite system and any calculations should be included with the TRACE models.
- **Always include the final TRACE input file and at least the Project Summary output report in project documentation.** For this project, only the TRACE input file was provided (actually two input files and in the same directory). However, none of the output files were provided. Since the results on the Project Summary report are used directly for HVAC savings, as a minimum, this file should be saved in the project documentation with the final calculations and the associated input file.
- **For non-AHRI rated equipment, always provide documentation and supporting calculations to support claimed HVACD efficiency values**. Because the counterfactual baselines will generally be based on IECC or federal equipment standards, ideally the incentivized equipment would be similarly rated for an apples-to-apples comparison. However, it seems that much of the specialized HVACD equipment is not certified, so it is imperative that any efficiency calculations be documented and traceable. If the calculated custom efficiency values are less than the reference IECC or federal equipment standard values, then consider not providing an incentive for that project or justify the reasoning for doing so.
- **Use the appropriate IECC code, size range and heating type to determine baseline system efficiencies.** On several projects, a single efficiency value was used for all HVACD systems regardless of size or heating type. Ideally the most correct values should be used, and the values that are used should be documented and summarized outside of the TRACE program, perhaps in the calculation workbook used to analyze the TRACE Project Summary results.

Site 9403 (Custom Indoor Ag)

Project Description

This project consists of a 44,177 square-foot new construction, second phase (Phase 2) addition to an existing greenhouse cultivation facility. The structure is a "hybrid" greenhouse that uses natural light admitted through a transparent polycarbonate panel, flat-arch type roof and also artificial lighting. The measures for this project are LED lighting in the flower room and veg room grow areas, and three high-efficiency, heat recovery air-cooled chillers serving the new Phase 2 space. A 2015 IECC baseline consistent with the location (Saint Louis City in Saint Louis County) was applied to estimate savings for the HVACD systems. A 1,000W HPS fixture is the assumed baseline for the grow room lighting. The evaluation was somewhat limited because Phase 2 was not yet operational, as a result of permitting delays, but per the site contact, it was expected to be at full operation by the end of March 2023.

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

Table 137. Site 9403 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Air Cooled Chiller	HVAC	3,635,755	1,614.21
EEM-2 Lighting – Flower & Veg Rooms	Lighting	1,202,879	228.50
	Total	**4,838,634**	**1,842.72**

Data Collection

Data collection for this project consisted of a desk review of project documentation and onsite verification. The evaluation team reviewed all available project documents to understand the scope of the project, the measures, and the basis for estimated energy savings. The documentation review included program applications, savings calculation workbook files, invoices, site plans and equipment schedules, HVAC and lighting equipment specification sheets, Trane TRACE® 3D Plus (TRACE) building energy model (BEM) input and output report files, and other supporting documents to determine the specific baseline and proposed equipment and conditions. All this information was referenced in developing the Excel-based engineering analysis workbook used to estimate ex post savings and document our data review. Key information and project characteristics obtained from the project documentation include the following notes:

General Notes

- This project appears to use a new version of the program application that rolls all grow lighting into a single record in the tracking data, even though there are distinctly different fixture and operating characteristics. This complicates traceability and transparency in the tracking data and will make it more difficult to apply and interpret ex post adjustments, as well as identify where implementation and program changes may be needed.

- There are minor discrepancies in the floor areas reported in the project documentation: the application shows 44,177 square feet, but the building simulation model reports 43,694 square feet in the TRACE Project Summary report.
- This is a very unique facility in that it is a true greenhouse with a transparent roof and typical framework-type structure versus the more typical commercial construction or warehouse building conversions.
- Inspection of satellite photos show two air-cooled package chiller units that serve the existing Phase 1.
- Invoices were used to verify both the lighting and chiller equipment.

HVACD Notes

- The ex ante claim assumed a package DX system as the baseline system. The assumed baseline efficiency values were not reported in the project documentation, but we reviewed the TRACE input model and determined that a 9.5 EER efficiency was used.
- The HVACD system plans confirmed 2015 IECC as applicable to this facility with this note: *"Design and installation in accordance with 2015 International Mechanical Code and the 2015 International Building Code."*
- HVACD system design plans and photos confirm this is a three-chiller plant, these are air-cooled packaged chillers, and the chillers are all the same size and type (Daikin), as shown in Figure 14. The chillers were part of a complete hydronic system designed by "BioTherm".

Figure 14. Site 9403 Mechanical Schedule Chiller Specification

AIR-COOLED CHILLER SCHEDULE			
PLAN REFERENCE	CH-1	CH-2	CH-3
QTY	1	1	1
NOMINAL TONS	201.3	201.3	201.3
EER	9.33	9.33	9.33
IPLV (EER)	16.43	16.43	16.43
COMPRESSOR TYPE	SCROLL	SCROLL	SCROLL
PROP GLYCOL %	30	30	30
COOLING			
GPM	483.6	483.6	483.6
EWT/LWT (°F)	48.0 / 37.0	48.0 / 37.0	48.0 / 37.0
WPD (FT)	11.8	11.8	11.8
AMBIENT TEMPERATURE (°F)	95	95	95
FULL LOAD KW	260	260	260
REFRIGERANT TYPE	R410A	R410A	R410A
REFRIGERANT CHARGE (LBS)	222	222	222
VOLTAGE	460/60/3	460/60/3	460/60/3
MCA/MOP	532 / 600	532 / 600	532 / 600
SHIPPING WEIGHT (LBS)	10,131	10,131	10131
OPERATING WEIGHT (LBS)	11,000	11,000	11000
MANUFACTURER	DAIKIN	DAIKIN	DAIKIN
MODEL NUMBER	AGZ241E	AGZ241E	AGZ241E
ACCESSORIES	1,2,3	1,2,3	1,2,3
ACCESSORIES 1. SINGLE POINT DISCONNECT SWITCH WITH CIRCUIT PROTECTION 2. DACNET MSTP 3. COIL LOUVER GAURDS			

- Only the TRACE input file was provided in the project documentation. None of the TRACE output reports were provided, including the Project Summary report from which the HVAC savings are derived. The

evaluation team successfully converted the input model to the newest version of TRACE and reran the model and obtained results very close to the ex ante values, which confirmed we had the right model.

- The chiller spec sheets contain two efficiency rating values: One rating value shown in Figure 15 appears earlier in the spec sheet and shows a 9.888 EER full load (FL) and 16.43 EER integrated part load value (IPLV). At the bottom of the spec sheet are the AHRI values shown in Figure 16, which list ratings of 10.24 EER FL and 16.43 EER IPLV.

Figure 15. Site 9403 Project Chiller Performance with Glycol Efficiencies

Unit Performance

Design			
Capacity	Input Power	Efficiency (EER)	IPLV.IP* (EER)
219.6 ton	266.5 kW	9.888 Btu/W.h	16.43 Btu/W.h

Figure 16. Project Chiller Performance AHRI-Rated Efficiencies

AHRI Certification

Certified in accordance with the AHRI Air-Cooled Water-Chilling Packages Certification Program, which is based on AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI). Certified units may be found In the AHRI Directory at www.ahridirectory.org. Unit contains freeze protection liquids in the evaporator and is certified when rated per the Standard with water.

Performance at AHRI Standard Condition – with Water

Unit					Evaporator				Condenser	
% Load	Capacity ton	Input Power kW	Efficiency (EER) Btu/W.h	IPLV.IP* (EER) Btu/W.h	Fluid Flow gpm	Pressure Drop ft H_2O	Entering Fluid °F	Leaving Fluid °F	Ambient Air °F	Altitude ft
100	230.0	269.5	10.24	16.43	550.4	10.8	54.00	44.00	95.0	0.000

Note: Performance with water given as reference only to show compliance with AHRI Standard 550/590. Unit will be configured from the factory to support glycol performance as rated. The unit must not operate with water only without consulting the factory.

Lighting Notes

Only grow room lighting measures were claimed for this project, Phase 2 for the facility.

- Phase 2 has only two grow room types: Flower Room and Veg Room.
  - Ex ante assumptions for hours per day of operation are 12 hours (annual is 4,380 hours) for Flower Room and 18 hours (annual is 6,570 hours) for the Veg Room.
- The LPD-exempt lighting baseline assumes HPS 1,000W lamp fixtures (1,060W) for both the Flower and veg rooms and T5HO 4 foot/8-lamp fixtures (432W) for the Veg Room. The ex ante analysis developed an equivalent quantity of baseline fixtures needed to provide the same lighting levels as the LED fixture. The ex ante fixture descriptions are presented in Table 138.

Table 138. Site 9403 Equivalent Quantity of Baseline Fixtures for A3i 1500W Fixture

Measure	Location	LED Fixture	New Qty	New Watts	Baseline Fixture Type	Base Qty	Base Watts	Equiv. Baseline Fixture Factor
EEM-2A	Flower Room	GE Arize L1000 Gen 2	385	625	HPS 1000W	431	1060	1.12
EEM-2B	Veg Room	GE Arize L1000 Gen 2	70	625	HPS 1000W	78	1060	1.11

- The source of the equivalent baseline fixture factors was the *KEM Ag Lighting PPF Equivalent Data.xlsx* workbook provided with the project documentation.[17]

Overall, the HVACD systems, layout, and operation of these sites is unique and complex--and especially unique for this hybrid greenhouse facility.

Onsite Verification Results

The evaluation team conducted an onsite verification on February 7, 2023. Verification staff were directed to verify as many of the verification points as possible but to prioritize the HVACD equipment and areas responsible for the largest portion of project savings. Key findings from the onsite verification include the following:

- The facility has not started operation, and the Phase 2 Flower Rooms were completely empty. Per the site contact, full operation was expected to start in four to six weeks from onsite visit (about mid- to end of March). However, Phase 1 of the facility, which is not in this project scope, was reported as fully operational.
- Total floor area for Phase 2 (this project) was confirmed. The facility is divided into three main sections. The processing and office are one area. The Veg Room is another area, and, finally, the Phase 2 and Phase 2 flower rooms, which are currently separated by a temporary dividing wall that the site contact said will be removed as part of the final operation plan.
- The three Daikin air-cooled packaged chillers serving Phase 2 were observed and confirmed via the nameplates. The chillers were confirmed to serve the Phase 2 Flower Rooms, Veg Rooms, and non-grow areas. Staff also confirmed these are heat recovery chillers and that the three chillers are operated in a typical lead/lag configuration.
- The onsite team also observed the original two chillers used for Phase 1, so there are a total of five air-cooled packaged chillers serving this facility.
- The BioTherm dehumidification/AHUs were observed and confirmed to be served by the central chiller and boiler systems.
- About half the lights were off in the Phase 2 Flower Room, and verification staff were told the lighting was being used at half-power while other equipment was being installed.

[17] The *KEM Ag Lighting PPF equivalent data.xlsx* workbook uses a PPFD-based approach to determine the equivalent number of baseline fixtures needed. One tab is used for Flower Rooms and uses an HPS baseline, another tab is used for veg rooms and uses an 8-lamp T5HO fixture, and the final tab contains the HPS and T5HO PPF basis used to develop the baseline fixture factor. It is a living document that is updated and maintained by the implementer and contains a catalog of the most common LED lighting fixtures.

- Phase 2 Flower Room lighting fixture model and quantities were confirmed. Verification staff confirmed a fixture array of 7X55 Fixtures for a total of 385 fixtures. They were also told that the Phase 1 Flower room was identical to this one. Planned future operation was also confirmed with the site contact to be 12 hours per day or 4,380 hours annually.
- Veg Room lighting fixture model and quantities were also confirmed. Verification staff observed a fixture array of 7 X 10 fixtures for 70 total fixtures. They also noted this is the only veg room and that some plants in the vegetative state were present; however, the room was not filled with plants and was not fully operational. They also observed the room was designed to be a single-tier configuration and noted it would have to be, given the facilities use of natural sunlight in all grow areas. Planned future operation was confirmed with the site contact to be 18 hours per day or 6,570 hours per year.
- Onsite verification staff were able to access the BAS and review the Flower and Veg Room settings (i.e., temperature, humidity, floor heat, dehumidifier settings, etc.), which matched ex ante assumptions.
- Extensive photographs were taken of the lighting systems, empty spaces, and HVACD equipment including the chillers, chiller nameplates, air handlers, duct heaters, and dehumidifiers.

Analysis

The evaluation analysis for this project is documented in an engineering analysis workbook. A summary of evaluation team findings is presented in this section for each measure category.

HVAC Energy Savings. The primary issue for this site was the use of an incorrect baseline HVACD system type for the ex ante approach. Consistent with recommendations from last year's evaluation and with the presence of the chiller system used for Phase 1, the correct baseline to use is a chiller/boiler system.

For the ex post chiller-based baseline system, we used minimum efficiencies consistent with the 2015 IECC energy code. Minimum efficiency requirements for air-cooled chillers are provided in Figure 17.

Figure 17. Site 9403 2015 IECC Minimum Equipment Efficiencies for Air-Cooled Chillers[18]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015		AS OF 1/1/2015		TEST PROCEDURE[a]
			Path A	Path B	Path A	Path B	
Air-cooled chillers	< 150 Tons	EER (Btu/W)	≥ 9.562 FL	NA[e]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15,800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA[e]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air cooled without condenser, electrically operated	All capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				

There are three chillers equal in size: 210 tons nominal rating. The 2015 IECC Path A and Path B minimum efficiency values for this size are summarized in Table 139. For the ex post analysis, Path A values were used as specified in the TRM, but this also makes sense because these systems will likely operate close to full load most hours due to the indoor dehumidification requirements.

[18] Reference: Ameren MO TRM Appendix H, 2015 IECC Chiller Minimum Efficiencies table.

Table 139. Site 9403 HVACD Model Evaluation Updated Efficiencies

Model Number	Nominal Tons	IECC Size Category	2015 IECC Path A (FL/IPLV)	2015 IECC Path B (FL/IPLV)
Daikin AGZ241E	210	≥ 150 tons	≥ 10.100 EER / ≥ 14.000 EER	≥ 9.700 EER / ≥ 16.100 EER

A summary of the ex ante and ex post efficiencies used for the TRACE models is provided in Table 140. The HVACD system type is also noted in parentheses below the values.

Table 140. Site 9403 Summary of Ex Ante and Ex Post HVACD System Efficiency Values

Model Number	Ex Ante Efficient Case Efficiency	Ex Ante Baseline Case Efficiency	Ex Post Efficient Case Efficiency	Ex Post Baseline Case Efficiency
Daikin AGZ241E	9.888 EER FL (chiller)	9.5 EER (package DX)	10.24 EER FL (chiller)	10.100 EER FL (chiller)

Results from the TRACE Project Summary output reports for ex ante and ex post models are presented in Figure 18 and Figure 19, respectively. Because the TRACE output reports for the ex ante simulation were not included in the project documentation, the results shown are those produced by the evaluation team's rerun of the input file so are slightly different from ex ante. We do not know which version of TRACE was used for the ex ante calculations since we had to convert the file to run it, but we confirmed the ex post version is 5.00.123. The Efficient and Baseline scenarios are clearly labeled in both figures. Note the lighting values shown in these simulations are not used for savings claims, though they will typically be very close to the claimed lighting savings.

Figure 18. Site 9403 TRACE Ex Ante Project Summary Report Simulation Results

	Efficient LED CW/HW		Baseline	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,198,147.00	775.41	5,414,174.00	1,967.14
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	1,056,479.00	120.60	1,533,990.00	175.11
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00
Heating	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	1,630,914.00	328.85	2,832,796.00	583.65
Interior Receptacles	75,094.98	8.71	75,094.98	8.71
Pumps	57,785.91	28.96	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	**5,018,420.89**	**1,262.52**	**9,856,054.98**	**2,734.61**

The results also include a "Pumps" enduse, in addition to the usual Cooling, Heating, and Fans enduses used to develop HVAC savings. The lack of Pumps energy use for the ex ante baseline is due to use of a package DX system baseline. The ex post results have Pumps energy use for both the efficient and baseline case.

Figure 19. Site 9403 TRACE Ex Post Project Summary Report Simulation Results

	Efficient LED CW/HW		Baseline CW/HW Path A	
	Energy (kWh)	Demand (kW)	Energy (kWh)	Demand (kW)
Cooling	2,128,795.00	750.16	3,285,234.00	893.49
Exterior Lighting	0.00	0.00	0.00	0.00
Exterior Receptacles	0.00	0.00	0.00	0.00
Fans	1,056,498.00	120.60	1,075,959.00	122.83
Heat Recovery	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00
Heating	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00
Interior Lighting	1,630,914.00	328.85	2,832,796.00	583.65
Interior Receptacles	75,094.98	8.71	75,094.98	8.71
Pumps	57,785.77	28.96	96,999.13	35.59
Refrigeration	0.00	0.00	0.00	0.00
Service Water Heating	0.00	0.00	0.00	0.00
Grand Total	**4,949,087.75**	**1,237.28**	**7,366,083.11**	**1,644.27**

Enduse Energy to Coincident Peak Demand Factor. An additional analysis was performed this year to determine whether an HVAC or Process CF is most appropriate for the project. CF values are applied to the annual energy savings to calculate the peak demand savings. Ex ante savings calculations use the HVAC CF for all projects, but the evaluation team recommended using the Process CF in the PY2021 Evaluation report, as it should better represent the year-round and relatively flat cooling required for an indoor agriculture facility. The Process and HVAC CFs from the Ameren Missouri TRM are presented in Table 141.[19]

Table 141. Site 9403 TRM Prescriptive Process and HVAC Coincidence Factors

Enduse	Process BUS	HVAC BUS
CF Value	0.0001379439	0.0004439830

To determine which of these CFs is more appropriate for this project, we developed a project-specific CF. We followed the following approach for this analysis:

- The ex post 8,760 hourly building simulation HVAC enduse results for the Efficient Case is the primary data source.
- For calculating the CF, we used all the building simulation HVAC enduses, which included Cooling, Heating, Fans, and Pumps.
- To develop the project-specific CF, we applied the same general approach used for the creation of the original CF factors, where the peak demand is based on the single hour during the year that corresponds to the Ameren Missouri system peak: Day 203, hour 17 (July 22, Hour 17).[20]

[19] Appendix G TRM Volume 1, Table 2 "Commercial and Industrial End-Use Category Monthly Shapes and Coincident Peak Factors"
[20] "Ameren Missouri Coincident Peak Demand Quantification Process", January 14, 2016, illustrates and explains the approach used to develop coincidence factors from enduse load shapes.

Results are summarized in Table 142, which shows that the project-specific CF is between the Process and HVAC CF factors but much closer to the Process CF; therefore, we applied a Process CF to estimate ex post demand savings. CF analysis details are available in the evaluation engineering analysis workbook.

Table 142. Site 9403 Peak Demand Coincidence Factor Comparison

Project-Specific Coincidence Factor	Process Enduse CF	HVAC Enduse CF	Process % Difference	HVAC % Difference
0.0002349425	0.0001379439	0.0004439830	**32%**	68%

A high-level summary of all ex post changes made versus the ex ante values is provided in the table below.

Table 143. Site 9403 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Baseline system type	Package DX	Air-cooled Chiller	Phase 1 chiller plant, Indoor Agriculture Baseline Memo
EEM-1	Baseline system efficiency	9.5 EER	10.1 EER	2015 IECC, Path A, Air-cooled chillers
EEM-1	Efficient case system efficiency	9.888 EER	10.24 EER	Full load, AHRI rating per spec sheet
EEM-1	Peak demand Coincidence Factor	HVAC endues	Process end use	Ex post analysis 8,760 hour TRACE model data
EEM-2	Lighting fixture watts, quantities, and annual operating hours	Vary by grow room type	No changes (but facility is not operating)	Onsite verification of installed fixtures but not actual operation

Results

The table below shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 144. Site 9403 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Air Cooled Chiller	3,635,755	1,215,113	33%	1,614.21	167.62	10%
EEM-2 Lighting - Flower & Veg Rooms	1,202,879	1,202,879	100%	228.50	228.50	100%
Total	**4,838,634**	**2,417,992**	**50%**	**1,842.72**	**396.12**	**21%**

Reasons for Discrepancies

All discrepancies were associated with the HVACD system: The ex ante approach incorrectly used a package DX system as the baseline for this central plant chiller/boiler HVACD system. In addition, the correct efficient and baseline chiller efficiencies were not used so had to be adjusted in the ex post analysis. Finally, the peak

demand coincident factor was adjusted from HVAC to Process. No discrepancies were found with the grow room lighting.

Other Findings and Recommendations

- **Consider not claiming a project until the program year in which it is expected to be operational.** This facility was not operational at the time of our onsite verification visit and was not expected to be operational until March of 2023. In its current state of non-operation, the project could only be partially verified and produced no actual savings in PY2022.
- **Consider requesting a preliminary evaluation review of projects with potential issues and those with large savings.** A preliminary review of the project would have identified the baseline issue, although the presence of the existing chillers for Phase 1 should have been all that was needed to show that a DX baseline was not appropriate.
- **The ex ante HVACD baseline should have used a chiller system.** This was a second-phase construction addition for this facility, and Phase 1 was already using a two-chiller system. Using a package DX system is not reasonable when the customer's baseline system is a chiller. In addition, this is a greenhouse with a transparent polycarbonate panel roof not the more typical commercial warehouse building structure where package DX would be commonly used.
- **Lighting detail by grow room should be retained in the tracking data.** The revised application results in a single record that encompasses all grow lighting areas so the fixture and operating hour differences between the rooms is lost. This will make both tracking and evaluation more difficult, and the realization rate for the individual rooms will be lost. We recommend restoring the room-level detail in the application for more traceable accounting and attribution of lighting discrepancies.

Appendix F. Desk Review and Onsite Reports: Retro-Commissioning Program

The evaluation of RCx projects included desk reviews and onsite visits for a sample of 5 projects. The table below summarizes these projects, including their ex ante and ex post savings and estimated realization rates.

Table 145. Summary of RCx 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
9626	Desk review with Onsite Verification	68,617	47,587	69%	9.47	6.56	69%
9627	Desk review with Onsite Verification	26,640	33,154	124%	3.67	4.57	124%
9628	Desk review with Onsite Verification	191,678	176,414	92%	85.10	78.32	92%
9629	Desk review	443,865	421,570	95%	61.23	58.15	95%
9630	Desk review	446,768	493,749	111%	61.63	68.11	111%

Site 9626 (Retro-Commissioning)

This project involved a Retro-Commissioning (RCx) study and leak repair of a compressed air system. The repaired leaks reduced the required cubic feet per minute (CFM), decreasing the amount of energy required by the system. The lower CFM requirement allowed for a restaging of the compressors so that only the more efficient compressor was in use. The table below describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 146. Site 9626 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Compressed Air System Leak Repair	Air compressor	68,617	9.47
	Total	68,617	9.47

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 RCx study of the compressed air system identified the make and model of system components and identified the size and locations of leaks to be repaired. The company conducting the study also metered the air compressors for more than three weeks to provide a picture of system function. CAGI data sheets provided model data for the existing compressors. The evaluation team also conducted a site visit to verify the make and model of the equipment, confirm hours of operation, and ensure the leaks were repaired.

Analysis

Ex ante savings were estimated using a load bin analysis and monitoring data collected during a retro-commissioning study of the site over more than a three-week period in March and April of 2021. The monitoring data included amps and pressure 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 for this project.

The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- Max kilowatt (kW) for the 75HP compressor changed from 69.9 kW to 63.5 kW for the ex post analysis based on the verified operating pressure
- Average kW for the baseline system changed from 65.9 kW to 63.6 kW based on the inclusion of zero airflow data points
- Average CFM for the adjusted system changed from 224 CFM to 284 CFM as a result of the max kW change
- Hours of Operation adjusted to 8,320 hours per year based on the HOU recommended in the AMO TRM

Table 147. Site 9626 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Hours of operation	8592	8320	AMO technical reference manual (TRM)
EEM-1	Compressor max CFM (100HP/75HP)	450/355	450/355	CAGI data sheets
EEM-1	Compressor max kW (100HP/75HP)	82.5/69.9	82.5/63.5	CAGI data sheets
EEM-1	CFM requirements post-leak Repair	224	284	Load bin analysis
EEM-1	CFM lost via leaks	48.5	48.5	Leak log and CAGI reference data

Results

The table below shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 148. Site 9626 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Compressed Air System Leak Repair	68,617	47,587	69%	9.47	6.56	69%
Total	**68,617**	**47,587**	**69%**	**9.47**	**5.72**	**69%**

Reasons for Discrepancies

- The power versus flow curve for the 75HP compressor was adjusted to account for an error in the interpretation of the compressor model data conditions. The model data was collected at the same pressure as that used onsite, so no power rating increase was necessary.
- The hours of operation used by the implementation team do not reflect those recommended for a 24/7 facility. The evaluation team adjusted these hours which reduced the energy savings for the project.

Other Findings and Recommendations

- The calculation of the average kW and CFM required from the system was adjusted so that time periods when the compressors were not drawing power were included when calculating the energy savings. The hours of operation now align with the recommendation of the TRM for 24/7 facilities. To accurately develop an overall average kW draw and CFM requirement over an entire year, all data points collected must be included rather than just those collected when the compressor system is active.

Site 9627 (Retro-Commissioning)

This project involved a Retro-Commissioning (RCx) study and leak repair of a compressed air system. The repaired leaks reduced the required cubic feet per minute (CFM), decreasing the amount of energy required by the system. Table 149 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 149. Site 9627 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Compressed Air System Leak Repair	Air compressor	26,640	3.67
	Total	26,640	3.67

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 RCx study of the compressed air system identified the make and model of system components and identified the size and locations of leaks to be repaired. The company conducting the study also metered the air compressors for one week to provide a picture of system function. Additionally, the evaluation team conducted a site visit to verify the make and model of the equipment, confirm hours of operation, and ensure the leaks were repaired.

Analysis

Ex ante savings were estimated using a load bin analysis and monitoring data collected during an RCx study of the site conducted in 2021. The monitoring data included amps and pressure 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 for this project.

The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- The site visit verified that only one compressor was functioning: the 75 hp compressor. The implementation team believed the 100 hp compressor to be the only compressor functioning.
- The site visit resulted in adjusted operating hours for the system.
- The max kW value for the 75 hp compressor was adjusted to align with the operating pressure of 115 psig rather than the max kW provided under testing conditions at 125 psig.
- The leakage rates were modified based on the operating pressure of 115 psig. The implementation team assumed leak rates associated with a pressure of 100 psig.

Table 150. Site 9627 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Hours of operation	8592	5140	Onsite visit
EEM-1	Compressor max kW	92.6	66.2	Onsite verification and CAGI data sheets
EEM-1	Leak CFM	44.6	50.4	CAGI leak data sheet and leak log

Results

Table 151 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 151. Site 9627 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Compressed Air System Leak Repair	26,640	33,154	124%	3.67	4.57	124%
Total	**26,640**	**33,154**	**124%**	**3.67**	**4.57**	**124%**

Reasons for Discrepancies

- Leak calculations assume an operating pressure of 100 PSI; the site visit shows an operating pressure of 115 PSI. At this increased pressure, the amount of air coming from the leaks is also increased. The values were taken from the Leakage Rate Reference Table.
- The ex ante savings were based on information that the 100 hp compressor had failed, not the 75 hp compressor. During the site visit, the 100 hp compressor was confirmed to be no longer in use; the 75 hp compressor is the sole compressor in use. Thus, the baseline was recalculated using the 75 hp compressor.
- The rated operating pressure of 75 hp compressor is 125 psig. The max kW value was adjusted down to 66.2 to align with a 115 psig operating pressure (1% drop for every two PSI reduced).
- Operating hours follow a clear pattern supported by the site visit. Data and hours of use are adjusted to coincide with those hours.

Other Findings and Recommendations

- N/A

Site 9628 (Retro-Commissioning)

This project involved optimizing the control of HVAC systems in a middle school following a Retro-Commissioning (RCx) study. The RCx measures included optimizing equipment scheduling, reducing minimum supply fan speed, programming static pressure resets, optimizing economizer operation, and lowering hot water pump minimum speed.

Table 152. Site 9628 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Equipment Optimization	HVAC	58,020	25.76
EEM-2 Supply Fan Modification	HVAC	113,194	50.26
EEM-3 Static Pressure Reset	HVAC	15,137	6.72
EEM-4 Economizer	HVAC	3,359	1.49
EEM-5 Hot Water Pumps	HVAC	1,969	0.87
	Total	191,678	85.10

Data Collection

The evaluation team reviewed all available project documents to understand the project scope, including the baseline and proposed equipment and conditions, and the basis for estimated energy savings. Additionally, an onsite visit was performed to verify the impacted equipment, which included 13 rooftop units (RTU) and two hot water pumps (HWP). RCx measure implementation details were verified through review of the building automation system (BAS), with assistance from the Facility Manager.

Analysis

The ex ante project savings were estimated through spreadsheet calculations using weather bin analysis, comparing existing and proposed equipment operation and energy consumption.

The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameters:

- Updated proposed occupancy schedules based on verification findings, resulting in fewer hours overall
- Verified that a static pressure reset was implemented on RTU-12; RTU-12 was not included in the ex ante calculations for this measure
- Cooling savings removed from the EEM-2 calculation

Table 153. Site 9628 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Optimized scheduling-RTU 1--13	RTU 1-13	RTU 1-13	Onsite review; discrepancies in specific hours versus ex ante
EEM-2	Lowered minimum supply fan speed	RTU-1, 2, 3, 5, 7, 12	RTU-1, 2, 3, 5, 7, 12	Onsite review
EEM-3	Static pressure reset schedule	RTU-1, 2, 3, 5, 7	RTU-1, 2, 3, 5, 7, 12	Onsite review

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-4	Adjust economizer setpoint	RTU-1, 2, 7	RTU-1, 2, 7	Ex ante calculations and RCx study; unable to verify
EEM-5	Lower pump speed	HWP-1, 2	HWP-1,2	Onsite review

[a] "Ex Ante" in this context refers to the equipment as described in the ex ante calculations, which sometimes differed from the equipment described in the RCx Study.

Results

Table 154 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 154. Site 9628 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Equipment Optimization	58,020	78,489	135%	25.76	34.85	135%
EEM-2 Supply Fan Modification	113,194	75,813	67%	50.26	33.66	67%
EEM-3 Static Pressure Reset	15,137	14,842	98%	6.72	6.59	98%
EEM-4 Economizer	3,359	5,346	159%	1.49	2.37	159%
EEM-5 Hot Water Pumps	1,969	1,924	98%	0.87	0.85	98%
Total	**191,678**	**176,414**	**92%**	**85.10**	**78.32**	**92%**

Reasons for Discrepancies

- The primary reason for the lower ex post savings is the reduced savings for EEM-2, Supply Fan Modification. The evaluation team determined the ex ante savings model is improperly calculating cooling savings for this measure, which involved lowering the minimum supply fan speed on certain RTUs. The evaluation team believes only fan savings should result from this measure since in the existing situation with a high minimum speed, the compressor would cycle on and off at part-load conditions, reducing the actual operating hours for the compressor such that the cooling energy would be approximately the same in the existing and proposed conditions.

Other Findings and Recommendations

- There are many discrepancies between measures as described in the RCx study versus the ex ante calculations, as well as between the ex ante calculations and implemented measures.

Site 9629 (Retro-Commissioning)

This project involved a Retro-Commissioning (RCx) study and leak repair of a compressed air system. The repaired leaks reduced the required cubic feet per minute (CFM), decreasing the amount of energy required by the system. Table 155 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 155. Site 9629 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Compressed Air System Leak Repair	Air compressor	443,865	61.23
	Total	**443,865**	**61.23**

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 RCx study of the compressed air system identified the make and model of system components and identified the size and locations of leaks to be repaired. The company conducting the study also metered the air compressors for one week to provide a picture of system function.

Analysis

Ex ante savings were estimated using a load bin analysis and monitoring data collected during an RCx study of the site conducted in 2021. The monitoring data included amps and pressure 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 for this project.

The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameter:

- The implementation team used 8760 hours per year for the hours of operation. The evaluation team used 8320 hours per year as recommended by the TRM.

Table 156. Site 9629 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Hours of operation	8,760	8,320	Ameren Missouri TRM
EEM-1	Compressors Total max CFM	8,164	8,164	CAGI data sheets
EEM-1	Compressor max kW	794.2	794.2	CAGI data sheets
EEM-1	CFM requirements post-leak Repair	2,686	2,686	Load bin analysis
EEM-1	CFM lost via leaks	116	115.958	Leak log and CAGI reference data

Results

Table 157 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 157. Site 9629 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Compressed Air System Leak Repair	443,865	421,570	95%	61.23	58.15	95%
Total	**443,865**	**421,570**	**95%**	**61.23**	**58.15**	**95%**

Reasons for Discrepancies

- The evaluation team adjusted the hours of operation to 8320 hours per year to account for holidays and other downtime. This lowered the realization rate for energy and demand savings.

Other Findings and Recommendations

- N/A

Site 9630 (Retro-Commissioning)

This project involved a Retro-Commissioning (RCx) study and leak repair of a compressed air system. The repaired leaks reduced the required cubic feet per minute (CFM), decreasing the amount of energy required by the system. Table 158 describes the energy efficiency measures and ex ante gross savings claimed for this project.

Table 158. Site 9630 Ex Ante Savings Summary

Measure Name	Enduse Category	Ex Ante Gross	
		kWh	kW
EEM-1 Compressed Air System Leak Repair	Air compressor	446,768	61.63
	Total	446,768	61.63

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 RCx study of the compressed air system identified the make and model of system components and identified the size and locations of leaks to be repaired. The company conducting the study also metered the air compressors for one week to provide a picture of system function.

Analysis

Ex ante savings were estimated using a load bin analysis and monitoring data collected during a retro-commissioning study of the site conducted in 2021. The monitoring data included amps and pressure 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 for this project.

The ex post analysis reviewed and adopted the ex ante savings calculation methods but updated the following parameter:

- The implementation team used 8,592 hours per year for the hours of operation. The evaluation team used 8,320 hours per year as recommended by the TRM.

Table 159. Site 9630 Key Parameters for Ex Ante and Ex Post Savings

Measure	Key Parameter	Ex Ante	Ex Post	Ex Post Source
EEM-1	Hours of operation	8,592	8,320	Ameren Missouri TRM
EEM-1	Compressors total Max CFM	8,164	8,164	CAGI data sheets
EEM-1	Compressors total Max kW	1,315	1,315	CAGI data sheets
EEM-1	CFM requirements post-leak Repair	11,884	11,883.1	Load bin analysis
EEM-1	CFM lost via leaks	231	231.53	Leak log and CAGI reference data

Results

Table 160 shows ex ante and ex post energy and demand savings for this project and the resulting realization rates.

Table 160. Site 9630 Evaluation Savings Results

Evaluation Savings Results Measure Name	Annual Energy (kWh)			Demand (kW)		
	Ex Ante Gross	Ex Post Gross	RR	Ex Ante Gross	Ex Post Gross	RR
EEM-1 Compressed Air System Leak Repair	446,768	493,749	111%	61.63	68.11	111%
Total	**446,768**	**493,749**	**111%**	**61.63**	**68.11**	**111%**

Reasons for Discrepancies

- The evaluation team adjusted the hours of operation to 8,320 hours per year to account for holidays and other down time. This lowered the realization rate for energy and demand savings.
- The evaluation team calculated a slightly different leak rate based on a leak rate reference document from CAGI. This resulted in higher energy and demand savings.
- The evaluation team calculated the demand savings using the air compressor coincidence factor rather than the delta in the kW calculated for the purposes of determining total energy savings.

Other Findings and Recommendations

- N/A

Appendix G. Standard and Custom Participant Survey

We conducted a quantitative online survey with Ameren Missouri business customers who participated in the Standard and Custom programs during PY2022. A combined survey was fielded in February 2023. The survey focused mainly on FR, but covered a few process-related topics, including sources of program information, participant satisfaction and material shortages.

The survey sample was designed to allow for the development of separate FR estimates for the Standard and Custom programs. For both programs, we stratified the sample by energy savings. While the sampling unit for this survey was the unique customer contact, the FR questions asked about a specific project completed by that customer. Because many customers had completed more than one project during PY2022, sometimes across more than one BizSavers program, our sampling approach prioritized projects in programs and strata with fewer available sample points, i.e., Custom projects and projects with larger savings.

The sample frame included 918 unique participants. We invited all 918 program participants to participate in the survey via e-mail (i.e., we attempted a census of participants), sending an initial invitation and three reminders. The initial invitation resulted in 38 bounced e-mails and 9 ineligible respondents, giving us a total of 871 valid sample points. Overall, 129 participants completed the survey (98 Standard Program participants and 31 Custom Program participants), resulting in a response rate of 14.8%.

Survey Instrument

PY2022 Ameren Missouri Standard &

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