Public Service Company of Oklahoma
2021 Energy Efficiency & Demand Response Programs: Annual Report

Prepared for:

Oklahoma Corporation Commission

In accordance with annual reporting requirements:
Title 165: Oklahoma Corporation Commission
Chapter 35. Electric Utility Rules
Subchapter 41. Demand Programs
165:35-41-7. Reporting

May 2022

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1 Executive Summary

This report presents an evaluation of the performance of the energy efficiency and demand response programs, also known as the Demand Portfolio, offered by the Public Service Company of Oklahoma (PSO) in 2021. PSO is submitting this report to fulfill the requirements outlined in Title 165: Oklahoma Corporation Commission Chapter 35. Electric Utility Rules Subchapter 41. Demand Programs 165:35-41-7.

On June 29, 2018, PSO filed a comprehensive portfolio of energy efficiency and demand response programs (Portfolio Filing) to the Oklahoma Corporation Commission (OCC) for Program Years 2019 - 2021. This portfolio was approved by the OCC in Cause No. PUD 201800073, Order No. 688452. The focus of this report is participation during the third program year (PY2021) of the implementation cycle, spanning from January 1, 2021, to December 31, 2021. [1]

For the purposes of this report, projected, reported, and verified impacts are defined as follows:

- **Projected Impacts** refer to the annual energy savings (kWh) and peak demand reduction (kW) estimates approved by the OCC as part of PSO's 2019 – 2021 portfolio filed on June 29, 2018 and approved on December 18, 2018.[2]
- **Reported Impacts** refer to annual energy savings (kWh) and peak demand (kW) reduction estimates based on actual customer participation in PY2021 before program evaluation activities.
- **Verified Impacts** refer to energy savings (kWh) and peak demand (kW) reduction estimates for PY2021 developed through independent program evaluation, measurement, and verification (EM&V).

PSO's independent, third-party evaluator, ADM Associates, Inc. (ADM), performed the evaluation, measurement, and verification of PSO's energy efficiency and demand response programs.[3] Verified impacts reflect actual program participation (as opposed to projected participation) and adjust for any findings from ADM's independent evaluation, which includes a detailed review of program materials and calculations, interviews with program participants, and, in some cases, detailed on-site data collection.

All impacts presented in this report represent energy savings or peak demand reduction at-the-meter except for Section 1.4, Appendix B, and Appendix C, where impacts are presented at the generator. At-the-generator impacts are adjusted using an estimated line

[1] All the programs represent program participation from January 1, 2021 – December 31, 2021, except the Energy Saving Products Program. The reported savings for LED retail discounts span the period of December 1, 2020 – November 30, 2021. This offset allows for reconciliation of retail sales data and manufacturer/retailer invoices.
[2] Approved by the OCC in Cause No. PUD 2018000733, Order No. 688452.
[3] A description of ADM and their commitment to safety is included in Appendix H.

loss factor of 1.0586 for energy efficiency and 1.0781 for demand. Program impacts including projected, reported, and verified annual energy savings and peak demand reduction during 2021 are summarized in the following sections.

1.1 2021 Program Offerings

In 2021, PSO offered customers eight energy-efficiency programs that includes five residential, one commercial/industrial, and two cross-sector programs. PSO also offered customers two demand response programs, one residential and one commercial/industrial. Program names, program year start dates, and targeted customer sectors are shown in Table 1-1.

Table 1-1: Program Start Dates

Program	Sector	Start Date
Energy-Efficiency Programs		
Business Rebates	Commercial & Industrial, Small Business	January 1st, 2021
Multifamily	Residential & Commercial	January 1st, 2021
Home Weatherization	Low-Income Residential	January 1st, 2021
Energy Saving Products	Residential	December 1st, 2020
Homes Rebates	Residential	January 1st, 2021
Education	Residential	January 1st, 2021
Behavioral Modification	Residential	January 1st, 2021
Conservation Voltage Reduction	Multiple Classes	January 1st, 2021
Demand Response Programs		
Power Hours	Residential	January 1st, 2021
Peak Performers	Commercial & Industrial	January 1st, 2021

1.2 Summary of Energy Impacts

At the portfolio level, reported annual energy savings for the program year were 142,727 MWh. Total gross verified annual energy savings were 146,054 MWh, resulting in a realization rate for gross energy savings of 102%.

The Net-to-Gross (NTG) ratio indicates the percentage of gross savings directly attributable to program influences. The portfolio-level NTG ratio is estimated as 82%, resulting in a net annual energy savings of 119,321 MWh. Table 1-2 summarizes the energy impacts of PSO’s energy efficiency and demand response programs for the program year.

Table 1-2: Summary of Gross Energy Impacts – PY2021[4]

Program	Gross Annual Energy Savings (MWh)				Net Impacts	
	Projected	Reported	Verified	Gross Realization Rate	NTG Ratio	Net Annual Energy Savings (MWh)
Energy-Efficiency Programs						
Business Rebates	41,671	43,522	43,865	101%	91%	39,816
Multifamily	1,585	4,256	4,355	102%	85%	3,694
Home Weatherization	2,395	4,230	4,228	100%	100%	4,228
Energy Saving Products	32,801	41,780	45,149	108%	52%	23,471
Home Rebates	7,247	7,204	7,100	99%	98%	6,961
Education	4,395	3,547	3,185	90%	100%	3,185
Behavioral	22,680	20,200	18,144	90%	100%	18,144
Conservation Voltage Reduction	15,620	15,970	16,772	105%	100%	16,772
Total – EE Programs	**128,394**	**140,710**	**142,797**	**101%**	**81%**	**116,270**
Demand Response Programs						
Power Hours	2,047	1,255	1,649	131%	87%	1,442
Peak Performers	134	514	1,361	265%	100%	1,361
Total - DR Programs	**2,181**	**1,769**	**3,010**	**170%**	**93%**	**2,803**
Research and Development Programs						
Research and Development	**151**	**248***	**248***	**100%**	**100%**	**248***
Total – R&D Programs	**151**	**248***	**248***	**100%**	**100%**	**248***
Portfolio Totals	**130,726**	**142,727**	**146,054**	**102%**	**82%**	**119,321**

*R&D savings represent savings generated from the Smart Street Lighting Pilot and Pool Pump Demand Response Pilot. Savings generated from the Non-Wires Solution Pilot are represented within the programs Home Weatherization, Home Rebates, and Business Rebates.

1.3 Summary of Peak Demand Impacts

At the portfolio level, reported peak demand reduction in the program year was 119.23 MW. Total gross verified peak demand reduction was 93.15 MW. The realization rate for peak demand reduction was 78%. The portfolio-level NTG ratio for peak demand reduction was estimated as 93%, resulting in a net peak demand savings of 86.91 MW.

[4] Rounding may affect totals and net-to-gross ratio multiplication/division in table.

Table 1-3 summarizes the peak demand impacts of PSO's energy efficiency and demand response programs during the program year.

Table 1-3: Summary of Demand Impacts – PY2021[5]

Program	Gross Peak Demand Reduction (MW)				Net Impacts	
	Projected	Reported	Verified	Gross Realization Rate	NTG Ratio	Net Peak Demand Reduction (MW)
Energy-Efficiency Programs						
Business Rebates	7.52	7.87	8.19	104%	92%	7.51
Multifamily	0.31	1.21	1.19	99%	99%	1.18
Home Weatherization	1.14	2.41	2.41	100%	100%	2.41
Energy Saving Products	3.98	7.81	8.95	115%	42%	3.75
Home Rebates	2.75	3.55	2.96	83%	89%	2.64
Education	0.52	0.73	0.64	88%	100%	0.64
Behavioral	4.12	3.74	3.54	95%	100%	3.54
Conservation Voltage Reduction	4.40	4.58	3.57	78%	100%	3.57
Total – EE Programs	**24.75**	**31.90**	**31.44**	**99%**	**80%**	**25.24**
Demand Response Programs						
Power Hours	20.69	13.83	16.14	117%	100%	16.10
Peak Performers	53.58	73.48	45.56	62%	100%	45.56
Total - DR Programs	**74.27**	**87.31**	**61.71**	**71%**	**100%**	**61.67**
Research and Development Programs						
Research and Development	**0.40**	**0.01***	**0.01***	**100%**	**100%**	**0.01***
Total – R&D Programs	**0.40**	**0.01***	**0.01***	**100%**	**100%**	**0.01***
Portfolio Total	**99.42**	**119.23**	**93.15**	**78%**	**93%**	**86.91**

*R&D Demand Reductions represents savings generated from the Pool Pump Demand Response Pilot. Demand Reduction generated from the Non-Wires Solution Pilot are represented within the programs Home Weatherization, Home Rebates, and Business Rebates.

[5] Rounding may affect totals and net-to-gross ratio multiplication/division in table.

Table 1-4 compares the verified net energy impacts to projected net savings for PSO's programs during the program year. The results indicate verified annual energy and peak demand reduction savings of 119,321 and 86.91, respectively.

Table 1-4: Summary of Net Energy Impacts – PY2021

Program	Projected Net		Verified Net		Percent of Verified/Projections	
	MWh	MW	MWh	MW	MWh	MW
Energy-Efficiency Programs						
Business Rebates	38,009	6.84	39,816	7.51	104%	109%
Multifamily	1,493	0.30	3,694	1.18	248%	397%
Home Weatherization	2,395	1.14	4,228	2.41	177%	211%
Energy Saving Products	14,788	1.79	23,471	3.75	159%	209%
Home Rebates	6,160	2.34	6,961	2.64	113%	113%
Education	3,095	0.36	3,185	0.64	103%	175%
Behavioral	22,680	4.12	18,144	3.54	80%	86%
Conservation Voltage Reduction	15,620	4.40	16,772	3.57	107%	81%
Total – EE Programs	**104,239**	**21.30**	**116,270**	**25.24**	**111%**	**118%**
Demand Response Programs						
Power Hours	1,535	20.69	1,442	16.10	94%	78%
Peak Performers	134	53.58	1,361	45.56	1016%	85%
Total - DR Programs	**1,669**	**74.27**	**2,803**	**61.67**	**168%**	**83%**
Research and Development Programs						
Research and Development	**144**	**0.40**	**248***	**0.01***	**172%**	**2%**
Total – R&D Programs	**144**	**0.40**	**248***	**0.01***	**172%**	**2%**
Portfolio Total	**106,052**	**95.97**	**119,321**	**86.91**	**113%**	**91%**

*R&D savings represent savings generated from the Smart Street Lighting Pilot and Pool Pump Demand Response Pilot. Savings generated from the Non-Wires Solution Pilot are represented within the programs Home Weatherization, Home Rebates, and Business Rebates.

1.4 Summary of Portfolio Benefit-Cost Ratios

ADM calculated the annual cost-effectiveness of PSO's programs based on reported total spending, verified net energy savings, and verified net demand reduction for each of the energy efficiency and demand response programs. Additional inputs to the cost effectiveness tests included estimates of natural gas savings, line-loss adjustments, emissions reductions, measure lives, discount rates, participant costs, and avoided costs. All program spending inputs were provided by PSO as shown in Appendix B. The total portfolio spend was $34,154,741. The methods used to calculate cost-effectiveness were informed by the California Standard Practice Manual. [6]

The specific tests used to evaluate cost-effectiveness for the Oklahoma Corporate Commission are the Utility Cost Test and the Total Resource Cost Test. The benefit-cost ratios for those tests as well as the Rate Payer Impact Test, the Societal Cost Test, and the Participant Cost Test are presented in Table 1-5. Detailed cost-effectiveness assumptions and findings are presented in Appendix B.

[6] California Standard Practice Manual: Economic Analysis of Demand Side Management Programs, October 2001. Available at: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/CPUC_STANDARD_PRACTICE_MANUAL.pdf.

Table 1-5: Benefit-Cost Ratios

Program	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost Test	Participant Cost Test
Energy-Efficiency Programs					
Business Rebates	3.42	2.46	0.76	2.82	3.48
Multifamily	2.58	3.62	0.67	4.23	5.38
Home Weatherization	2.06	2.97	0.79	3.57	3.91
Energy Saving Products	6.49	7.31	0.60	11.95	24.37
Home Rebates	1.30	1.78	0.56	2.17	3.40
Education	2.20	2.41	0.58	2.70	4.07
Behavioral	1.22	1.28	0.44	1.28	-
Conservation Voltage Reduction	1.34	1.47	0.57	1.86	-
Total - EE Programs	**2.13**	**2.16**	**0.65**	**2.67**	**5.37**
Demand Response Programs					
Power Hours	2.16	2.29	1.22	2.36	8.66
Peak Performers	2.51	7.18	2.42	7.18	4.19
Total - DR Programs	**2.39**	**4.23**	**1.84**	**4.27**	**5.10**
Research and Development Programs					
Research and Development	**1.43**	**1.04**	**0.44**	**1.22**	**3.47**
Total - R&D Programs	**1.43**	**1.04**	**0.44**	**1.22**	**3.47**
Portfolio Total	**2.15**	**2.26**	**0.72**	**2.74**	**5.36**

Portfolio performance can also be reviewed on a levelized dollar per energy savings (kWh) or dollar per peak demand reduction (kW) basis. Energy-efficiency programs are designed to reduce energy usage while providing the same or improved service to the end-user in an economically efficient way, regardless of whether energy usage occurs during peak or non-peak periods. Energy savings occur for the lifetime of the energy efficiency measures installed. As such, program performance was assessed on a levelized dollar per lifetime energy savings (kWh) basis for energy-efficiency programs. Levelized cost in $/kWh is calculated as shown in the formula below:

Equation 1-1: Levelized Cost ($/kWh)

$$Levelized\ Cost\ (in\ \$/kWh)\ =\ C\ x\ Capital\ Recovery\ Factor\ /\ D$$

$$Capital\ Recovery\ Factor =\ [A * (1 + A)\hat{}(B)]/[(1 + A)^{B} - 1]$$

Where:

A = Societal Discount rate (5%)

PSO WACC Discount Rate (7.35%)

B = Estimated measure life in years[7]

C = Total program costs

D = Annual kWh savings

Table 1-6 shows how PSO's portfolio of energy-efficiency programs performed on a levelized cost basis for the program year from a societal (5% discount rate) and a weighted average cost of capital (WACC) (7.35% discount rate) based calculations. The verified net lifetime energy savings in Table 1-6 are at the generator and include a line loss adjustment factor of 1.0586.

Table 1-6: Levelized $/kWh for Energy-Efficiency Programs[8]

Program Year	Total Costs	Verified Net Lifetime Energy Savings (kWh)	Levelized $/kWh	Verified Net Lifetime Energy Savings (kWh)	Levelized $/kWh
		Societal Discount (5%)		Weighted Average Cost of Capital Discount (7.32%)	
2021 Residential[9]	$16,969,400	$393,899,834	$0.043	$342,753,229	$0.050
2021 Commercial[10]	$11,184,264	$420,805,452	$0.027	$364,332,294	$0.031
2021 CVR	$16,014,808	$250,231,915	$0.064	$201,074,136	$0.080
2021 EE Programs	**$44,168,472**	**$1,064,937,201**	**$0.041**	**$908,159,659**	**$0.049**

Demand response programs are designed to encourage customers to change their normal consumption patterns during periods when prices are high, or system reliability is potentially constrained. These programs encourage load reduction during a short period of time, usually a limited number of days during the summer. As such, demand response program performance was assessed on a peak demand reduction (kW) per dollar basis. Table 1-7 shows how PSO's portfolio of demand response programs (Peak Performers and Power Hours) performed on a $/kW reduction basis for the program year. The verified net peak demand reduction in Table 1-7 includes a line loss adjustment factor of 1.0781.

Table 1-7: $/kW for Demand Response Programs

Program Year	Total Costs	Verified Net Peak Demand Reduction from DR (kW)	$/kW
2021	$4,417,586	66,891	$66.04

[7] Calculated as described in Appendix B.
[8] Lifetime savings reduced by 5% societal discount or weighted average cost of capital discount factor.
[9] Residential Programs include Home Weatherization, Home Rebates, Energy Savings Products, Education, and Behavioral.
[10] Commercial Programs include Business Rebates and Multifamily.

1.5 Cumulative Portfolio Performance

This was the third program year for the 2019 – 2021 Demand Portfolio. Portfolio level energy and demand impact estimates for the program year and historical years are shown in Table 1-8.

Table 1-8: 2019 - 2021 Portfolio Performance – Verified Energy and Peak Demand Impacts

Program Year	Verified Gross Annual Energy Savings (GWh)	Verified Net Annual Energy Savings (GWh)	Verified Gross Peak Demand Reduction (MW)	Verified Net Peak Demand Reduction (MW)
Energy-Efficiency Programs				
2019	159.20	132.69	29.81	25.16
2020	151.59	129.40	32.14	27.77
2021	142.80	116.27	31.44	25.24
Cumulative EE Totals	**453.59**	**378.35**	**93.39**	**78.17**
Demand Response Programs				
2019	2.92	2.57	63.66	63.66
2020	2.81	2.47	53.65	53.60
2021	3.01	2.80	61.71	61.67
Cumulative DR Totals	**8.74**	**7.85**	**179.02**	**178.93**
Research and Development Programs				
2019	0.00	0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00
2021	0.25	0.25	0.01	0.01
Cumulative R&D Totals	**0.25**	**0.25**	**0.01**	**0.01**
Cumulative Portfolio Totals	**462.58**	**386.45**	**272.42**	**257.11**

1.6 Summary of Overall Program Satisfaction

Participants from each program were surveyed about their satisfaction with their overall experience with the program. In general, participant satisfaction for the program year is estimated at 87%.[11] Participant satisfaction results by program are summarized in Table 1 9. Process evaluation findings by program are presented in Chapters 3 and 4 of this report.

Table 1 9: Overall Program Satisfaction Reported by Program Participants

Program	Percent Satisfied
Business Rebates – Prescriptive and Custom	97%
Business Rebates – SBES	100%
Multifamily[12]	83%
Home Weatherization	96%
Energy Saving Products	74%
Homes Rebates - Single Upgrades	89%
Homes Rebates - Multiple Upgrades	94%
Homes Rebates – New Homes[13]	89%
Education[14]	91%
Behavioral[15]	79%
Power Hours	61%
Peak Performers	91%

[11] Program participants that report being either somewhat satisfied or very satisfied with the overall program they participated in.
[12] Percent of owners/managers that reported being somewhat satisfied or very satisfied with the overall PSO Multifamily program.
[13] Percent of builders that reported being somewhat satisfied or very satisfied with the PSO New Homes program.
[14] Percent of teachers that would participate again in the program if asked to.
[15] Percent of program participants that reported being somewhat satisfied or very satisfied with the combined aspects of the Home Energy Report.

2 Introduction

This report presents an evaluation of the performance of the energy efficiency and demand response programs offered by Public Service Company of Oklahoma (PSO) in 2021. PSO is submitting this report to fulfill the requirements outlined in Title 165: Oklahoma Corporation Commission Chapter 35. Electric Utility Rules Subchapter 41. Demand Programs 165:35-41-7.

PSO contracted with ADM to perform comprehensive program evaluation, measurement, and verification (EM&V) for PY2021. ADM's evaluation findings for each energy-efficiency program are provided in Chapters 3 of this report, evaluation findings for the demand response program are provided in Chapter 4, and evaluation findings for pilot programs are provided in Chapter 5.

Table 2-1 summarizes program-level participation, program contribution to portfolio-level savings, and number of measures offered.

Table 2-1: Program Level Participation

Program	% Of Portfolio Savings (Reported)	Participants*	Number of Measure Types
Business Rebates	30.49%	1,414	26
Multifamily	2.98%	3,063	17
Home Weatherization	2.96%	2,214	9
Energy Saving Products	29.27%	2,155	15
Home Rebates	5.05%	3,715	16
Education	2.48%	15,782	5
Behavioral	14.15%	174,380	1
Conservation Voltage Reduction	11.19%	29,385	1
Cumulative EE Totals	**98.59%**	**232,108**	**90**
Power Hours	0.88%	23,891	2
Peak Performers	0.36%	1,834	1
Cumulative DR Totals	**1.24%**	**25,725**	**3**
Cumulative R&D Totals	**0.17%**	**136**	**33**
Cumulative Portfolio Totals	**100%**	**257,969**	**126**

*Participants represents a residence or business who participated as opposed to the number of measures or projects. For Energy Saving Products, the actual number of customers is unknown and instead this count is of unique customers that received rebates for qualifying downstream measures. ESP in total rebated 1,012,363 products.

2.1 Reduced Emissions and Water Consumption

Reduced emissions occur as the result of energy savings achieved through PSO's Demand Portfolio displacing marginal fossil fuel based electric generation. The EPA's Emissions and Generation Resource Integrated Database (eGRID) is a comprehensive source of emissions data related to the electric power sector in the U.S. The technical support document for eGRID, based on 2018 data, was released in January of 2019, and revised in March of 2019. Included in the database are estimates of non-baseload emission rates for various greenhouse gasses in different sub regions of the country. The PSO service territory falls into eGRID sub region SPP South (SPSO). Table 2-2 below lists the most recent eGRID non-baseload output emission rates for SPSO.

Table 2-2: Generation Resource Integrated Database Greenhouse Gas Annual Output Emission Rates

eGRID Sub region	Annual Non-baseload Output Emission Rates		
	Carbon dioxide (CO_2) (lb/MWh)	**Methane (CH_4) (lb/GWh)**	**Nitrous oxide (N_2O) (lb/GWh)**
SPP South (SPSO)	1,662.55	121	19

Using the eGRID emission rates and lifetime energy savings for measures installed through the PSO Demand Portfolio in 2021 results in the estimated emissions reductions listed in Table 2-3.

Table 2-3: Emission Reduction Estimates

Lifetime Energy Savings (Net at Generator) (MWh)	Carbon dioxide reduction (CO_2) (tonnes)	Methane reduction (CH_4) (tonnes)	Nitrous oxide reduction (N_2O) (tonnes)
1,532,937	1,156,016	84	13

Reductions in water consumption at participant homes/facilities resulting from PSO's 2021 portfolio of programs were not tracked. Many of the energy efficiency measures commonly associated with water savings in the residential sector (faucet aerators, low flow shower heads, efficient clothes washers, dishwashers, etc.) were limited in the portfolio design because of the high prevalence of natural gas water heating in the PSO service territory. The Business Rebates Program does offer incentives for measures that have water saving potential for C&I customers (e.g., variable frequency drives on pump motors). The effects on water consumption for these measures were not quantified for PY2021.

There are also water savings associated with reduced energy generation attributable to PSO's energy efficiency and demand response programs. PSO's generation fuel mix in

2021 was made up of coal (11%), natural gas (19%), purchased power non-wind (46%) and wind (24%).

All non-wind generation fuel sources are used in thermoelectric power plants which boil water to create steam, which in turn drives turbines. After the steam passes through a turbine, it is cooled so that it condenses, and the water can be reused. The process of cooling the steam accounts for almost all water use in most thermoelectric power plants, as the steam itself circulates in a closed system. A portion of the water used for this cooling process is lost to evaporation. The specifics regarding how much water is consumed in the process depend largely on the technologies used in each power plant (once-through water cooling, recirculating water cooling, dry-cooling).

A 2003 report by the National Renewable Energy Laboratory (NREL) provides estimates of water consumption per MWh of energy consumed for all U.S. states. The estimate in Oklahoma is 510 Gallons per MWh consumed. Using the NREL water consumption estimates and lifetime energy savings for measures installed through the PSO Demand Portfolio in 2021 results in the lifetime water savings estimates listed in Table 2-4.

Table 2-4: Water Savings Estimates, Thermoelectric Generation

Lifetime Energy Savings (Net at Generator) (MWh)	Overall Generation Percentage Thermoelectric	Water Consumption per MWh Consumed (Gallons/MWh)	Lifetime Water Savings (Gallons)
1,533,603	78%	510	610,067,428

2.2 Milestones Achieved in Market Transformation Programs

While eight of PSO's energy-efficiency programs are designed primarily as energy efficiency resource acquisition programs, there are some market transformation characteristics, briefly summarized below.

Energy Saving Products (ESP) Program: The main component of the ESP Program in 2021 was retail markdowns of certain LED light bulbs. The goal of the markdowns is to increase sales to customers who would have otherwise purchased less efficient options in the absence of the price discount. These programs have long been considered to have market transformation effects in terms of retailer stocking decisions and manufacturer shipment decisions.

Starting in 2019, PSO expanded their offerings to include rebates for Level 2 electric vehicle chargers as well as point of sale discounts on an assortment of home maintenance measures (door sweeps, door seals, air filters, and spray foam). The addition of these measures is an example of how PSO continues to transform the market by affecting customer purchasing decisions.

Home Rebates – New Homes: The program provides educational trainings for both builders and raters that influence energy efficiency offerings in building performance and new homes. During 2021, the program offered no cost HERS ratings to builders who were not yet participating in a home energy rating program.

Commercial Midstream: During 2019 PSO added a midstream commercial program offering. Midstream programs provide opportunities for market transformation by increasing stocking of energy efficient equipment options by participating distributors. Stocking can be increased either directly through the provision of stocking incentives or indirectly through reducing the cost of more expensive efficient equipment, and in that way, reduce the amount of capital the distributor has tied up in stock. Midstream programs leverage distributors to educate end-users and purchasers.

Service Provider Recruitment and Training: PSO's Business Rebates and Home Rebates programs include service provider training opportunities that focus on increasing awareness and knowledge of building science approaches to energy efficiency. This aspect of the programs has potential market transformation effects beyond the energy savings induced through the program. For a complete list of service provider training events refer to Appendix E. Service provider participation continues to grow for the Business Rebates Program.

2.3 Annual Utility Growth Metrics and Portfolio Ratios

The Oklahoma Title 165:35-41-7 reporting rules provide guidance for providing context on the utility load growth and the Demand Portfolio relative to load and revenue. Table 2-5 shows weather-normalized annual growth rates for PSO's total utility energy sales, distribution, and peak demand, for the program year as well as the previous two years.

Table 2-5: Utility Growth Rates 2019 – 2021

Year	Net Sales (GWh)	Sales Growth	Energy at Generator (GWh)	Energy Growth	Peak Demand (MW)	Demand Growth
2019	18,662	-1.14%	19,775	-0.91%	4,104	-0.08%
2020	17,668	-5.33%	18,782	-5.02%	3,884	-5.37%
2021	18,294	3.55%	19,283	2.66%	4,042	4.09%
Compound Growth Rate	-0.99%		-1.25%		-0.75%	

Table 2-6 and Table 2-7 show weather-normalized annual growth rates and 2019 - 2021 compound growth rates (CPGR) for utility energy sales by customer class.

Table 2-6: 2019 – 2021 Weather Normalized Retail Meter Sales

	Residential		Commercial		Industrial		Other Retail		Total Retail		FERC	
Year	GWh	%Chg	GWh	%Chg	GWh	%Chg	GWh	%Chg	GWh	%Chg	GWh	%Chg
2019	6,136	0.26%	4,931	0.27%	6,156	0.52%	1,240	1.02%	18,463	0.12%	8	-6.06%
2020	6,336	3.27%	4,712	4.45%	5,711	7.23%	1,202	3.08%	17,961	2.72%	8	-0.27%
2021	6,325	-0.18%	4,931	4.67%	5,834	2.16%	1,224	1.79%	18,314	1.97%	8	-0.99%
CPGR	1.53%		0.01%		2.65%		0.67%		0.40%		0.63%	

Table 2-7: 2019 – 2021 Total System Weather Normalized Retail Meter Sales

	Total System	
Year	**GWh**	**%Change**
2019	18,472	0.11%
2020	17,969	-2.72%
2021	18,323	1.97%
Compound Growth Rate	-0.40%	

Table 2-8 shows 2021 Demand Portfolio funding as a percent of total annual electricity revenue.

Table 2-8: 2021 Demand Portfolio Funding

Funding	Value
2021 Demand Portfolio Program Cost ($M)	$34.2
2021 Operating Revenues ($M)	$1,501.3
Program Cost as % of Utility Operating Revenue	2.3%

Table 2-9 shows 2021 Demand Portfolio net energy savings as a percent of total annual energy sales.

Table 2-9: 2021 Demand Portfolio Energy Savings

Metric	Value
2021 Demand Portfolio Net Energy Savings (GWh)	119
2021 Metered Energy Sales (GWh)	18,294
Savings as % of Utility Sales	0.65%

2.4 High-Volume Electricity User Opt Out

The Oklahoma Title 165:35-41-4 rules allow for High-Volume Electricity Users "to opt out of some or all energy efficiency or demand response programs by submitting a notice of such decision to the director of the Public Utility Division and to the electric utility." A High-Volume Electricity User is defined as any single customer that consumes more than 15 million kWh of electricity per year, regardless of the number of meters or service locations. The number of customers eligible for High-Volume Electricity User opt out, their aggregate load as a percentage of total sales, the number of such customers that opted out of energy-efficiency programs for the program year, and the opt out percentage of total energy sales.

Table 2-10: High-Volume Electricity User Opt-Out – Energy Efficiency

Metric	2021	
	Opt-Out Eligible	Chose to Opt-Out -EE
Number of accounts	7,817	4,173
2021 Electric Sales (GWh)	7,031	6,415
Aggregate load as a percentage of total sales	38.4%	35.1%

Table 2-11 provides a summary of high-volume customers who opted out of demand response programs.

Table 2-11: High-Volume Electricity User Opt-Out – Demand Response

Metric	2021	
	Opt-Out Eligible	Chose to Opt-Out -DR
Number of accounts	7,817	4,002
2021 Electric Sales (GWh)	7,031	5,996
Aggregate load as a percentage of total sales	38.4%	32.8%

2.5 Fuel Switching Impacts

PSO did not provide incentives for installation of electric heating or electric water heating to replace natural gas fueled equipment during the program year. A review of the program tracking data found no instances in which natural gas equipment were replaced with electric equipment that was rebated through a PSO program.

2.6 Program Implementation & Strategic Alliances

PSO has ten full-time employees dedicated to the implementation of energy efficiency and demand response programs. Additionally, PSO entered contracts with several energy services companies (ESCOs) and contractors to aid in program implementation. A complete list of implementation contractors, including contact name, title, business address, phone number, email address, and program associations, is provided in Appendix D.

ICF International (ICF) was contracted to implement the Business Rebates and Home Rebates Programs. CLEAResult was contracted to implement the ESP Program. The Home Weatherization Program was largely implemented by Titan ES, LLC, with some program participation also coming through Revitalize T-Town, a volunteer organization working to preserve and revitalize low-income homes and communities. PSO contracted with AM Conservation to provide energy-efficiency kits distributed through the Education Program. At PSO's direction, load management events were initiated through the Demand Response Automation Server (DRAS) maintained by Honeywell, the third-party implementer for the Power Hours Program. Finally, the Peak Performers program was implemented "in-house" by PSO, with database support provided by AEG. Additional customer engagement materials and services for the entire portfolio of programs were provided by Medium Giant, formerly known as Belo. Examples of creative content materials used during the program year to promote PSO's energy efficiency and demand response programs are provided in Appendix F.

For most programs in the program year portfolio, service providers were recruited to participate by submitting rebate applications on behalf of customers implementing qualifying energy efficiency measures. PSO's website contains lists of registered service providers and the associated products/services they provide.

2.7 Training and Customer Outreach

PSO regularly conducts various service provider training and customer outreach events, which are summarized in Appendix E. During the program year, PSO's energy efficiency and demand response programs sponsored:

- 48 in-store residential lighting promotional events
- 51 other customer outreach and service provider training events, including:
  - Portfolio overview presentations
  - Program specific service provider training
  - One-on-one presentations with potential participants
  - Trade show and event booths promoting the portfolio

2.8 Summary of Process Evaluation Findings

During the third and fourth quarters of the program year, ADM completed surveying and interview efforts for the process evaluation. Program participants, service providers, and program staff were largely satisfied with the program year portfolio offerings. Key process evaluation-related findings are summarized below. Additional findings are presented in Chapters 3 and 4.

2.8.1 Business Rebates

The business rebates program includes Prescriptive and Custom, Small Business Energy Solutions, and Commercial Midstream.

2.8.1.1 Prescriptive & Custom

- The program was able to sustain a high level of program savings given some of the challenges implementation faced in 2020 and continued into 2021. Verified gross energy impacts were slightly higher than estimated. Net annual energy savings for the program year are 27,781,415 kWh for an overall net realization rate of 90%.
- Lighting projects continue to contribute most to program level energy savings, but the wide range of offerings presents many opportunities for customers.
- Evaluation risk was found for measures. Indoor agriculture grow lighting and multiple measure projects represent the largest project level realization rate risk. Multiple measure projects such as sites that had controlled environment agricultural-lighting and HVAC. In those cases, the driver of the evaluation risk was the lighting. Nevertheless, studies show this industry historically has many energy efficiency opportunities in need of transformation.
- Participant surveys indicate there is an opportunity to improve the Custom and Prescriptive design and application process. Forty percent of respondents recommended improving the application process.
- Most program participants indicated that the COVID-19 pandemic had affected their company adversely, though the majority stated it had not affected their ability to take advantage of PSO's rebates or incentives.
- Trade ally surveys suggest there is room to grow program awareness for the Prescriptive and Customer programs.
- Trade allies were largely satisfied with program administration and design, though they offered several recommendations for program improvement.
- Survey and staff discussion findings indicate PSO Business Energy Coaching program delivers useful energy analysis and usage information to customers but ensuring customers complete recommended actions can be a challenge.
- The Energy Coaching customer journey is well understood, but there are opportunities to develop the participation process and add additional touchpoints.
- Consistent with past program years, satisfaction remains high. Most survey respondents shared high levels of satisfaction across all aspects of the program as well as the programs overall.

2.8.1.2 Small Business Energy Solutions (SBES)

- Energy impact goals were met for the program year with net verified annual energy savings exceeding the reported estimates. Lighting projects made up 97% of program annual energy savings with the remaining 3% from refrigeration measures.
- Program tracking and quality control remained consistent with previous program years and there were no issues reported with the current system for data tracking or quality control.
- Survey and interview findings indicate that contractors and vendors were the most frequent source of program awareness and the most important source of influence on customers' decision to participate.
- Findings from trade ally and staff interviews indicate the program was able to maintain strong participation in 2021, building upon past year's successes and outreach methods.
- Consistent with past program years, program satisfaction remains high. Most survey respondents shared high levels of satisfaction across all aspects of the program as well as the programs overall.
- Some SBES participants noted possible areas for program improvement including increasing communication from PSO and providing additional information about other rebate programs.
- Most program participants indicated that the COVID-19 pandemic had affected their company adversely.

2.8.1.3 Commercial Midstream

- The Midstream subprogram more than doubled in participation and annual energy savings per participant from the previous year. An increase was expected as we return to normalcy from COVID-19, however, the previous year's program saw an increase despite the pandemic.
- Findings from ADM's facilitated discussion with PSO and ICF staff as well as lighting distributor interviews suggest there is an opportunity to expand Midstream lighting offerings to reach a larger segment of PSO's commercial customers as well as sell more efficient products.
- The program discounts act as motivation for most customers, but survey results suggest a portion of the Midstream lighting and HVAC customers would purchase energy efficient equipment without the program.

- There is an opportunity for program staff to increase coordination or collaboration with Lighting distributors. The lighting distributors mentioned two opportunities to increase program support:
    - Engagement with staff earlier in the year to ensure a timely launch.
    - Working with staff to ensure customers do not engage in “rebate shopping”.
- Distributors indicate some frustration with the incentive process that may present an opportunity for improved program performance.
- External factors may play an increasing role in the program’s future performance due to continued supply chain issues, increasing equipment costs, and federal requirements for baseline efficiency ratings.

2.8.2 Multifamily

- The program is driven by repeat direct participants as well as recruitment from service providers and word-of-mouth referrals from past participants. Decisionmaker survey responses suggest that the program’s service providers and staff play a crucial role in recruiting participants. During the customer journey map facilitated discussion, the program staff confirmed that the awareness generated from their initial outreach in PY2019 had led to continued interest and awareness in PY2021 from multifamily property owners and managers.
- Duct sealing was the largest contributor with program savings (45% of program portfolio) with retrofit lighting a second. However, there is a diversification of lighting related measures that could be expanded on in the future (lighting controls, New Construction lighting).
- Incentivized measures offered by the program have expanded from the previous year, but new additions to the program have minimal impact on program savings. There have been multiple measures that have appeared for the first time this year, and some from last year weren’t present.
- Staff interviews indicate that the program was successfully promoted in 2021; however, findings from ADM’s service provider interviews suggest that there is an opportunity to increase outreach collaboration efforts.

2.8.3 Home Weatherization

- The program met its energy savings goals. Final program data indicated the program attained its savings goals and provides a beneficial service to PSO customers.
- Overall, reported and evaluated energy savings were consistent. The program had an overall realization rate of 100% and measure level realization rates at or close

to 100% for the largest contributors to the program. The only measurable realization rate risk is in the adjustment of gross energy savings for In-Service Rates (ISR).

- PSO and Titan have a strong relationship, with open communication and a focus on continuous program improvement. Findings from the program staff facilitated discussion indicates the staff have a common understanding of the program's strengths, weaknesses, opportunities, and threats.
- The program offers an easy, straightforward no-hassle service to low-income customers in PSO's territory. Customers indicated that signing up and scheduling for the Program is quick and easy. Survey findings also show that most customers are satisfied with the quality of the weatherization improvements and their experience with the program implementation contractor.
- Some customer skepticism and misunderstandings regarding the program persist. Findings from the facilitated discussion with Titan and PSO staff indicate that it is occasionally a challenge to overcome skepticism of the program being offered for "free" or no-cost to customers. Discussion participants also stated that educating customers regarding the program's offerings and limitations can be a challenge.
- Participant satisfaction is high. Most survey respondents were satisfied with the program overall, the measures they received, as well as with PSO as their electric utility. A very small portion of respondents voiced dissatisfaction with some aspect of their experience.
- There is an opportunity to bolster customer understanding of program improvements and the benefits of energy efficiency. About one-fifth of survey respondents said that they either had not received or did not recall receiving one or more improvement that the tracking data indicated they received. Furthermore, less than half of survey respondents said the program contractor had spoken with them about ways to use less energy in their home.

2.8.4 Energy Saving Products

- The lighting free ridership score increased significantly in 2021 compared to 2020. This was identified both through the population of program participants who completed the general population survey and was supported by the free ridership estimates calculated through the price response model.

2.8.5 Home Rebates

The Home Rebates Program consists of energy efficient New Homes, Single Upgrades, and Multiple Upgrades.

2.8.5.1 New Homes

- Continue improving the relationship with stakeholders. As the state continues to adapt to the new socio-economic changes resulting from the past couple of years, program staff could benefit from strengthening their relationships with all their stakeholders. Program staff could consider creating additional meetings with interest groups to discuss innovative strategies on how to better meet the needs of the territory.
- Expand campaigns to educate the public on PSO's standards of high energy efficiency homes. The implementation team's customer and builder engagement tactics as well as other energy-efficiency programs are cross promotional ways to inform the public on why homes built with a PSO standard of energy efficiency is better. The team could develop social media material, printed flyers, vlogs/blogs, showing the benefits of homes constructed with energy efficiency as a top priority. Program staff could also work with other programs (e.g., Power Hours, Energy Saver Kits, etc.) to further explain how energy efficient homes can help save more money when the ratepayer participates in these programs.
- Revisit Ekotrope baseline models to ensure the energy code is properly followed. Some aspects of the energy models are still unclear and may need fine-tuned. For example, percentage of CFL lighting in the baseline condition is not clearly defined.

2.8.5.2 Multiple Upgrades

- Recommend increasing target engagement materials and tactics in rural areas. Regional diversity is a goal for the program. Increased communication to rural areas outside of the Tulsa area where there is less program activity may help increase the regional diversity for both customers and service providers who may not know about the program. Increasing customer awareness about the program and desire to receive program incentives can help increase the number of service providers who participate in the program as well.
- Recommend developing a ticket system to increase communication regarding test-out assessments. It has been indicated by both PSO program staff and implementation staff that there is a lack of communication with the third-party verifiers which can delay the test-out assessments. This delay can create customer hesitancy to have the test-out assessment performed as part of the program. If a test-out assessment is not performed, the participant no longer qualifies for the program. To increase contractor/sales communication, a service provider could create a ticket when a test-out assessment is ready to be scheduled. ICF would then follow-up with the third-party verifier until the test-out is complete. This would create an automated communication process to help finish a project and receive rebates.

- Verification of reported energy and demand savings for duct replacement projects should be in place. There was one duct replacement project in the Multiple Upgrades Program tracking data for 2021. This one project had reported savings in both corresponding projects for duct replacement and duct sealing. Additional verification processes may be needed to ensure that all energy and demand savings for duct replacement projects are captured in the corresponding duct sealing project.
- Ensure the inputs in the program tracking data align with the 2016 Federal Minimum Efficiency Requirements. The EER baseline values being used from the program tracking data in some of the reported savings calculations for central air conditioners, air source heat pumps, and ground source heat pumps do not align with current Federal Minimum Efficiency Requirements (southeast region). This is causing a difference between the reported savings and verified savings since the verified savings calculations use the Federal Minimum Efficiency Requirements for all baseline values.

2.8.5.3 Single Upgrade

- Validate refrigerant added data collection for the HVAC tune-ups without burdening the contractors. The ADM evaluation team is unable to verify if and how much refrigerant is added during the tune-up process even after reviewing the project documentation in VisionDSM. The evaluation team should work with the implementation team on a system to verify a refrigerant charge as to not add additional burdens to the tune-up contractors.
- Verify process for how the post-HVAC tune-up EER is calculated. For HVAC tune-ups, the average improvement in EER_pre to EER_post is 400%. This also includes projects that did not have any refrigerant charge reported in the program tracking data. The evaluation team should work with the implementation team on a system to verify if best practices are in place.
- Recommend program staff communicate with current customers. Many customers expressed a lack of understanding about the rebate process. Communication with program staff was rated highly by customers, so having program staff reach out to a select number of customers periodically may increase customers' knowledge and understanding of the program process. It will also reassure customers that their needs are being met. Additional hand-out material for service providers to provide to customers may also be beneficial.
- Recommendation to continue focusing on customer engagement. Most customers learn of the program through their service providers as opposed to knowing about the program before they make an appointment to upgrade their equipment. Additional engagement tactics can persuade customers to consciously make

appointments to upgrade their equipment. These materials can also be used by the service providers to better explain the benefits of the qualifying higher-efficiency measures that they may be recommending to customers.

- Ensure the inputs in the program tracking data align with the 2016 Federal Minimum Efficiency Requirements. The EER baseline values being used from the program tracking data in some of the reported savings calculations for central air conditioners, air source heat pumps, and ground source heat pumps do not align with current Federal Minimum Efficiency Requirements (southeast region). This is causing a difference between the reported savings and verified savings since the verified savings calculations use the Federal Minimum Efficiency Requirements for all baseline values.

2.8.6 Education

- Measures in the kits remained the same from 2020 to 2021. Implementers continued to provide digital materials and activities for student and teachers to assist in virtual learning objectives as many schools shift to hybrid learning modes.
- Verified annual energy savings were slightly reduced from the previous year. Gross energy savings are primarily adjusted by the percentage of energy efficiency measures installed, as determined through survey efforts. In 2021, ADM found lower installation rates compared to the previous year, resulting in a 10% reduction in annual energy savings.
- Program was successful in reaching customers and achieved 98.6% of the kit distribution goal of 16,000 kits. Over 70% of teachers surveyed indicated they are repeating program participants, of which 63% stated they have participated for the past four years or more. A total of 15,782 kits were sent to 465 different fifth grade teachers within the PSO territory for PY2021. According to the data, the implementer sent 554 kits during the spring semester and 15,228 in the fall. The largest proportion of distributed kits occurred in the cities of Tulsa (23%), Broken Arrow (13%), and Lawton (7%).
- Teachers indicated that the COVID-19 pandemic affected different aspects of their instructional time. More than half of teachers indicated that the COVID-19 pandemic impacted their instructional time. Fifty percent reported it impacted their lesson plans, 64% stated it impacted their classroom activities, and 25% said the pandemic impacted the distribution of the kits to students.
- Teachers were satisfied with the program, wanted to participate again, and overall did not feel that the program significantly added to their workload. Almost all teachers (91%) stated they would participate in the program again if given the opportunity. Many survey respondents had positive comments and feedback about

the program. Forty-nine percent of teachers indicated that their participation in the program did not add to their overall workload, and none reported a significant increase in their workload because of the program. Many teachers indicated their lessons and curriculum would not have been as interactive, and they would not have taught energy efficiency as thoroughly as the program provides.

- Students were happy with the program and broadened their knowledge of energy efficiency and energy use. Quizzes completed by students before and after completing the curriculum showed an increase in knowledge after participation. Overall, 58% of students stated their family changed energy usage and 61% indicated they worked with their family. Eighty-nine percent rated the PSO Energy Saver Kit as either good or excellent.
- The program continues to reach rural and underserved communities. A total of 820 kits were delivered to schools in cities and towns with fewer than 500 inhabitants. An additional 1,012 kits were delivered to cities and towns with more than 500 and fewer than 1,000 inhabitants (based on 2020 Census data).

2.8.7 Behavioral Modification

- The PSO Behavioral program fell slightly short of the projected energy savings for PY2021. Final verified net annual energy savings totaled 18,143,843 kWh and verified net peak demand reduction totaled 3,535.55 kW, for a program-level realization rate of 90% for kWh and 95% for kW.
- Most survey respondents have consistently rated the energy saving tips and recommendations included in the HERs as valuable since 2019. On average, 70% of survey respondents indicate the energy saving tips and recommendations are valuable to them.
- Participants who reported behavioral changes engaged with more program components. 80% of respondents said that the information provided in the HERs was important in their decision to take energy-saving actions. Many of the people who underwent behavioral changes reported logging on more frequently to the My Energy Advisor web portal. Of those who said they logged on, 76% reported making some changes, compared to only 61% of those who did not say they logged on to the portal.
- Most respondents reported buying LED bulbs in 2021, and just over 20% of respondents reported purchasing or installing energy efficient equipment or appliances other than lighting in 2021. The most common items were ENERGY STAR® certified appliances.

- Approximately three-quarters of survey respondents reported spending more time at home in 2021 and 48% noticed a change in their electricity bill since the start of the pandemic, with most indicating an increase.

2.8.8 Power Hours

- The program called eight DLC events in PY2021. This is a significant increase from PY2020, during which only one DLC event was called.
- 3,532 participants joined the program during PY2021 (compared to 3,369 in PY2020 and 3,463 in PY2019). Of those, 1,769 received a new smart thermostat through the program (compared to 3,357 in PY2020 and 2,694 in PY2019).
- Based on survey results, the largest source of program awareness for all sub program types was from bill inserts and utility mailers followed by program emails and the PSO website.
- Forty percent of survey respondents first became aware of an event by noticing the difference in how the temperature in the residence felt. This was followed by seeing a thermostat notice. In addition, of actions taken to maintain comfort during an event, 37% of responses turned on supplemental fans. This was followed by changing into lighter clothing. Thirty-two percent of survey respondents ended up overriding the temperature adjustment during an event.
- Approximately two-thirds of survey respondents avoided washing and drying clothes and avoided the use of the dish washer during peak periods. This demonstrates a strong awareness of energy savings but also indicates continued potential in energy efficiency education.
- Survey results indicates the program yields an overall satisfaction of 61% (representing satisfied and very satisfied). Satisfaction is high with rebate amounts and the thermostats but is only 46% satisfied with questions or concerns addressed by customer care agents.
- Forty-one percent of survey respondents were very satisfied or satisfied with energy bill savings.

2.8.9 Peak Performers

- Average peak demand reduction per participant was lower for the three consecutive day events in August. The percentage of load reduction ranged from 22% to 36% across seven events.
- The program called seven DR events in PY2021. This is a significant increase from PY2020, during which only test events were called.

- The top three facility types that participated during PY2021 were K-12 schools (27%), public services or government entities (15%), and industrial/ manufacturing facilities (11%).
- Most participants are satisfied with the Peak Performers program. Ninety-one percent of participants are somewhat or very satisfied with the program.
- On average, surveyed organizations indicated they would like to participate in about five events per year.

3 Energy-Efficiency Programs

PSO's energy-efficiency portfolio in 2021 consisted of ten programs: five residential, one commercial/industrial, two cross-sector programs and two demand response programs. This chapter reports on the energy-efficiency programs. Chapter 4 reports on the demand response programs. Energy-efficiency programs annual energy impacts are summarized in Table 3-1.

Table 3-1: Annual Energy Savings – Energy-Efficiency Programs

Program	Gross Peak Annual Energy Savings (MWh)					Net Impacts	
	Projected	Reported	Verified	Verified Lifetime Savings	Gross Realization Rate	NTG Ratio	Net Annual Energy Savings (MWh)
Energy-Efficiency Programs							
Business Rebates	41,671	43,522	43,865	615,675	100%	91%	39,816
Multifamily	1,585	4,256	4,355	66,525	102%	85%	3,694
Home Weatherization	2,395	4,230	4,228	72,723	100%	100%	4,228
Energy Saving Products	32,801	41,780	45,149	495,382	108%	52%	23,471
Home Rebates	7,247	7,204	7,100	129,300	99%	98%	6,961
Education	4,395	3,547	3,185	28,184	90%	100%	3,185
Behavioral	22,680	20,200	18,144	18,144	90%	100%	18,144
Conservation Voltage Reduction	15,620	15,970	16,772	419,294	105%	100%	16,772
Energy-Efficiency Totals	**128,394**	**140,710**	**142,797**	**1,844,484**	**101%**	**81%**	**116,270**

Program-level peak demand reduction (kW) for the energy-efficiency programs is summarized in Table 3-2.

Table 3-2: Peak Demand Reduction – Energy-Efficiency Programs

Program	Gross Peak Demand Reduction (MW)				Net Impacts	
	Projected	Reported	Verified	Gross Realization Rate	NTG Ratio	Net Peak Demand Reduction (MW)
Energy-Efficiency Programs						
Business Rebates	7.52	7.87	8.19	104%	92%	7.51
Multifamily	0.31	1.21	1.19	99%	99%	1.18
Home Weatherization	1.14	2.41	2.41	100%	100%	2.41
Energy Saving Products	3.98	7.81	8.95	115%	42%	3.75
Home Rebates	2.75	3.55	2.96	83%	89%	2.64
Education	0.52	0.73	0.64	88%	100%	0.64
Behavioral	4.12	3.74	3.54	95%	100%	3.54
Conservation Voltage Reduction	4.40	4.58	3.57	78%	100%	3.57
Energy Efficiency Totals	**24.75**	**31.90**	**31.44**	**98%**	**80%**	**25.24**

The remainder of this section provides evaluation findings for each of the program year PSO energy-efficiency programs including program performance metrics, evaluation methodologies, energy and demand impacts, and process evaluation findings.

3.1 Business Rebates Program

This chapter presents findings from the impact and process evaluation of the 2021 program year.

3.1.1 Program Overview

PSO's Business Rebates Program provided a range of energy efficiency measures for small businesses, large businesses, schools, municipalities, and industrial businesses to participate in receiving an incentive to reduce energy consumption. The Business Rebates Program offered subprograms of Small Business Energy Solutions (SBES), Midstream, and Custom and Prescriptive (C&P). The program offers incentives for many commercial and industrial measures including lighting, plug load & controls, Insulation, Appliance & Equipment, HVAC, and Refrigeration.

To participate in the Small Business Energy Solutions (SBES) subprogram, businesses must use 220,000 kWh or less annually (2 GWh aggregated annually) and use a PSO-approved service provider. Current energy efficiency offerings in this subprogram include lighting and refrigeration measures.

The midstream program is designed to influence distributor stocking practices, as well as promote the sale of higher efficiency equipment, such as light bulbs, air conditioners, and heat pumps. This subprogram allows customers to receive instant rebates on qualifying equipment through distribution channels. The program is focused on lighting and HVAC distributors.

The Custom & Prescriptive path allows all business types and sizes to participate through a large offering of energy efficiency measures. In addition to the wide range of prescriptive measures, as listed on the Power Forward website[16], customers have additional options to receive incentives through custom applications. Custom applications include a channel for Oil & Gas and Agriculture projects as well as Energy Coaching. PSO has partnered with Trane to conduct free preliminary assessments to determine energy efficiency potential. If potential is found, Trane will conduct a detailed audit to provide recommendations on improvements in operations, controls, and mechanical system equipment.

3.1.2 Evaluation Summary

The Business Rebates Program exceeded annual energy savings goals within budget for the 2021 program year. Table 3-3 summarizes projected, ex-ante (reported), and ex-post (verified) demand impacts as well as other program performance metrics. Detailed Business Rebate program results by subprogram and measure are presented in this chapter.

[16] https://powerforwardwithpso.com/business/rebates/

Table 3-3: Performance Metrics – Business Rebates Program

Metric	PY2021
Number of Projects	1,414
Budgeted Expenditures	$11,806,139
Actual Expenditures	$10,940,031
Energy Impacts (kWh)	
Projected Energy Savings	41,670,793
Reported Energy Savings	43,522,039
Gross Verified Energy Savings	43,864,694
Net Verified Energy Savings	39,816,029
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	7,519.16
Reported Peak Demand Savings	7,869.75
Gross Verified Peak Demand Savings	8,188.61
Net Verified Peak Demand Savings	7,514.77
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	2.46
Utility Cost Test Ratio	3.42

The evaluation included a process evaluation as well as an impact evaluation. Evaluation activities included surveying, in-depth interviews, program tracking data review, virtual verification interviews, field verification visits, gross energy savings analysis, and net energy savings analysis. Table 3-4 summarizes the achieved sample sizes for the various data collection activities for the Business Rebates Program evaluation.

Table 3-4: Sample Sizes for Data Collection Efforts

Data Collection Activity	Achieved Sample Size		
	Custom/Prescriptive	SBES	Midstream
Virtual M&V Interviews	16	2	-
On-Site M&V Visits & Engineering Analysis	24	20	-
Engineering Desk Reviews Only (including billing regression analysis and provided system trend data)	2		Census (2)
Customer Decision Maker Survey	35	47	33
Program Staff Facilitated Discussions (SWOT Analysis)	2	1	1
Trade Ally or Distributor (Midstream) Survey	11	4	10
Energy Coaching Customer Decision Maker Survey	6	N/A	N/A

The evaluation determined overall gross annual energy savings approximately the same as estimated. Differences at the project level can be attributed to the estimate of annual operating hours, baseline condition variables, efficient equipment quantities, and algorithm discrepancies. When accounting for the effects of free-ridership and spillover, the net program savings are approximately 10% below estimated (ex-ante) annual energy savings. Free ridership was determined through interview and survey results with participants. Free ridership scores are based on participant responses to questions regarding the influence of the Business Rebates program on their decision to install energy efficient equipment.

3.1.3 Custom and Prescriptive

PSO's Business Rebates Program seeks to generate energy savings for custom and prescriptive projects by promoting high-efficiency electric end-use products. The program allows PSO's customers to participate by either self-sponsoring or by working through a third-party service provider to leverage technical expertise. The program seeks to combine the distribution of financial incentives with access to technical expertise to maximize program penetration across the range of potential commercial and industrial customers. Additionally, the program aims to accomplish the following:

- Increase customer awareness and knowledge of applicable energy-saving measures and their benefits,
- Increase the market share of commercial-grade high-efficiency technologies sold through market channels,

- And increase the installation rate of high-efficiency technologies in C&I facilities by businesses that would not have done so in absence of the program.

For custom and prescriptive projects, ADM found a 101% realization rate for gross energy savings and a 104% realization rate for gross peak demand reduction. ADM found a 3-year net-to-gross ratio of 90% for energy savings and 89% for peak demand reduction.

3.1.3.1 Impact Evaluation Overview

PSO's prescriptive and custom projects provided rebates for a total of 456 projects. Lighting system retrofit projects continued to be the main source of program savings with approximately 42% of ex-ante annual energy savings (kWh). Custom projects accounted for approximately 18% of ex-ante savings, and projects with multiple measures account for approximately 29%. Individual measures within this category differed across 37 different projects, roughly a third included a lighting component. A breakdown of measure type (aggregated by category based on provided measures type) by the percentage of program savings is shown in Table 3-5.

Table 3-5: Measure Type as Percentage of Reported Annual Energy Savings

Aggregated Measure List	Percent of Program
Retrofit Lighting	42%
Multiple	29%
Custom	18%
Oil & Gas	4%
Agriculture	4%
New Construction Lighting	2%
Refrigeration & Kitchen Equipment	<1%
Building Envelope	<1%
Business Appliances	<1%
Total	**100%**

Overall, the number of rebated projects decreased from 587 in 2020 to 456 in 2021, however, the magnitude of reported annual energy savings was only reduced by approximately 10%. Compared to 2020, the measure mix is relatively consistent with a higher number of projects reporting multiple prescriptive measures. Table 3-6 provides a summary of Custom and Prescriptive project savings in the program.

Table 3-6: Performance Metrics – Custom & Prescriptive

Metric	PY2021
Number of Projects	456
Energy Impacts (kWh)	
Reported Energy Savings	30,903,276
Gross Verified Energy Savings	31,200,540
Net Verified Energy Savings	28,013,382
Peak Demand Impacts (kW)	
Reported Peak Demand Savings	4,841.47
Gross Verified Peak Demand Savings	5,045.83
Net Verified Peak Demand Savings	4,503.51
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	2.11
Utility Cost Test Ratio	3.71

3.1.3.2 Process Evaluation Overview

The process evaluation consisted of participant surveys, trade ally surveys, and facilitated discussions with program staff. The objective of the participant survey was to assess sources of program awareness, factors that influenced project decision making, experience with the application process or energy consultant, and program satisfaction. A total of 35 customer decision makers responded to the participant survey. A process evaluation memo was provided to PSO in December 2021.

ADM researchers facilitated two discussions with PSO, Trane, and ICF staff in October 2021 that focused on PSO's Business Energy Coaching Program. The purpose of the first discussion was to investigate the program's internal strengths and weaknesses as well as its external opportunities and threats (SWOT). The second discussion focused on building a visual representation of customers' journey through this program.

Participation in the program accelerated toward the end of the year. Figure 3-1 displays the accrual of ex-ante energy savings as well as the monthly savings into the program.

Figure 3-1: Accrual of Reported kWh Savings During the Program Year

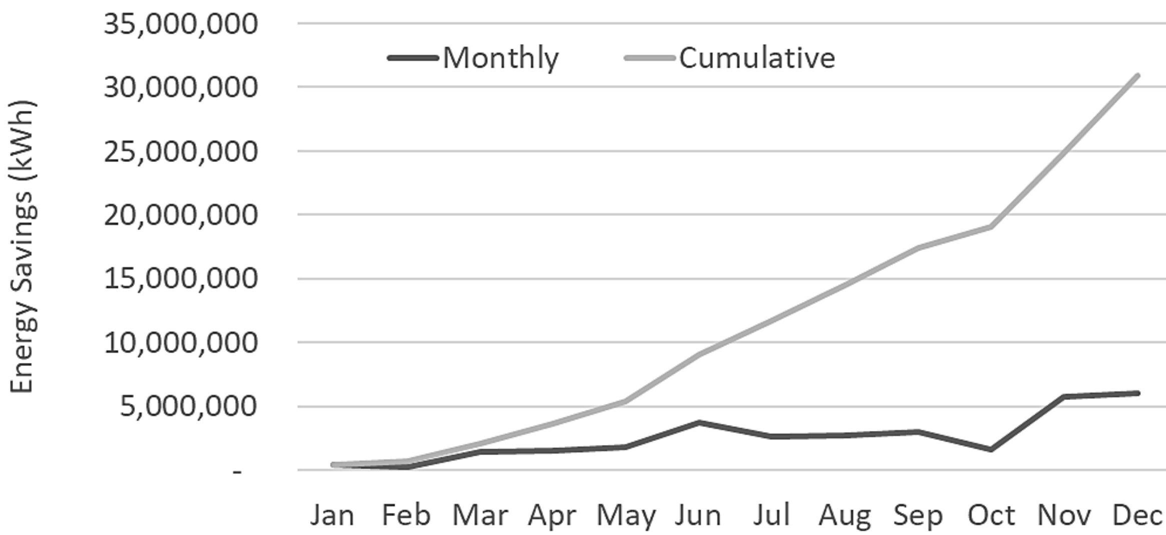


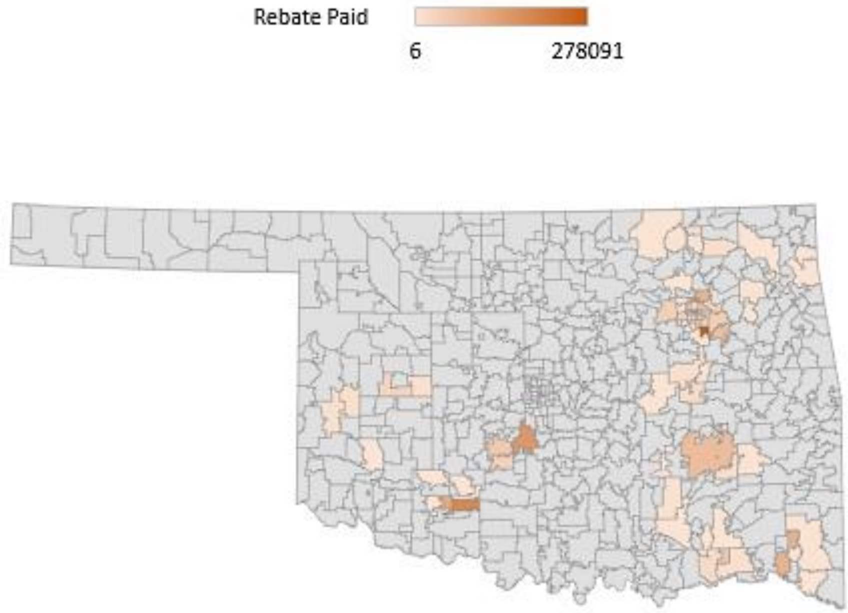
Table 3-7 summarizes the share of ex-ante savings by district. As with past program years, a large amount of savings comes from the Tulsa region; however, compared to the previous program year, the Eastern and Western District saw an increase in annual energy savings.

Table 3-7: District Share of Reported kWh Savings

Region	Sum of Reported Energy Savings (kWh)	Percentage of Program	Reported Rebate Dollars Paid	Percent of Reported Rebate Dollars Paid
Eastern District	3,125,983	10%	$334,505	13%
Tulsa District	19,785,167	64%	$1,496,721	60%
Tulsa Northern District	665,468	2%	$57,976	2%
Western District	7,326,659	24%	$610,197	24%
Total	**30,903,276**	**100%**	**$2,499,398**	**100%**

A detailed depiction of geographic incentive allocation is shown in Figure 3-2. This heat map shows the concentration of incentive dollars throughout the PSO Territory based on zip code.

Figure 3-2: Distribution of Custom and Prescriptive Projects



** Grey zip code did not receive funding. Sunset-colored zip codes received funding.*

3.1.3.3 Evaluation Methodology

This section provides a brief overview of the data collection activities and process evaluation activities that ADM employed in the evaluation of the program. Detailed energy savings methodologies are provided in Appendix G of this report.

Data Collection

Data for analysis is collected through a review of program materials, on-site inspections, virtual inspections, end-use metering, provided site trend data (such as energy management system data), and interviews with participating customers and service providers. PSO uses Sightline in conjunction with an SQL Server Reporting Services (SSRS) system as their central tracking and reporting system. Based on program tracking data provided by PSO through SSRS, a random sample is developed for the evaluation sample to statistically represent the population with verified energy impacts.

Site-specific verification visits are performed for projects selected in the random sample. For 2021, verification visits were achieved physically on-site or virtually through a combination of phone interviews, email exchanges, and video calls. The preferred method was selected by the participant. Site verification visits are used for verification of baseline conditions, energy efficiency equipment specifications, quantities, and operating conditions. When available, data from energy monitoring is collected to support the energy savings analysis. For a subset of sampled projects, grow lighting equipment was monitored to obtain accurate operational profiles. Data is collected through building automation systems, equipment control systems, or facility tracking systems.

All available project documentation is acquired for sampled projects. Project documentation includes ex-ante energy savings analysis, invoices, specification sheets, trend data, and pre-and-post implementation inspection reports. ADM uses Advanced Meter Infrastructure (AMI) data provided daily through secure transfer for data visualization and consumption analysis. In the situation where all data and information requested is not available during on-site/virtual verification, these project documents may be relied on to support verification. Projects evaluated in which only partial information was collected from the site contact are to be considered desk reviews.

In addition to on-site/virtual collection, customer surveys provide self-reported data for the NTG analysis and process evaluation. Service provider, or trade ally interviews, were conducted to gain feedback on program participation, barriers, and satisfaction from a stakeholder perspective. Trade ally interviews were conducted with eleven program contractors.

ADM researchers facilitated two discussions with PSO, Trane, and ICF staff in October 2021 that focused on PSO's Business Energy Coaching Program. The purpose of the first discussion was to investigate the program's internal strengths and weaknesses as well as its external opportunities and threats (SWOT). The second discussion focused on building a visual representation of customers' journey through this program. Table 3-8 shows the achieved sample sizes for the different types of data collection utilized for this evaluation.

Table 3-8: Sample Sizes for Data Collection Efforts

Data Collection Activity	Achieved Sample Size
On-site M&V Visits	24
Virtual M&V Interviews	16
Sample Desk Review	2
Customer Decision Maker Surveys	35
Trade Ally Surveys	11
Program Staff Facilitated Discussion (SWOT)	2
Energy Coaching Customer Decision Maker Surveys	6

Sampling Plan

ADM created a stratified random sample based on the amount of annual energy savings and the type of measure installed in each project. Ratio estimation is used to determine precision (better than +/- 10% based on annual energy savings) at a 90% confidence interval across all Custom and Prescriptive strata. Realization rates (the ratio of ex-post to ex-ante savings) for projects sampled in each stratum are only extrapolated to other projects within that stratum. Verification of sample precision, using each stratum's contribution to variance, is then performed on the ex-post extrapolated annual energy savings (kWh) for the program.

Occasionally energy savings for a given project are impacted by circumstances that are not consistent with similar projects. In these situations, the verified energy savings are held for the project but are not extrapolated to any other projects. An example of this situation may be the destruction of the facility through natural disasters. No custom or prescriptive projects required removal from extrapolation.

The sample size was designed to meet ex-ante annual energy savings at ±10% precision at the 90% confidence level for the program. Separate samples were drawn for custom and prescriptive projects, SBES projects, and Midstream projects. Table 3-9 shows the sample design that was used for custom and prescriptive projects. Stratum classifications were based on verified measure installations. The 42 projects that were sampled for evaluation verification account for approximately 43% of ex-ante program annual kWh savings.

Table 3-9: Sample Design for Prescriptive and Custom

Stratum Name	Reported kWh Savings	Strata Boundaries (kWh)	Population of Projects	Design Sample Size
Custom & Other 1	1,209,602	1,047 – 69,340	48	7
Custom & Other 2	4,082,354	88,543 – 334,582	22	6
Custom & Other 3	5,098,984	438,111 – 1,062,867	7	5
Custom & Other 4	6,586,287	1,340,333 – 2,361,956	4	4
NC Lighting 1	730,278	5,358 – 180,327	17	2
Prescriptive	138,308	61 – 71,070	8	3
Retrofit Lighting 1	2,753,974	144 – 29,989	234	6
Retrofit Lighting 2	4,024,914	30,082 – 105,749	72	4
Retrofit Lighting 3	4,074,877	120,708 – 282,048	23	3
Retrofit Lighting 4	2,203,697	289,618 – 602,954	5	2
Total	**30,903,276**		**456**	**42**

Impact Evaluation Methodology

The verification of gross annual energy savings and peak demand reduction from projects rebated through the program can be broken down into the following steps:

- The program tracking database is reviewed to determine the scope of the program and to ensure there are no duplicate project entries, missing data, or data entry errors. The tracking database is used to define a discrete set of rebated projects that make up the program population. A sample of projects is then drawn from the population established in the tracking system review.

- A detailed desk review is conducted for each project sampled for On-site/virtual verification and data collection. The desk review process includes a thorough examination of all project materials including invoices, equipment cut sheets, pre- and post-inspection reports, and estimated savings calculators. This review process informs ADM's On-site/virtual fieldwork by identifying potential uncertainties, missing data, and sites where monitoring equipment is needed to verify key inputs to the ex-ante savings calculations.
- After reviewing project materials, On-site/virtual verification/data collection interviews are scheduled for sampled projects. If sufficient information and data was provided that represented verification, then a desk review may be considered to reduce participant fatigue. The interviews are used to collect data for savings calculations, verify measure installation, and determine measure operating parameters.
- The data collected during the On-site/virtual verification visits are used to revise savings calculations, as necessary. For example, if the ex-ante savings calculations relied on operating hours for a given measure that was found to be inaccurate based on the On-site/virtual verification and data collection, changes are made to reflect actual operating conditions more accurately.
- After determining the ex-post savings impacts for each sampled project, results are extrapolated to the program population using project-specific sampling weights. This allows for the estimation of program level gross ex-post annual energy (kWh) savings with a given amount of sampling precision and confidence.

Net-to-Gross Estimation (NTG)

The purpose of net savings analysis is to determine what portion of gross savings achieved by PSO customers is the direct result of program influence. Information collected from a sample of program participants through a customer decision maker survey is used for the net-to-gross analysis. These survey responses are reviewed to assess the likelihood that participants were free riders or whether there were spillover effects associated with non-rebated purchases by program participants.[17] Both the Custom and Prescriptive and SBES Programs utilized the same NTG methodology.

Several main criteria are used to determine the likelihood that a customer is a free rider. The first criterion is based on the participant having the financial capability to purchase the energy-efficient equipment without the support of the program.

17 The spillover analysis is limited to participant spillover. Non-participant spillover effects may exist for the program, but they are not estimated and therefore assumed to be zero.

The second criterion was the impact of the Program timing on the decision to implement the energy efficiency measure. The AR TRM stipulates a decision-maker must have installed a measure within one year to be considered a free rider. Consistent with that stipulation, ADM determined customers were not free riders if they stated that they would have installed a measure in more than one year. Specifically, respondents were asked the following questions:

- Did you implement the measure earlier than you otherwise would have because of the information and inducements available through the program?
- When would you otherwise have installed the measure?

Respondents who answered yes to the first question and indicate that they would have installed the measure one or more years later in the second question were deemed not to be free riders.

For decision makers that indicated that they were able to undertake energy efficiency projects without financial assistance from the program and would have done so within one year of when they undertook it, three factors are analyzed to determine the likelihood that they are free riders. The three factors are:

- Plans and intentions of the firm to install a measure even without support from the program.
- Influence that the program has on the decision to install a measure; and
- A firm’s previous experience with a measure installed under the program.

For each of these factors, rules are applied to develop binary variables indicating if a participant’s behavior indicated free ridership.

- The first factor determines if a participant states that they intend to install an energy efficiency measure without the program. Answers to a combination of several questions are used with a set of rules to determine whether a participant’s behavior indicated likely free ridership.
- The second factor determines if a customer reported that a recommendation from a program representative or experience with the program was influential in the decision to install a piece of equipment or measure.
- The third factor determines if a participant in the program indicated that he or she had previously installed an energy efficiency measure like one that they installed under the program without an energy-efficiency program incentive during the last three years. A participant indicating that he or she had installed a similar measure is considered to have a likelihood of free ridership.

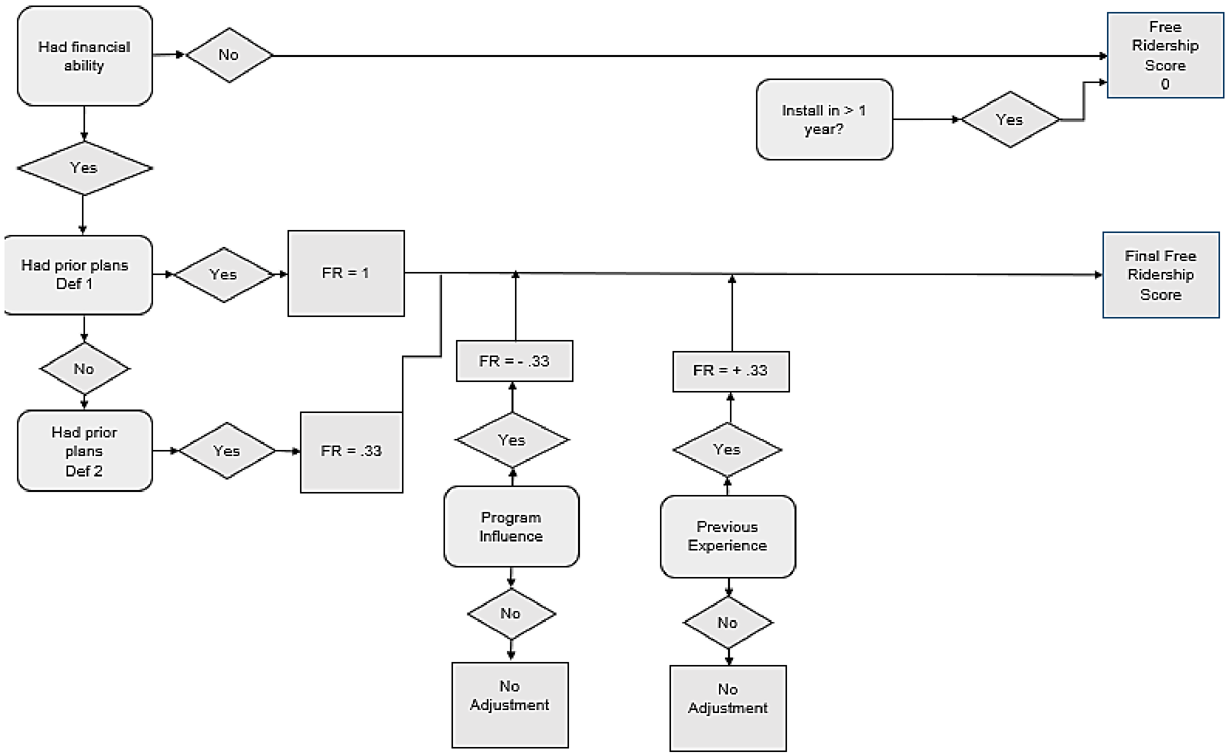
The four factors described above are used to construct four indicator variables that address free ridership behavior. For each customer, a free ridership value is assigned based on the combination of variables. With the four indicator variables, there are 12 applicable combinations for assigning free ridership scores for each respondent, depending on the combination of answers to the questions creating the indicator variables. Table 3-10 shows these values.

Table 3-10: Free Ridership Scores for Combinations of Indicator Variable Responses

Had Plans and Intentions to Install Measure Without C&I Program? (Definition 1)	Had Plans and Intentions to Install Measure Without C&I Program? (Definition 2)	C&I Program had Influence on Decision to Install Measure?	Had Previous Experience with Measure?	Free Ridership Score
Y	N/A	Y	Y	100%
Y	N/A	N	N	100%
Y	N/A	N	Y	100%
Y	N/A	Y	N	67%
N	Y	N	Y	67%
N	Y	N	N	33%
N	Y	Y	N	0%
N	Y	Y	Y	33%
N	N	N	Y	33%
N	N	N	N	0%
N	N	Y	N	0%
N	N	Y	Y	0%

Determination of free ridership from the four variables is represented as a flow chart in Figure 3-3.

Figure 3-3: Flow Chart of Free Ridership Determination



The customer decision maker survey also includes a series of questions used to analyze whether there are potential spillover effects associated with non-rebated purchases by program participants.[18] Specifically, survey respondents are asked:

- "We would like to know if you have installed any additional energy-efficient equipment because of your experience with the program that you DID NOT receive an incentive for. Since participating in the program, has your organization installed any ADDITIONAL energy efficiency measures at this facility or at your other facilities within PSO's service territory that did NOT receive incentives through PSO's program?"

Customers who indicate "yes" are identified as potential spillover candidates. Potential spillover candidates are asked to identify the type of additional equipment installed and provide information about the equipment for use in estimating energy savings. For each type of equipment that respondents report installing, respondents are asked the following two questions, which were used to assess if any savings resulting from the additional equipment installed was attributable to the program.

18 The spillover analysis is limited to participant spillover. Non-participant spillover effects may exist for the program, but they are not estimated and therefore assumed to be zero.

- [SP1] How important was your experience with the program in your decision to install this [Equipment/Measure]? [Rated on a scale where 0 means not at all important and 10 meant very important]
- [SP2] If you had NOT participated in the program, how likely is it that your organization would still have installed this [Equipment/Measure]? [Rated on a scale where 0 means not at all likely and 10 meant very likely]

A spillover score was developed based on these responses as follows:

$$\textit{Spillover Score} = \text{Average (SP1, SP2)}$$

The energy savings of equipment installations associated with a spillover score of greater than six are attributed to the program.

Lifetime Energy Savings

Lifetime energy savings (kWh) is the product of annual energy savings (kWh) multiplied by the Effective Useful Life (EUL). The EUL considers the technical lifespan of the equipment as well as the change in energy savings over time. The EUL is determined by measure for each measure within each project of the evaluation sample. The EUL for prescriptive measures is sourced from the AR TRM v7.0. If a measure is not listed in the AR TRM, then a different industry standard reference, such as another technical reference manual is considered. For custom equipment, the EUL is determined based on the lifespan of the equipment or if that cannot be determined then the industry standard of 20 years is applied. Energy savings for any behavioral measures in the program is only granted one year of EUL.

For lighting equipment, ADM determines lifetime savings by dividing the manufacturer specified useful life of the equipment by the verified annual operating hours. This is performed on a line-item basis for each fixture type and usage schedule within a project.

The lifetime savings for each project is the aggregation of the lifetime savings for all equipment incentivized within the project. Extrapolation to the population of projects is achieved in a similar fashion as applying a realization rate. A strata level aggregated lifetime energy savings is divided by the strata level aggregated annual energy savings to determine a strata-level EUL. This EUL is then applied to all projects in the population outside of the sample.

Process Evaluation Methodology

The process evaluation is designed to research and document the program delivery mechanisms and collective experiences of program participants, partners, and staff. The process evaluation is designed to answer the following research questions:

- How does PSO market this program?
  - How effective are the marketing efforts for the program?

    - Which marketing methods are most effective?
- How well do PSO staff and service providers work together? Are there rebate processing, data tracking, and/or communication efficiencies that can be gained?
- Did the program implementation reflect its design? Are there underlying assumptions about program implementation and design that are being made about how the program will unfold? Are there ways to improve the design or implementation process?
- Were participants satisfied with their experience? What was the level of satisfaction with the rebate amount, the application process, the rebated measures, and other aspects of program participation?
- How is the program working to meet its regional and measure diversity goals? Are new measures or pilot programs being explored?
- What are PSO staff and implementation staff perspectives on the program? What are the reactions to program design choices that have been implemented?
- What types of buildings/facilities participated in the program? Could certain facility types be targeted more effectively?
- What customer barriers to participation do distributors see? How can these be mitigated?
- Were there any significant obstacles during each program year?
- Looking forward, what are the key barriers and drivers to program success within PSO's market?
- What changes, if any, were made to the program design or implementation procedures?
- Are trade allies satisfied with the program? Are referrals effectively shared among them? Are trade allies aware of any barriers to participation?

To address these questions, ADM's process evaluation activities include surveys to program participants as well as in-depth interviews with program staff and trade allies. Table 3-11 provides a summary of data collection activities for the process evaluation.

Table 3-11: Custom and Prescriptive Research Questions

Data Collection Activity	Process Evaluation Research Objectives
Program Staff Facilitated Discussions	Assess program staff perspectives regarding program operations, strengths, or barriers to success. Discuss customer journey to create a common understanding of participation experience and identify key touchpoints to create a journey map.
Participant Surveys	Source of program awareness, factors that influenced project decision making, experience with the application process, energy consultant, and program satisfaction.
Trade Ally Surveys	Assess program changes, barriers to participation, satisfaction with program procedures and how it compares to other programs in the region, assessment of program marketing materials, training, and communications with program staff

3.1.3.4 Impact Evaluation Findings

Impact evaluation findings determine net annual energy savings and net coincident peak demand reduction. Program level results are achieved by extrapolation of verified (ex-post) project level savings; known as gross results. Gross results are adjusted for program free-ridership and participant spillover to determine net results.

Gross Annual Energy Savings

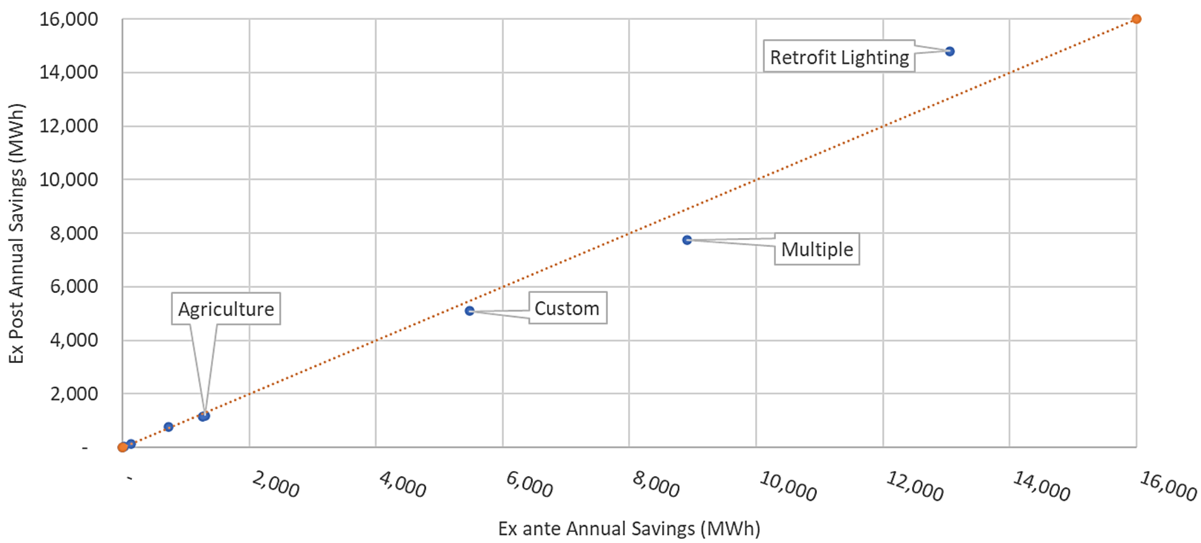
The ex-post gross annual energy savings for Prescriptive and Custom projects are summarized, by sampling stratum, in Table 3-12.

Table 3-12: Reported and Verified Gross kWh Savings by Sampling Stratum – Prescriptive and Custom

Stratum	Reported kWh Savings	Verified Gross kWh Savings	Gross kWh Realization Rate
Custom & Other 1	1,209,602	1,281,793	106%
Custom & Other 2	4,082,354	3,389,967	83%
Custom & Other 3	5,098,984	3,981,165	78%
Custom & Other 4	6,586,287	6,823,894	104%
NC Lighting 1	730,278	771,560	106%
Prescriptive 1	138,308	138,308	100%
Retrofit Lighting 1	2,753,974	3,923,849	142%
Retrofit Lighting 2	4,024,914	4,386,028	109%
Retrofit Lighting 3	4,074,877	4,303,617	106%
Retrofit Lighting 4	2,203,697	2,200,357	100%
Total	**30,903,276**	**31,200,540**	**101%**

The achieved sample design results in ex-ante gross annual energy savings estimates with ±8.7% relative precision at the 90% confidence interval, and ±9.6% in ex-post gross annual energy savings.[19] Overall annual energy savings were found to be as expected. Large variability was found within individual projects, with realization rates ranging from 32% to 311%. Figure 3-4 demonstrates the impact of measure type realization rates for the program. The dotted line represents a theoretical realization rate of 100%. As can be seen, retrofit lighting has the largest impact based on the magnitude and is at a 113% realization rate. The retrofit lighting realization rate was partially offset by projects with multiple measures represented the second largest impact based on magnitude. Projects with multiple measures commonly included, lighting (horticultural and retrofit), HVAC, refrigeration, and kitchen equipment.

Figure 3-4: Realization Rate Impact



The following sections discuss the results based on specific measure types from the evaluation sample.

Lighting Projects

Dedicated lighting projects were included in two strata categories; retrofit (Retrofit Lighting 1-4), and new construction lighting (NCL1). Due to the difference in energy savings methodologies, new construction lighting is extrapolated separately from retrofit lighting. Project level realization rates ranged from 82% to 311%.

Retrofit Lighting Projects

Differences between ex-ante and ex-post energy savings can be explained by differences in reported and verified hours of use (HOU), with the occasional difference in fixture

[19] That is, we are 90% confident that the true verified gross savings are between 28,204,164 and 34,196,917 kWh based on the uncertainty introduced by sampling.

quantities. ADM used lighting schedules from detailed interviews with facility staff as well as deemed hours of use when applicable. Lighting settings from Energy Management Systems (EMS), timers, and photocells were used, where appropriate, based on On-site/virtual interview findings. When an accurate HOU was not available, or the HOU varied, deemed values from the Arkansas TRM v7 were used.

The driver of evaluation risk for retrofit lighting projects was HOU and interactive effects. On-site/virtual verifications indicated that generally as found HOU were greater than the HOU the ex-ante utilized. Additionally, there were some sites where the ex-ante did not apply interactive effects for conditioned spaces while the Evaluator found these projects to have conditioned spaces. The overall realization rate was 113%.

New Construction Lighting Projects

Energy savings analyses for new construction lighting projects require a lighting power density (LPD) approach to determine the proper baseline condition. The LPD baseline condition is based on allowable building codes and are stipulated by space type. Project realization rates ranged from 82% to 113%. The variation in realization rates was due to some variation in the hours of use. The overall realization rate was 106%.

Custom & Other Projects

The variance in realization rates for custom and other equipment projects varies by measure and savings algorithm implemented. Custom analyses were performed for measures such as Oil & Gas, Chiller, indoor grow lighting, and whole facility new construction. These measure types were grouped in the sample due to the nature of the measure, the number of projects, and the annual energy savings (kWh). Some larger projects underwent pre-payment reviews to help mitigate evaluation risk. Additionally, intensity lighting logger monitoring was conducted on three custom indoor grow lighting projects.

All sampled projects fell within a realization rate of 32% to 219%. Projects representing a higher level of risk included:

- ADM installed intensity lighting loggers at three indoor grow lighting projects and gathered ~2 months of monitored data. The loggers were installed to verify hours of use and dimming schedules. The monitoring data generally confirmed the sites expressed hours and dimming schedules. The ex-ante analysis did not account for dimming, this difference resulted in realization rates ranging from 32% to 66%. Additionally, a fourth indoor grow lighting project ADM visited but did not monitor had a realization rate of 68%. This was because ADM's analysis utilized dimming schedules confirmed with site contact during ADM field verification. The ex-ante analysis did not account for dimming, but the implementation team has updated their methodology for the next program year.

- Two projects received incentives for the installation of new LED lighting. Measurement and verification showed higher savings due to the application of interactive effects. During ADM's site visit, it was confirmed that the lighting was installed in conditioned spaces, the ex-ante did not utilize interactive effects for these projects. These differences resulted in realization rates of 106% and 110%, respectively.

Overall, custom projects represented a realization rate of 106%.

Energy Coaching

Trane Energy Coaching uses available data to find building-specific issues that could be addressed to reduce energy usage. The principal focus is on operational and behavioral improvements. Energy Coaching projects have been listed as Custom projects in the program tracking data and were treated as such. Four Energy Coaching projects were in the evaluation sample. A review of these projects indicates energy savings based on IPMVP Option C, a whole facility billing regression analysis.[20] Project level realization rates ranged from 51% to 219% with an overall realization rate of 121%.

ADM adhered to ASHRAE Guide 14 and IPMVP guidelines in performing billing regression analyses. This resulted in the use of additional baseline data in the regression as well as the application of normalizing the baseline and efficient condition regressions to typical year (TMY3) weather. The regression analysis is normalized to a typical year because of the measure life exceeds one year. In addition, ADM reviewed each project for impacts of non-routine events.

Measure-Level Results

Realization rate by measure type for the program is presented in Table 3-13.

20 https://www.nrel.gov/docs/fy02osti/31505.pdf

Table 3-13: Realization Rate by Project Type

Project Type	Realization Rate	Percent of Custom and Prescriptive
Retrofit Lighting	113%	42%
Multiple (Retrofit and Grow Lighting, HVAC, Kitchen Equipment, etc.)	87%	29%
Custom	106%	18%
Oil & Gas	91%	4%
Agriculture	91%	4%
New Construction Lighting	106%	2%
Refrigeration & Kitchen Equipment	100%	<1%
Building Envelope	111%	<1%
Business Appliances	100%	<1%

Gross Coincident Peak Demand Reduction (kW)

The ex-post gross coincident peak demand reduction (kW) is summarized by the sampling stratum in Table 3-14. The peak demand reduction realization rate for prescriptive and custom projects is 104%.

Table 3-14: Reported and Verified Gross Peak Demand Reduction by Sampling Stratum

Stratum	Reported Peak kW Reduction	Verified Gross Peak kW Reduction	Verified Gross kW Realization Rate
Custom & Other 1	256.67	552.94	215%
Custom & Other 2	553.13	549.92	99%
Custom & Other 3	884.27	614.34	69%
Custom & Other 4	827.72	857.88	104%
NC Lighting 1	161.21	152.13	94%
Prescriptive 1	20.17	20.17	100%
Retrofit Lighting 1	516.75	277.69	54%
Retrofit Lighting 2	689.75	602.93	87%
Retrofit Lighting 3	609.60	1,010.60	166%
Retrofit Lighting 4	322.20	407.22	126%
Total	**4,841.47**	**5,045.83**	**104%**

The achieved sample design resulted in ex-ante gross peak demand reduction estimates with ±16.62% relative precision at the 90% confidence interval and 18.00% for ex-post peak demand reduction.[21] Peak demand reduction was variable from project to project, resulting in a high precision value. Differences between ex-ante and ex-post demand reduction may be attributed to:

- Instances where the ex-ante did not calculate demand reduction, but the ex-post found demand reduction savings present.
- Use of stipulated coincidence factors (CF) that did not align well with actual equipment schedules.
- Varying peak demand reduction from the defined peak period, or
- Differences in the definition of peak demand savings.[22]

For lighting projects, the ADM ex-post lighting calculators generate an hourly curve (8760 hours) to determine the average peak demand value across the peak demand period for each lighting schedule. Custom calculations and energy simulations provide similar results. For other prescriptive measures, the ADM calculators used the deemed coincidence factors provided in the AR TRM v7.

Net-to-Gross Estimation

The data used to assign free ridership scores were collected through a survey of customer decision makers for projects rebated through the Business Rebates Program during the 3-year evaluation cycle. Completed survey responses represent 148 custom and prescriptive projects. Calculation of NTG was determined based on the ridership criteria (four areas of questions) and spillover.

Table 3-15 shows percentages of total gross ex-post annual energy savings associated with different combinations of free ridership indicator variable values for the custom and prescriptive incentive component. The magnitude of free ridership was determined by the amount of annual energy savings and peak demand reduction attributed to free ridership within each project.

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[21] That is, we are 90% confident that the ex-post gross peak demand reduction is between 4,138 and 5,954 kW based on the uncertainty introduced by sampling.

[22] Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. National Renewable Energy Laboratory (NREL), 2013.

Table 3-15: Estimated Annual Energy Savings Free Ridership for Custom and Prescriptive

Had Plans and Intentions to Install Measure Without C&I Program? (Definition 1)	Had Plans and Intentions to Install Measure Without C&I Program? (Definition 2)	C&I Program had Influence on Decision to Install Measure?	Had Previous Experience with Measure?	Percentage of Total Gross kWh Savings	kWh Free Ridership Score
Y	Y	Y	Y	0%	100%
Y	Y	N	N	3%	100%
Y	Y	N	Y	0%	100%
Y	Y	Y	N	6%	67%
N	Y	N	Y	0%	67%
N	Y	N	N	2%	33%
N	Y	Y	N	0%	0%
N	Y	Y	Y	0%	33%
N	N	N	Y	7%	33%
N	N	N	N	45%	0%
N	N	Y	N	26%	0%
N	N	Y	Y	10%	0%
Required program to implement measures				0%	0%
Project would have been deferred by one year or more in the absence of a program				0%	0%
Total				**100%**	**10%**

Overall, the estimated percentage of 3-year program free ridership is 10%. Project specific free ridership was determined on a measure level basis. ADM found moderate levels of free ridership in several projects that consisted of lighting and air conditioning units.

Customer decision maker survey responses were also analyzed to estimate participant spillover effects. A few respondents reported installing efficient equipment that met the attribution criterion and for which energy savings could be estimated; thus, a minor spillover was determined.

The NTG for the program is calculated as 1 – free-ridership + participant spillover. This results in a 3-year NTG of 90% for annual energy savings and 89% for peak demand reductions. Table 3-16 shows the amount of savings and peak demand reduction impacted by free ridership and spillover.

Table 3-16: 2021 Free-Ridership and Spillover for Custom and Prescriptive

Savings	Free Ridership	Spillover
Annual Energy Savings (kWh)	3,206,278	19,120
Peak Reduction (kW)	545.73	3.41

The gross and net ex-post annual energy savings and peak demand reduction for Custom and Prescriptive projects are summarized in Table 3-17.

Table 3-17: Summary of Verified Gross and Net Impacts

Program	Verified Gross kWh Savings	Verified Net kWh Savings	Net-to-Gross Ratio	Verified Gross kW Reduction	Verified Net kW Reduction
Custom and Prescriptive	31,200,540	28,013,382	90% - kWh 89% - kW	5,045.83	4,503.51

Lifetime Energy Savings

Lifetime savings were determined for each equipment type or line item incentivized within each project. Lifetime savings were aggregated for all projects within each stratum to determine a strata level lifetime savings. These lifetime savings were divided by the aggregated annual gross and net energy savings for each stratum to determine an effective useful life (EUL) to be extrapolated to the population by strata. Sample level EUL's by strata as well as total population lifetime energy savings are shown in Table 3-18.

Table 3-18: C&P EUL's and Lifetime Energy Savings

Stratum	EUL	Gross Program Lifetime Energy Savings (kWh)	Net Program Lifetime Energy Savings (kWh)
Custom & Other 1	17.38	22,273,117	19,997,902
Custom & Other 2	17.28	58,579,895	52,595,916
Custom & Other 3	12.61	50,204,298	45,075,892
Custom & Other 4	15.07	102,831,764	92,327,424
NC Lighting 1	14.81	11,426,161	10,258,970
Prescriptive 1	17.30	2,392,042	2,147,693
Retrofit Lighting 1	13.67	53,627,304	48,149,236
Retrofit Lighting 2	13.78	60,459,974	54,283,943
Retrofit Lighting 3	14.12	60,771,843	54,563,954
Retrofit Lighting 4	8.76	19,271,777	17,303,151
Total	**14.16**	**441,838,175**	**396,704,082**

3.1.3.5 Process Evaluation Findings

The process evaluation consisted of a participant survey, trade ally survey, and program staff facilitated discussions which resulted in a SWOT analysis and customer journey map. ADM provided a detailed process evaluation memo to PSO after the completion of the 2021 program year.

Program Staff Facilitated Discussions

ADM researchers facilitated two discussions with PSO, Trane, and ICF staff in October 2021 that focused on PSO's Business Energy Coaching Program. The purpose of the first discussion was to investigate the program's internal strengths and weaknesses as well as its external opportunities and threats (SWOT). The second discussion focused on building a visual representation of customers' journey through this program.

During the calls, ADM staff shared their computer screen via video call and took notes to ensure attendees' thoughts were accurately captured. After each discussion, ADM updated each figure to synthesize the ideas shared during the facilitated discussion and subsequently reshared to solicit any additional questions, comments, or feedback to improve the figures.

Energy Coaching SWOT

We present the result of the SWOT analysis facilitated discussion below. For additional information, refer to the process evaluation memo.

Figure 3-5: PSO Business Energy Coaching Program SWOT Analysis

	INTERNAL FACTORS		
POSITIVE	**S** ▪ Customer recruitment. ▪ Usefulness of Energy Optics Tool. ▪ Personnel at Trane. ▪ Educational value. ▪ Customer Follow ups. ▪ Project Tracking (Trellow).	**W** ▪ Vetting process. ▪ Developing relationships with new customers. ▪ Accessibility of Energy Optics Report. ▪ Program design may not motivate some customers. ▪ Time Consuming. ▪ Communication with other contractors. Design of program.	**NEGATIVE**
	O ▪ Identifying the right segment of customers. ▪ Collaborate with ICF to target additional participants/buildings. ▪ Create a tiered approach. ▪ Create a flow chart or journey map. ▪ Incorporate the peak performers program. ▪ Tariff analysis. ▪ Possible program structure revision to improve engagement. ▪ Promote program by highlighting non-energy benefits. ▪ Rising utility costs. ▪ Utilize existing tools for engagement tracking.	**T** ▪ Limited eligible customer base. Opt-in / opt-out nature of energy efficiency program. ▪ Customer commitment to act. ▪ Occasional customer skepticism. ▪ Competitors to PSO Energy Coaching Program. ▪ Natural disasters.	
	EXTERNAL FACTORS		

- The program could bolster its participants' benefit by incorporating the peak performers program. By coupling Energy Coaching with Peak Performers, customers could make a significant improvement to their Building Automation Systems' operations.
- Trane's follow-up strategy and the project tracking tool help promote the implementation of recommended actions. Discussion participants noted that check-ins with customers help ensure they are taking actions and following through with coaching and that the project tracking system ("Trellow") stores customer information that could potentially be utilized as a customer contact tool.

- Customer recruitment was identified as a program strength, though discussion participants noted there were opportunities to target additional customers. The program started out seeking MUSH (Municipal, Universities, Schools, Hospitals) participants, however many of these organizations have opted out of PSO efficiency programs. The discussion participants noted that Trane, PSO, and ICF could collaborate to target customers that had completed energy efficiency upgrades and recruit customers with potential for additional kW reduction/kWh savings. They also noted that targeting small to midsized facilities (25-75K square feet) was an opportunity.
- To increase enrollment, discussion participants suggested different promotion approaches. Contacts suggested promoting the program by focusing conversations or outreach efforts on topics such as non-energy benefits like comfort, reducing environmental harm, and reducing burdens on building staff.

Customer Journey Map

A journey map is a graphic representation of how a customer or participant interacts with a program or product. It may display touchpoints, satisfaction, actions, key moments, pain points, or emotions. ADM presented a draft customer journey map and sought to clarify and enhance the contents by guiding the staff in a discussion of the various customer experience phases.

ADM researchers started the facilitated discussion by explaining customer journey mapping and setting ground rules for the discussion. Next, ADM guided the contacts through each element of the map and inquired whether each of the map's components accurately reflected PSO Business Energy Coaching customers' journey.

Upon completion of the discussion, the initial customer journey map was updated and distributed to discussion participants for feedback. The final customer journey map is shown in Figure 3-6. ADM's detailed process evaluation memo contained additional background and narrative information regarding customers' journey with the Energy Coaching Program.

Figure 3-6: PSO Business Energy Coaching Customer Journey Map

Customer Group: Energy managers, maintenance staff, building owners/managers, school superintendents

Objective: Create a common understanding of the participation experience, identify key touchpoints & opportunities for program improvement

PSO BUSINESS ENERGY COACHING PROGRAM	AWARENESS & INITIAL CONTACT	PRELIMINARY ENERGY ANALYSIS	FULL ANALYSIS AND IMPLEMENTATION	POST IMPLEMENTATION
TOUCHPOINT	*PSO website, Trane, ICF/PSO Staff*	*Trane*	*Trane*	*Trane*
CUSTOMER ACTION	1. Reach out to PSO regarding high bill or other complaint 2. Receive information from Trane or PSO/ICF staff about energy coaching (e.g., in person meetings, phone calls, trade shows, targeted emails from Trane with internal/external customers) 3. (If interested) Customer gives permission to Trane to look at interval data.	1. Have a 30-60 minute meeting with Trane to review interval data and high level google earth audit analyzed by Trane 2. Decide if they'd like to participate in full analysis	1. Have energy engineer onsite for full day (level of involvement depends on customer). This includes full mechanical inspection, type of HVAC system, setpoints etc. 2. Share floorplans, gas and water bills, mechanical/electrical drawings with Trane. 3. Meet 1-2 hours to discuss findings including Energy Optics Report from Trane with recommended actions to improve building efficiency, including potentially rebated/incentivized equipment 4. Make low and no cost improvements to facility (if interested)	1. Receive outreach from Trane to check in regarding their decision on next steps. 2. (if needed) Receive additional coaching on actions or improvements to increase building efficiency and improve operations. 3. Have short conversation or email discussion with Trane about energy savings.
CUSTOMER THOUGHTS	• My bill is high, how can I lower it? • **Our building is already very efficient, you cannot help me. (KMOT)** • **I know my building is not running efficiently, how can you help? (KMOT)** • Are we able to participate in this program if we have agreements with another energy or equipment contractor? • Do I have the authority and ability to enroll my property? • What is my commitment? What do you need from me? • Is there a catch? • Does this program offer analysis from a qualified engineer?	• Does this program offer analysis from a qualified engineer? • How much time and effort will it take to coordinate with Trane? • What do we do next? • **We are not interested in continuing with this program– time commitment is too much, and energy/cost savings are not sufficient to warrant effort. (KMOT)**	• How much will each recommendation cost to implement? • How long will it take for us to see energy use? • Will this cause comfort problems? • How much time and resources will each recommended action take to implement successfully?	

Energy Coaching Customer Survey

ADM conducted a mixed-mode (phone/email) survey of PSO's Business Energy Coaching Program participants in November 2021. Business Energy Coaching staff provided contact information for 17 participants. ADM contacted each respondent up to four times (two emails, two phone calls). Six participants responded to the survey, including three facilities managers, two school superintendents, and an engineering operations manager.

Survey findings indicate reducing energy usage or costs was generally the primary motivation for signing up. Five participants mentioned reducing energy costs (two participants), energy usage (two participants), or both (one participant) as the primary reason for participation. One of these participants also stated that they decided to participate to "get money back on the front end". The remaining participant observed that the Return on Investment (ROI) for participating in the program was "very fast".

Survey findings suggest the respondents had a consistent participation experience. The contacts noted having a meeting to review their electricity use as part of a high-level audit. Following this initial review and meeting, the contacts each confirmed having onsite visits with Trane staff to inspect mechanical equipment, setpoints, and opportunities for savings. All contacts stated that they had a second meeting and some form of follow-up contact with Trane to discuss their organization's energy report, program recommendations, and decisions regarding implementation.

Survey findings indicate the contacts found program participation beneficial and were overwhelmingly satisfied. All contacts said the information provided through the program's energy report and meetings with staff was useful.

Prescriptive and Custom Customer Survey

ADM conducted an email survey of Prescriptive and Custom participants in November 2021. PSO staff sent 160 Prescriptive and Custom program participants an email to notify them of the survey and then ADM sent a survey invitation, two reminder emails to all potential respondents, and one additional targeted reminder to 22 respondents. The survey resulted in 35 completes.

Most respondents were satisfied with their overall experience as well as individual aspects of the program such as the incentive amount and the time it took to receive their rebate payment (Figure 3-7). This is consistent with past program years (see Figure 3-8 for overall satisfaction from 2019-2021).

Figure 3-7: Overall Respondent Satisfaction with Aspects of Program Participation

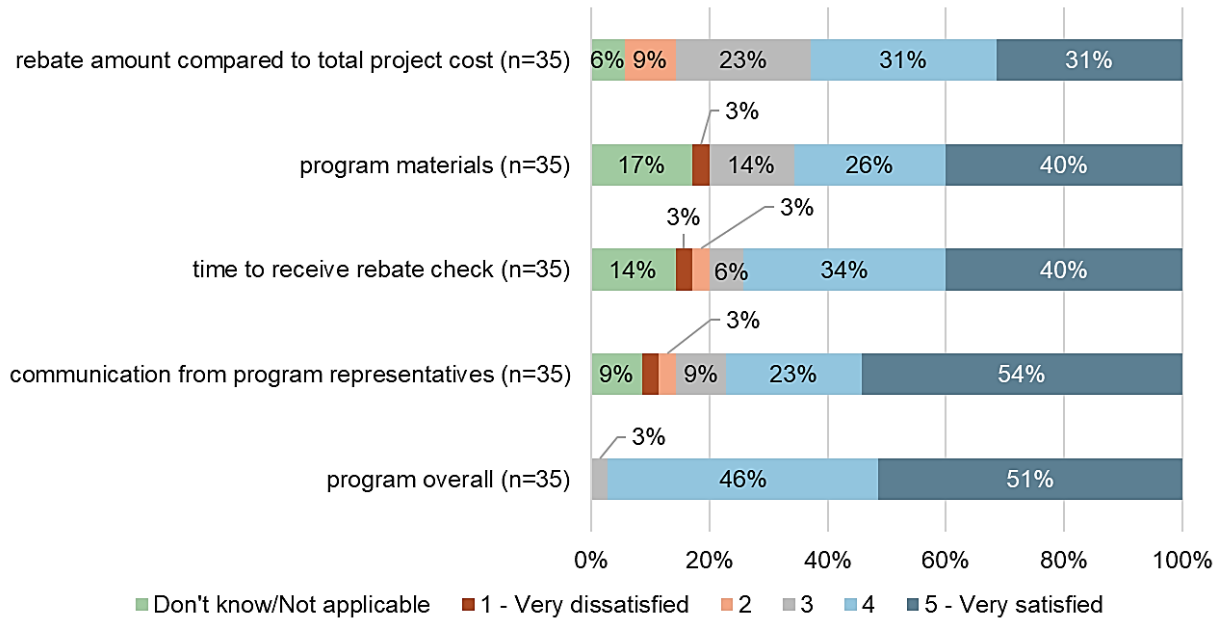
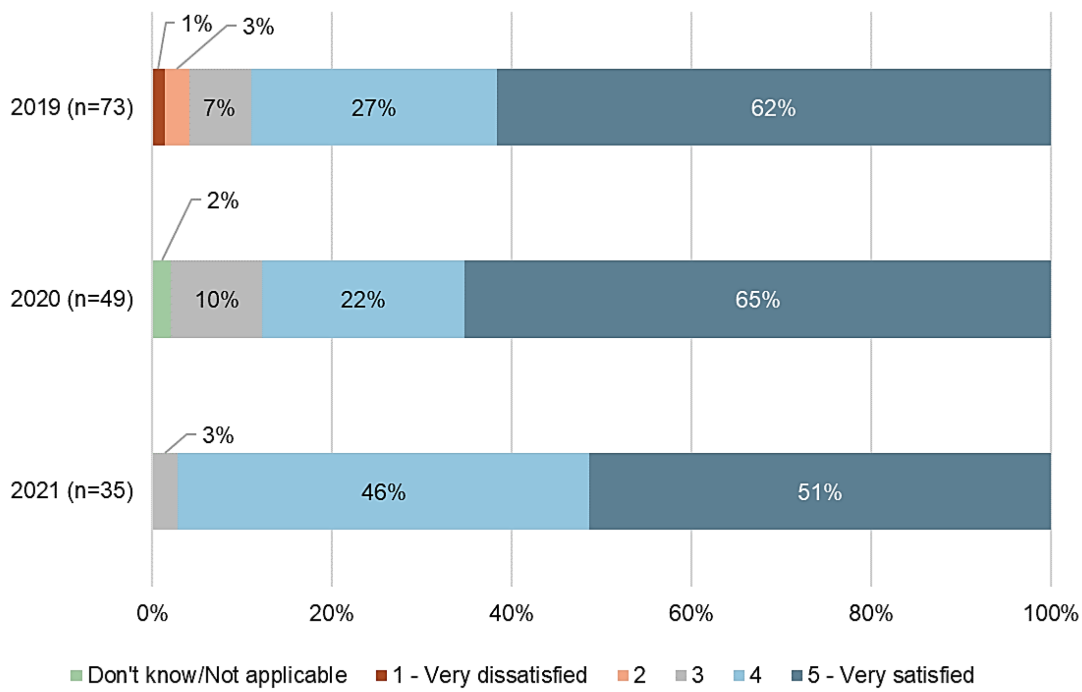


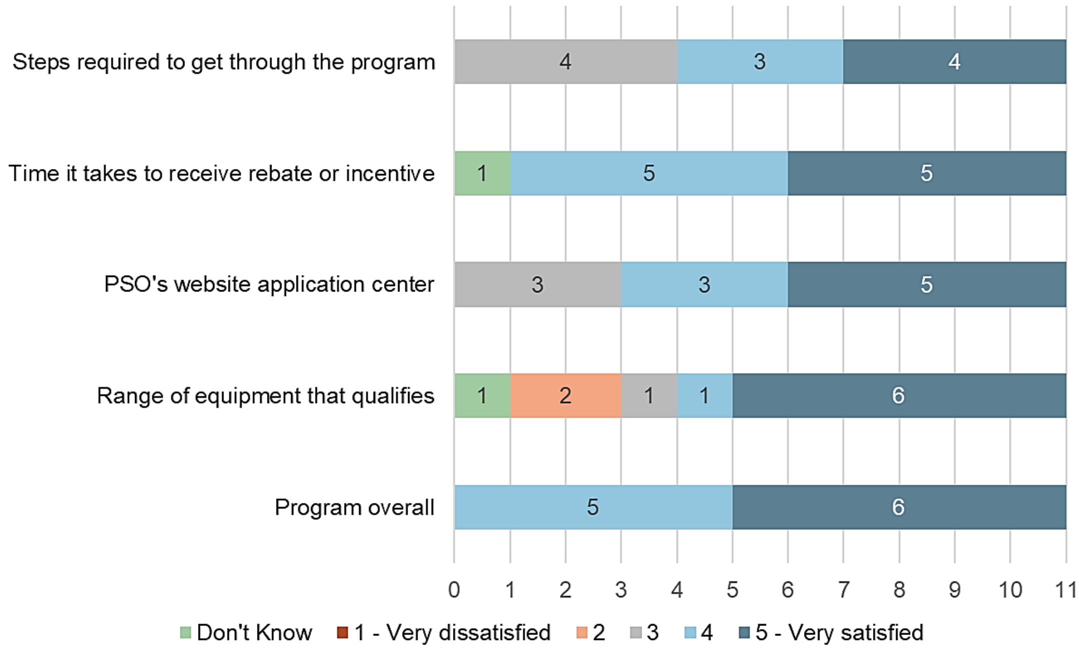
Figure 3-8: Overall Respondent Satisfaction 2019-2021



Prescriptive and Custom Trade Ally Survey

In November 2021, ADM collected survey responses from 11 Prescriptive and Custom rebate trade allies, including energy consultants, electrical, HVAC, mechanical contractors, lighting/electrical distributors, as well as rebate or incentive assistance companies. Trade allies are largely satisfied with the program design and participation process, with some offering suggestions for improvement. All trade allies indicated they were satisfied with the program overall (Figure 3-9).[23]

Figure 3-9: Trade Ally Satisfaction



3.1.3.6 Custom and Prescriptive Conclusions and Recommendations

This section presents conclusions and recommendations for the Custom and Prescriptive subprogram based on the 2021 evaluation.

Conclusions

- The program was able to sustain a high level of program savings given some of the challenges implementation faced in 2020 and continued into 2021. Verified gross energy impacts were slightly higher than estimated. Net annual energy savings for the program year are 28,013,382 kWh for an overall net realization rate of 91%.
- Lighting projects continue to contribute most to program level energy savings, but the wide range of offerings presents many opportunities for customers.
- Evaluation risk was found for several measures. Grow lighting and multiple measure projects represent the largest project level realization rate risk. Multiple measure projects such as sites that had controlled environment agriculture lighting and HVAC. In those cases, the driver of the evaluation risk was the grow lighting.

23 A rating of 4 or 5 on a scale from 1 (very dissatisfied) to 5 (very satisfied).

- Participant surveys indicate there is an opportunity to improve the Custom and Prescriptive design and application process. Forty percent of respondents recommended improving the application process.
- Most program participants indicated that the COVID-19 pandemic had affected their company adversely, though the majority stated it had not affected their ability to take advantage of PSO's rebates or incentives.
- Trade ally surveys suggest there is room to grow program awareness for the Prescriptive and Customer programs.
- Trade allies were largely satisfied with program administration and design, though they offered several recommendations for program improvement.
- Survey and staff discussion findings indicate PSO Business Energy Coaching program delivers useful energy analysis and usage information to customers but ensuring customers complete recommended actions can be a challenge.
- The Energy Coaching customer journey is well understood, but there are opportunities to develop the participation process and add additional touchpoints.
- Consistent with past program years, satisfaction remains high. Most survey respondents shared high levels of satisfaction across all aspects of the program as well as the programs overall.

Recommendations

- Retrofit lighting presented a large realization rate risk. There was great realization rate variability (94% to 311%) in retrofit lighting projects regardless of project size. Common discrepancies were hours of operation and interactive effects. There is potential for mitigation with more detailed ex-ante analysis.
- Grow lighting participation increased from last year and that trend is expected to continue. Grow lighting resulted in high realization rate risk in 2021. We recommend requesting pre-payment reviews by ADM for large grow projects.
- Consider reviewing the Prescriptive and Custom customer application portal's design with a focus on presenting program requirements and limitations clearly and effectively to improve user experience.
- If the Energy Coaching Program is continued there may be room to improve the recruitment process.
    - Develop and implement a pre-participation customer survey to streamline the enrollment process and ensure the program is engaging with customers that have the potential to benefit from the program.
    - Increase collaboration between Trane, PSO, and ICF to mutually target potential participants.

    - Consider developing materials or outreach approaches that focus on topics such as non-energy benefits like comfort, reducing environmental harm, and reducing burdens on building staff.
    - Incorporate peak demand reduction into program literature and structure to encourage kW-focused customers to participate.
- The Energy Coaching projects demonstrate the potential for projects falling into the spectrum of continuous energy improvement or strategic energy management. These types of implementation strategies could provide value to the business rebates program.
- Based on feedback from Trade Allies, consider additional measures to encourage greater adoption. Trade allies suggested prescriptive incentives for heat pump water heaters, smart motors, evaporation controls with defrost controllers for refrigeration, evaporation controls for ECM motors, closers and hinges for walk-in coolers, and freezers (Auto closers for walk-in), sports lighting, large dehumidifiers, and additional smart Wi-Fi thermostat brands.

3.1.4 Small Business Energy Solutions (SBES)

This section reports findings from the Small Business Energy Solutions (SBES) evaluation. ADM performed an impact and process evaluation. The gross ex-post annual energy savings estimates for SBES resulted in a 101% realization rate for gross energy savings and a 106% realization rate for gross peak demand reduction.

The program seeks to generate energy savings for small commercial and industrial customers by promoting high-efficiency electric end-use lighting and refrigeration products. The program seeks to combine provision of financial inducements with access to technical expertise to maximize program penetration across the range of potential small business customers. The program has the following additional goals:

- Increase customer awareness and knowledge of applicable energy saving measures and their benefits.
- Increase the market share of commercial grade high-efficiency technologies sold through market channels.
- Increase the installation rate of high-efficiency technologies in small businesses by customers that would not have done so absent the program.

Direct install rebates are available to customers that qualify for the SBES portion of the program. To qualify for the program, businesses must use 220,000 kWh or less annually and use a PSO approved service provider. Customers may request an exemption of these requirements. Exemptions are granted on a case-by-case basis, determined by how a customer fits within the program goals.

3.1.4.1 Impact Evaluation Overview

The impact evaluation of the SBES Program consisted of a gross and net annual energy savings and peak demand reduction determination. Gross energy savings were determined through M&V practices with on-site and virtual data collection. Net-to-gross was determined through survey efforts of participants and trade allies to calculate values of free ridership and spillover.

PSO provided rebates for a total of 383 SBES projects. The number of rebated projects decreased from 412 in PY2020 to 383 in PY2021. The ex-ante energy savings decreased from 10,188 MWh (PY2020) to 8,156 MWh (PY2021). As with previous years, program energy savings were driven by lighting projects.

The estimated annual energy savings NTG ratio decreased from 99.8% in 2020, to 99.5% in 2021. The estimated peak demand NTG ratio changed from 99.4% in PY2020 to 99.7% for PY2021. Table 3-19 provides projected, ex-ante, and ex-post energy and demand impacts, as well as other program performance metrics for SBES projects.

Table 3-19: Performance Metrics – Small Business Energy Solutions

Metric	PY2021
Number of Projects	383
Energy Impacts (kWh)	
Reported Energy Savings	8,155,929
Gross Verified Energy Savings	8,211,436
Net Verified Energy Savings	8,169,066
Peak Demand Impacts (kW)	
Ex-ante Peak Demand Savings	2,222.71
Gross Verified Peak Demand Savings	2,359.51
Net Verified Peak Demand Savings	2,351.51
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	4.08
Utility Cost Test Ratio	4.98

3.1.4.2 Process Evaluation Overview

The process evaluation included participant surveys, trade ally surveys, and a facilitated discussion with program staff to perform a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. The objectives of the participant survey were to assess the source of program awareness, factors that influenced project decision making, experience with the application process or energy consultant, and program satisfaction. A total of 47 customer decision makers responded to the participant survey. A detailed process evaluation memo was delivered to PSO in November of 2021.

Participation in SBES increased steadily as the year progressed, with a notable increase at the end of the year. Figure 3-10 displays the accrual of ex-ante energy savings.

Figure 3-10: Accrual of Reported kWh Savings During the Program Year

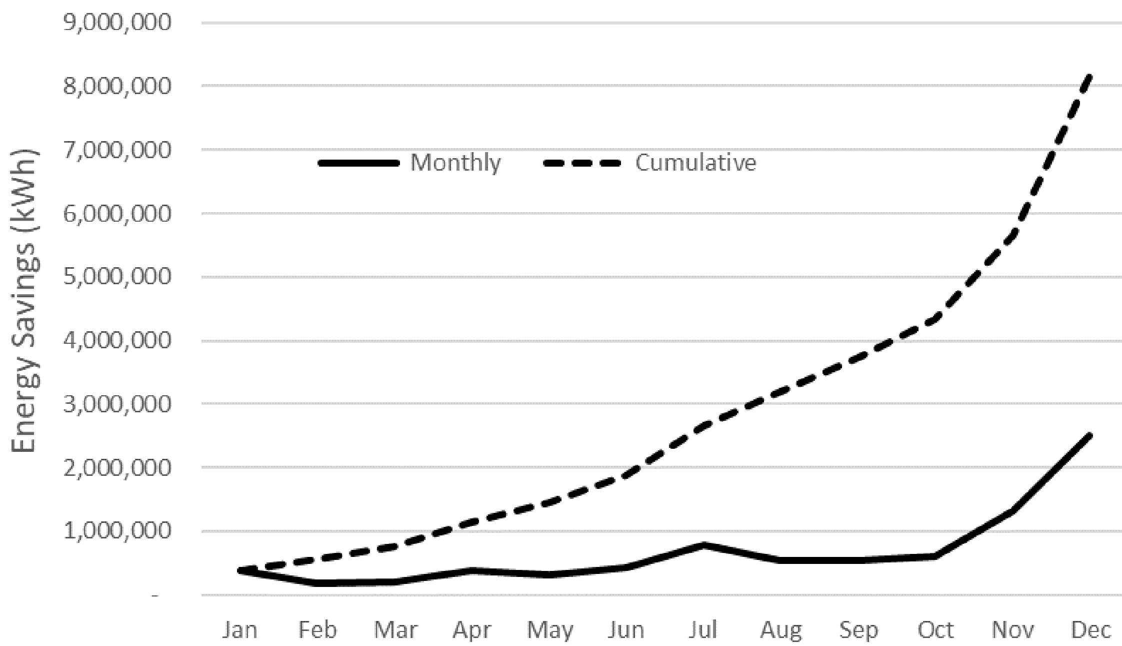


Table 3-20 summarizes program activity by service provider. Four lighting service providers represented most of the energy savings. National Resource Management (NRM) represented 3% of energy savings with refrigeration equipment, an increase from PY 2020.

Table 3-20:Summary by Service Provider

Service Provider	Sum of Reported Energy Savings (kWh)	Percentage of Projects kWh
Bridgepoint Electric	1,854,645	23%
Entegrity Partners	2,008,869	24%
First Light Systems	2,927,386	36%
Luminous of OK	1,132,470	14%
National Resource Management	232,560	3%

Project Activity by Location

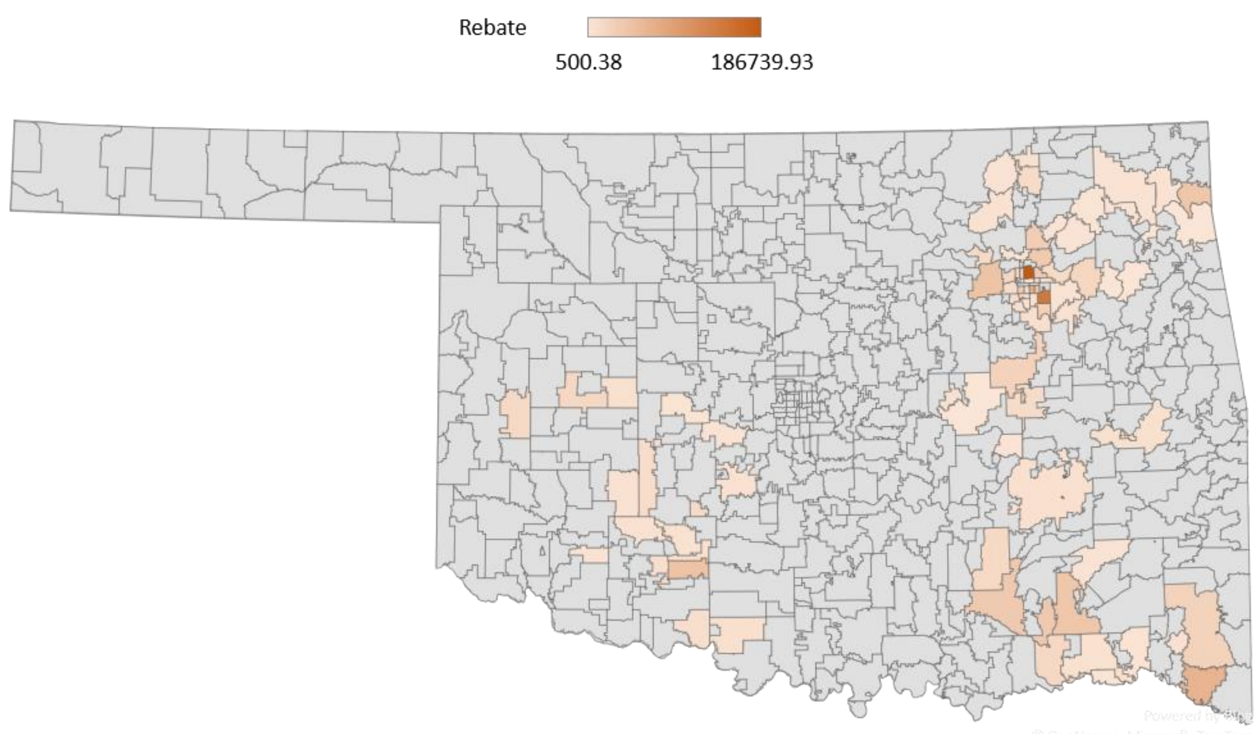
Table 3-21 displays the share of SBES savings by district. The distribution of savings is consistent with program goals. As expected, savings are associated with regions that have a higher density of businesses.

Table 3-21: District Share of Reported kWh Savings

Region	Sum of Reported Total Energy Savings (kWh)	Percentage of Projects kWh
Eastern District	2,034,654	25%
Tulsa District	4,478,948	55%
Tulsa Northern District	491,606	6%
Western District	1,150,722	14%
Total	**8,155,929**	**100%**

Figure 3-11 shows a heat map of the location of SBES projects across the service territory based on zip code. The density of projects increases as the color darkens; based on the number of projects. Zip codes represented in grey indicate that no incentives were achieved.

Figure 3-11: Distribution of Small Business Energy Solutions Projects



*Grey zip code did not receive funding. Sunset colored zip codes received funding.

Two projects consisting of reported annual energy savings over 200,000 kWh represented 8.67% of SBES projects annual energy savings. The two projects were manufacturing facilities located in the Tulsa District.

3.1.4.3 Evaluation Methodology

This section provides an overview of the data collection activities, gross and net impact calculation methodologies, and process evaluation activities that ADM employed in the evaluation of the SBES program.

Data Collection

Data for the analysis were collected through review of program materials, on-site and virtual inspections, and interviews with participating customers, service providers, and program staff. A sample was developed for on-site and virtual data collection based on program tracking data obtained via SSRS.

Participating contractors used an online proposal tool called Audit Direct Install (ADI) software. Within ADI, space-by-space inventories are created for each project. The implementation team can generate reports directly from ADI which contain enough information to conduct desk reviews, on-site and virtual verification visits. Additional project materials including invoices, equipment cut sheets, pre- and post-inspection reports, and estimated savings calculators assist in preparing for visits and during analysis. On-site and virtual visits were used to collect data for gross impact calculations, to verify measure installation, and to determine measure operating parameters. Facility staff members were interviewed to determine the operating hours of the installed systems and provide any additional operational characteristics relevant to calculating energy savings.

In addition to the on-site and virtual data collection effort, customer surveys provided self-report data for the net-to-gross analysis and process evaluation. A total of 47 customer decision makers who completed SBES incentive projects completed the survey. Trade ally interviews were conducted to gain feedback on program participation, barriers, and satisfaction from a stakeholder perspective. Trade ally interviews were conducted with four program contractors.

Table 3-22 shows the achieved sample sizes for the different types of data collection employed for this study.

Table 3-22: Sample Sizes for Data Collection Efforts – SBES

Data Collection Activity	Achieved Sample Size
On-Site M&V Visits & Engineering Analysis	20
Virtual M&V Interviews & Engineering Analysis	2
Customer Decision Maker Survey	47
Program Staff Facilitated Discussions (SWOT)	1
Trade Ally interviews	4

Sampling Plan

As with Custom and Prescriptive projects, ADM created a stratified sample based on the amount of annual energy savings and type of measure installed in each project. Sample sizes were designed to meet ±10% precision at the 90% confidence level at the program level. Table 3-23 below shows the sample design that was used for SBES projects. Stratum classifications were based on verified measure installations. The 22 projects sampled for measurement and verification account for approximately 18% of reported program annual energy savings.

Table 3-23: Sample Design for the Business Rebates Program Small Business

Stratum Name	Reported kWh Savings	Strata Boundaries (kWh)	Population of Projects	Design Sample Size
Lighting 1	795,736	0-10,000	149	5
Lighting 2	1,471,259	10,000-20,000	102	2
Lighting 3	2,417,081	20,000-42,000	82	5
Lighting 4	1,577,586	42,000-85,000	27	3
Lighting 5	1,216,602	85,000-250,000	10	3
Lighting 6	445,105	250,000+	1	1
Refrigeration 1	25,378	0-15,000	4	1
Refrigeration 2	207,182	15,000-50,000	8	2
Total	**8,155,929**		**383**	**22**

Impact Evaluation Methodology

The evaluation of gross ex-post annual energy savings and peak demand reduction from projects rebated through the SBES Program can be broken down into the following steps:

- The program tracking database was reviewed to determine the scope of the program, check for data completeness, data entry errors, outlier values, and to ensure there were no duplicate project entries. The tracking database was used to define a discrete set of rebated projects that made up the program population. A sample of projects was then drawn from the population established in the tracking system review.
- A detailed desk review was conducted for each project sampled for in person and virtual verification and data collection. The desk review process included a thorough examination of all project materials including invoices, equipment cut sheets, pre- and post-inspection reports, and estimated savings calculators. This review process informed ADM's on-site and virtual fieldwork by identifying potential uncertainties and missing data. Additionally, the review process involved

assessing the reasonableness of deemed savings values and calculation input assumptions.

- After reviewing the project materials, on-site and virtual verification visits for data collection were scheduled for sampled projects. The on-site and virtual visits were used to collect data for savings calculations, to verify measure installation, and to determine measure operating parameters.
- The data collected during the on-site and virtual verification visits was used to revise savings calculations, as necessary. For example, if the reported savings calculations relied on certain measure operating hours that were determined inaccurate based on the facilities actual schedule, changes were made to reflect actual operating conditions more accurately.
- After determining the ex-post savings impacts for each sampled project, results were extrapolated to the program population using project-specific sampling weights. This allows for the estimation of program level gross ex-post annual energy (kWh) savings with a given amount of sampling precision and confidence. For the SBES projects, the sample was designed to ensure ±10% or better relative precision at the 90% confidence level for kWh reductions.

Net-to-Gross Estimation (NTG)

The purpose of net savings analysis is to determine what portion of gross savings achieved by PSO customers is the direct result of program influence. This methodology includes both free ridership and participant spillover. The methodology for SBES is the same as Custom and Prescriptive and described in the Custom and Prescriptive Evaluation Methodology section.

Lifetime Energy Savings

Lifetime energy savings (kWh) is the product of annual energy savings (kWh) multiplied by the Effective Useful Life (EUL). The EUL considers the technical lifespan of the equipment as well as the change in energy savings over time. The EUL is determined by measure for each measure within each project of the evaluation sample. The EUL for prescriptive measures is sourced from the AR TRM v7.0. If a measure is not listed in the AR TRM, then a different industry standard reference, such as another technical reference manual is considered. For custom equipment, the EUL is determined based on the lifespan of the equipment or if that cannot be determined then the industry standard of 20 years is applied. Energy savings for any behavioral measures in the program is only granted one year of EUL.

For lighting equipment, ADM determines lifetime savings by dividing the manufacturer specified useful life of the equipment by the verified annual operating hours. This is performed on a line-item basis for each fixture type and usage schedule within a project.

The lifetime savings for each project is the aggregation of the lifetime savings for all equipment incentivized within the project. Extrapolation to the population of projects is achieved in a similar fashion as applying a realization rate. A strata level aggregated lifetime energy savings is divided by the strata level aggregated annual energy savings to determine a strata-level EUL. This EUL is then applied to all projects in the population outside of the sample.

Process Evaluation Methodology

The process evaluation was designed to research and document the program delivery mechanisms and collective experiences of program participants, partners, and staff. The process evaluation was designed to answer the following research questions:

- How does PSO market this program?
    - How effective are the marketing efforts for the program?
    - Which marketing methods are most effective?
- How well do PSO staff and service providers work together? Are there rebate processing, data tracking, and/or communication efficiencies that can be gained?
- Did the program implementation reflect its design? Are there underlying assumptions about program implementation and design that are being made about how the program will unfold? Are there ways to improve the design or implementation process?
- Were participants satisfied with their experience? What was the level of satisfaction with the rebate amount, the application process, the rebated measures, and other aspects of program participation?
- How is the program working to meet its regional and measure diversity goals? Are new measures or pilot programs being explored?
- What are PSO staff and implementation staff perspectives on the program? What are reactions to program design choices that have been implemented?
- What types of buildings/facilities participated in the program? Could certain facility types be targeted more effectively?
- What customer barriers to participation do distributors see? How can these be mitigated?
- Were there any significant obstacles during each program year?
- Looking forward, what are the key barriers and drivers to program success within PSO’s market?
- What changes, if any, were made to the program design or implementation procedures?

- Are small business service providers satisfied with the program? Are referrals effectively shared among them? How does PSO's Small Business Program compare to other small business programs? Are service providers aware of any barriers to participation?

To address these questions, ADM's process evaluation activities included surveys to program participants as well as in-depth interviews with program staff and trade allies. Table 3-24 provides a summary of data collection activities for the process evaluation.

Table 3-24: SBES Research Questions

Data Collection Activity	Process Evaluation Research Objectives
Program Staff Facilitated Discussions	Assess program staff perspectives regarding program operations, strengths, or barriers to success. Discuss customer journey to create a common understanding of participation experience and identify key touchpoints to create a journey map.
Participant Surveys	Source of program awareness, factors that influenced project decision making, experience with the application process, energy consultant, and program satisfaction.
Trade Ally Interviews	Assess program changes, barriers to participation, satisfaction with program procedures and how it compares to other programs in the region, assessment of program marketing materials, training, and communications with program staff
Review of Program Tracking Data	Assesses program tracking data through the end of September to present a summary of projects, by location, in the utility service territory.

3.1.4.4 Impact Evaluation Findings

Impact evaluation findings determine net annual energy savings and net coincident peak demand reduction. Net energy impacts are achieved through several steps of evaluation, starting from M&V on a statistically representative sample of projects in which gross energy impacts are extrapolated to the population. The effects of free ridership and spillover are then applied to the population (on a project level basis) to determine program level net energy impacts.

Gross Annual Energy Savings

The ex-post gross annual energy savings for SBES projects are summarized by sampling stratum in Table 3-25 Projects saw an overall realization rate of 101%. Ninety-seven percent of verified annual energy savings for the SBES Program resulted from lighting projects.

Table 3-25:Reported and Verified Gross Annual Energy Savings by Sampling Stratum – SBES

Stratum	Reported kWh Savings	Verified Gross kWh Savings	Gross kWh Realization Rate
Lighting 1	795,736	864,059	109%
Lighting 2	1,471,259	1,459,703	99%
Lighting 3	2,417,081	2,486,683	103%
Lighting 4	1,577,586	1,504,343	95%
Lighting 5	1,216,602	1,177,980	97%
Lighting 6	445,105	466,529	105%
Refrigeration 1	25,378	18,119	71%
Refrigeration 2	207,182	234,021	113%
Total	**8,155,929**	**8,211,436**	**101%**

The achieved sample design resulted in ex-ante gross annual energy savings estimates with ±9.38% relative precision at the 90% confidence interval and ex-post at ±9.40% for kWh.[24] Realization rates varied from project to project and stratum to stratum.

Differences from reported to verified energy savings stem from annual hours of operation and baseline wattage assumptions. In cases where baseline wattage was not able to be determined during on site and virtual verification visits, ADM used default baseline wattages as presented in the Arkansas TRM v7 (AR TRM). Annual hours of use for ex-post calculations were determined either through on site or virtual verification interviews or referenced the AR TRM; however, annual operating hours for schools was based on the 2018 analysis conducted by ADM to determine an annual hour of use of 2,556.

Project level realization rates ranged from 71% to 149%. The project with the lowest realization rate was incentivized for LED case lights which was part of the refrigeration program. The ex-ante calculations for these measures used differing baseline wattage and hours whereas ADM incorporated the AR TRM v7.0 baseline wattages and actual hours of use. All measures for refrigeration program sampled included LED case lighting, walk-in ECM, cooler & freezer door heater controls and evaporator/compressor controls for cooler. Each of the three refrigeration projects sampled (1 R1, 2 R2) included LED case lighting and in each case ex ante baseline wattage for lights and hours of use differed from what ex post found during on-site visits.

24That is, we are 90% confident that the true verified gross savings are between 7,439,200 and 8,983,673 kWh based on the uncertainty introduced by sampling.

For Small Business lighting projects linear tubes are the highest percentage of equipment type retrofitted through the program as can be seen from Table 1-24 at around 73% of the program.

Table 3-26:Percentage of Lighting by Type

Type	% Of Lighting
Abandoned Fluorescent	0.04%
Abandoned HID	0.05%
LED Case Lights	0.62%
LED Exit Sign	3.23%
LED Exterior Lights	7.66%
LED Fixture	7.92%
LED Linear Tubes	72.79%
LED Screw-ins	6.48%
Occupancy Sensor	1.20%
Total	**100%**

Gross Coincident Peak Demand Reduction (kW)

The ex-post gross peak demand reduction is summarized by sampling stratum in Table 3-27. Overall, the ex-post gross peak demand reduction is equal to 106% of the reported reduction for SBES projects.

Table 3-27: Reported and Verified Gross kW Reduction by Sampling Stratum

Stratum	Reported Peak kW Reduction	Verified Gross Peak kW Reduction	Verified Gross kW Realization Rate
Lighting 1	296.49	245.32	83%
Lighting 2	450.25	514.44	114%
Lighting 3	595.09	711.49	120%
Lighting 4	435.98	434.43	100%
Lighting 5	305.19	307.58	101%
Lighting 6	114.56	115.01	100%
Refrigeration 1	2.78	1.91	69%
Refrigeration 2	22.38	29.32	131%
Total	**2,222.71**	**2,359.51**	**106%**

The achieved sample design resulted in ex-ante gross peak demand reduction estimates with ±20.79% relative precision at the 90% confidence interval and ex-post at ±21.38%.[25] Much of the difference between ex-ante and ex-post demand reduction, as in past program years, is explained by either 1) variation of annual operating hours, or 2) use of stipulated coincidence factors (CF) that did not align well with actual equipment schedules. For lighting projects, the ADM ex-post lighting calculators generate an hourly curve (8760 hours) to determine the average peak demand reduction value across the peak demand period for each lighting schedule within a project. For Refrigeration 1 our sampled project included only LED case lights and the major factor controlling this realization rate is hours of use and baseline wattage for the fixtures. ADM incorporated the AR TRM v7.0 baseline wattages and actual hours of use.

Net-to-Gross Estimation

The data used to assign free ridership scores were collected through a survey of SBES customer decision makers for projects rebated. Free ridership was estimated using the methodology described in the Evaluation Methodology section for Custom and Prescriptive. Results are based on 47 respondents representing 47 unique projects. A percentage of free ridership was determined for each of the 47 projects based on the four avenues of questions. The percentage of free ridership was then applied to each project's ex-post annual energy savings. The overall results were then extrapolated to the remaining projects in the program.

25 That is, we are 90% confident that the ex-post gross peak demand reduction is between 1,996 and 2,919 kW based on the uncertainty introduced by sampling.

Table 3-28 shows percentages of total gross ex-post savings associated with different combinations of free ridership indicator variable values for the SBES incentive component.

Table 3-28: Estimated Free-Ridership for SBES

Had Plans and Intentions to Install Measure Without SBES Program? (Definition 1)	Had Plans and Intentions to Install Measure Without SBESI Program? (Definition 2)	SBES Program had Influence on Decision to Install Measure?	Had Previous Experience with Measure?	Percentage of Total Gross kWh Savings	Free Ridership Score
Y	Y	Y	Y	0%	100%
Y	Y	N	N	0%	100%
Y	Y	N	Y	0%	100%
Y	Y	Y	N	0%	67%
N	Y	N	Y	0%	67%
N	Y	N	N	0%	33%
N	Y	Y	N	0%	0%
N	Y	Y	Y	0%	33%
N	N	N	Y	2%	33%
N	N	N	N	39%	0%
N	N	Y	N	55%	0%
N	N	Y	Y	4%	0%
Required program to implement measures				0%	0%
Project would have been deferred by one year or more in the absence of the program				0%	0%
Total				**100%**	**0.52%**

Only a small amount of free ridership was determined through survey efforts. The small amount is attributed to participants with prior plans and intentions to purchase the equipment without the presence of the program.

Customer decision maker survey responses were also analyzed to estimate participant spillover effects. None of the survey respondents reported meeting the attribution criterion for any energy savings to be estimated. Therefore, no spillover was found in the program during this program year.

Both spillover and free ridership are determined as a percentage of each project for both annual energy savings and peak demand reduction. The magnitude determined of these metrics is shown in Table 3-30.

Table 3-29: Free-Ridership and Spillover for SBES Projects

Savings	Free Ridership	Spillover
Annual Energy Savings (kWh)	42,371	0
Peak Reduction (kW)	8.00	0

The final net-to-gross ratio for SBES projects is calculated as 1 – free-ridership + participant spillover. This results in an NTGR of 99.5% for annual energy savings and 99.7% for peak demand reductions. The SBES gross and net ex-post energy savings and peak demand reduction are summarized in Table 3-30.

Table 3-30: Summary of Verified Gross and Net Impacts

Program	Verified Gross kWh Savings	Verified Net kWh Savings	Net-to-Gross Ratio	Verified Gross kW Reduction	Verified Net kW Reduction
SBES	8,211,436	8,169,066	99.5% - kWh 99.7% - kW	2,359.51	2,351.51

Lifetime Energy Savings

Lifetime savings were determined for each equipment type or line item incentivized within each project. Lifetime savings were aggregated for all projects within each stratum to determine a strata level lifetime savings. These lifetime savings were divided by the aggregated annual gross and net energy savings for each stratum to determine and EUL to be extrapolated to the population by strata. Sample level EUL's by strata as well as total population lifetime energy savings are show in Table 3-31.

Table 3-31:SBES EUL's and Lifetime Energy Savings

Stratum	EUL	Gross Program Lifetime Energy Savings (kWh)	Net Program Lifetime Energy Savings (kWh)
Lighting 1	12.14	10,491,101	10,436,967
Lighting 2	13.86	20,238,431	20,134,001
Lighting 3	13.34	33,171,089	32,999,927
Lighting 4	11.93	17,943,558	17,850,970
Lighting 5	12.94	15,246,763	15,168,090
Lighting 6	14.67	6,843,184	6,807,873
Refrigeration 1	5.71	103,421	102,887
Refrigeration 2	12.72	2,976,369	2,961,011
Total	**12.16**	**107,013,915**	**106,461,727**

3.1.4.5 Process Evaluation Findings

The process evaluation consisted of a participant survey, trade ally interviews, and program staff facilitated discussions. ADM provided a process evaluation memo to PSO presenting detailed findings from all activities of the process evaluation.

ADM conducted a mixed mode (phone/email) survey of SBES participants, in November 2021. PSO staff sent 165 SBES participants an email to notify them of the survey and then ADM sent a survey invitation and two reminder emails. After email distribution of the survey, ADM made additional survey completions through phone calls.

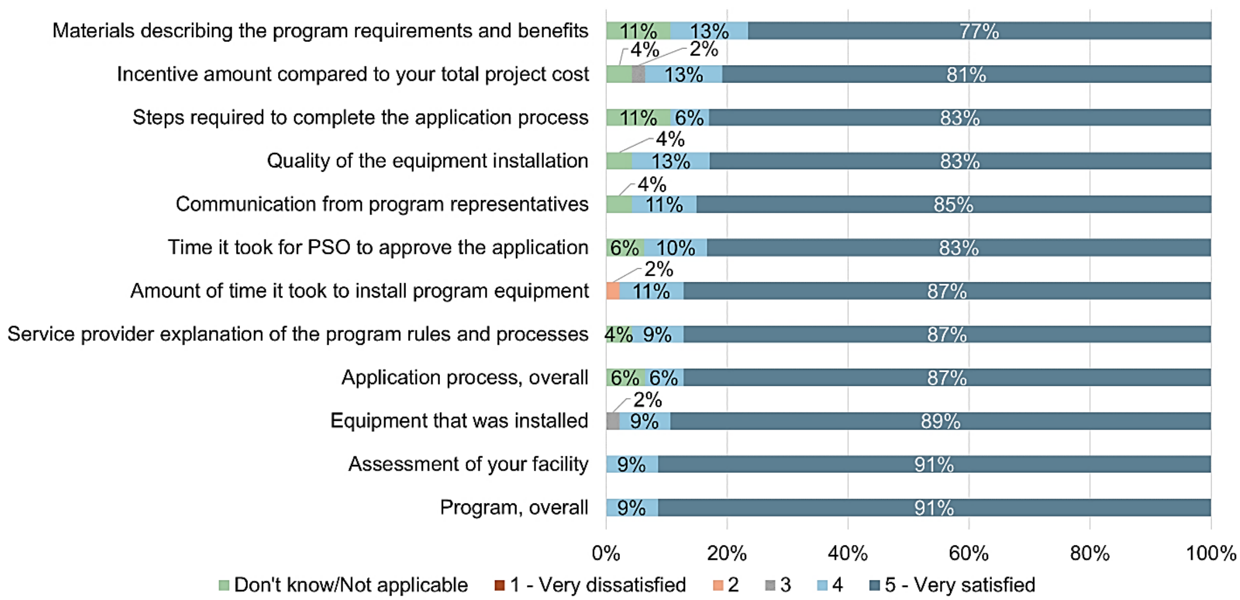
Service providers may have an overreliance on one equipment installation company. Program staff said that there are many local installation companies, but service providers have formed a habit of relying on one installation company. It may be possible to distribute SBES program incented projects more evenly to local installers to lessen the burden on this company and ensure a timely participation process.

SBES trade allies noted expanding the focus of promotional techniques. Consistent with 2020, all four trade allies said that they focus on lowering monthly energy costs and the payback period during their sales pitch. This year all four trade allies also mentioned focusing on decreased operations and maintenance costs as well as greater equipment reliability during their sales pitches. Additionally, two said they focused on increased comfort and three said they focused on increased equipment productivity. These findings suggest the SBES trade allies incorporated a greater variety of promotional tactics in 2021 than in 2020.

The three lighting-focused SBES trade allies said that the current incentive levels were effective at motivating small business customers to buy high-efficiency equipment. However, two of these trade allies said that the inability or unwillingness to pay upfront costs were important reasons that businesses did not implement energy-efficient equipment or participate in this program. One of these trade allies noted there were no significant barriers to participation for their customers and said that his company provided financing and explained the benefits of the program thoroughly.

Overall, responses showed a high degree of program satisfaction (Figure 3-12). Moreover, 65% of survey respondents either would not change anything about the program (58%) or did not know what they would change to improve the program (6%).

Figure 3-12: Participant Satisfaction with the SBES program



3.1.4.6 SBES Conclusions and Recommendations

This section presents conclusions and recommendations for the SBES Program based on the 2021 process and impact evaluation findings.

Conclusions

- Energy impact goals were met for the program year with net verified annual energy savings exceeding the ex-ante estimates. Lighting projects made up 97% of program annual energy savings with the remaining 3% from refrigeration measures.
- Program tracking and quality control remained consistent with previous program years and there were no issues reported with the current system for data tracking or quality control.
- Survey and interview findings indicate that contractors and vendors were the most frequent source of program awareness and the most important source of influence on customers’ decision to participate.

- Findings from trade ally and staff interviews indicate the program was able to maintain strong participation in 2021, building upon past year's successes and outreach methods.
- Consistent with past program years, program satisfaction remains high. Most survey respondents shared high levels of satisfaction across all aspects of the program as well as the programs overall.
- Some SBES participants noted possible areas for program improvement including increasing communication from PSO and providing additional information about other rebate programs.
- Most program participants indicated that the COVID-19 pandemic had affected their company adversely.

Recommendations

- Consider creating targeted marketing for specific program measures or to highlight certain types of energy saving projects. Trade ally interviews and survey responses indicate that there is a lack of awareness or understanding of non-lighting energy efficiency rebates that are available for PSO Business Customers. Trade allies suggested prescriptive incentives for heat pump water heaters, smart motors, evaporation controls with defrost controllers for refrigeration, evaporation controls for ECM motors, closers and hinges for walk-in coolers, and freezers, sports lighting, large dehumidifiers, and additional smart Wi-Fi thermostat brands.
- Continue searching for ways to market refrigeration measures to customers and working with trade allies to promote refrigeration measures.

3.1.5 Commercial Midstream

This section reports findings from the Commercial Midstream lighting and HVAC program. The commercial midstream program aims to influence stocking practices to promote energy efficient equipment for various commercial lighting and HVAC equipment. ADM performed an impact and process evaluation specific to this subprogram. The gross ex-post annual energy savings estimates for midstream projects resulted in a 98% realization rate for gross energy savings and a 97% realization rate for gross peak demand reduction. Net energy impacts were determined through survey efforts of program participants. Separate net-to-gross ratio's (NTG) for both annual energy savings and peak demand reduction were determined for lighting and HVAC. The lighting NTG is 72.45% for annual energy savings and 69.82% for peak demand reduction. The HVAC NTG is 90.93% for annual energy savings and 96.79% for peak demand reduction.

The midstream portion of the Business Rebates Program, started in 2019, is designed to generate long-term energy savings for PSO business customers. The goal of the program is to influence distributor stocking practices, as well as promotion and sales of higher efficiency equipment to encourage energy efficiency. The program provides rebates and support directly to qualifying distributors who then work directly with service providers or customers to promote the sale of higher efficiency equipment.

3.1.5.1 Impact Evaluation Overview

PSO's midstream program provided rebates for a total of 575 projects. 345 projects consisted of lighting measures and 230 projects consisted of HVAC equipment, an increase in project total year-over-year of 96% and 111%, respectively. Table 3-30 provides projected, ex-ante, and ex-post energy and demand impacts, as well as other program performance metrics for midstream projects.

Table 3-30: Performance Metrics – Midstream Lighting and HVAC

Metric	PY2021
Number of Projects	575
Energy Impacts (kWh)	
Reported Energy Savings	4,462,833
Gross Verified Energy Savings	4,452,718
Net Verified Energy Savings	3,633,581
Peak Demand Impacts (kW)	
Reported Peak Demand Savings	805.78
Gross Verified Peak Demand Savings	783.26
Net Verified Peak Demand Savings	659.75
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	2.69
Utility Cost Test Ratio	1.41

3.1.5.2 Process Evaluation Overview

The process evaluation consisted of facilitated discussions with program staff, interviewing distributors, and surveying end use customers. The objective of the survey was to assess the source of program awareness, factors that influenced project decision making, experience with the application process or energy consultant, program satisfaction, and inform the calculation of a Net-to-Gross ratio.

3.1.5.3 Evaluation Methodology

This section provides an overview of the data collection activities, gross and net impact calculation methodologies, and process evaluation activities that ADM employed in the evaluation of the midstream projects.

Data Collection

Data for the analysis was collected through provided program and project documentation, program staff facilitated discussion, distributor interviews, and end-use customer surveys. Program materials and documentation were gathered through the Sightline data management system. These materials were supplemented with information from manufacturers as well as the Air Conditioning, Heating and Refrigeration Institute (AHRI).

Impact Evaluation Methodology

The overall objective of the impact evaluation is to develop statistically valid estimates of gross and net annual energy savings (kWh), lifetime energy savings (kWh), and peak demand reductions (kW). ADM performed a census review of all midstream projects and line items. Ex-post savings from the Midstream Lighting program channel are determined through a review of the implementation database, end-use customer surveys, and distributor interviews. For lighting measures, we employed an engineering analysis to determine the ex-post verified energy savings for each lamp type sold through the program. The verified energy savings per fixture or lamp was calculated with methods consistent with chapter 6 of The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. For HVAC units, we employed the methodology from the Arkansas TRM v7.

Knowledge of baseline conditions is often not available in midstream applications. Baseline assumptions were determined with the implementation team following the AR TRM as well as other industry standards where the AR TRM is not applicable.

Determination of gross impacts from the Midstream channel will consist of several activities used to verify savings associated with the program. Those activities include:

- Verification of Equipment Counts: The number of units sold through the program will be verified through a review of distributor invoices.
- Verification of Fixture/Lamp Wattage and Lumen Output: Fixture and lamp wattages are reported in the program database and/or in the Point-of-Sale (POS) data provided by participating distributors. We will verify the reported values are correct by reviewing manufacturer specification sheets, Design Lighting Consortium (DLC), and/or ENERGY STAR® certifications for a census of all fixtures/lamps sold through the program. The verified lumen output of the sold lamps will then be compared to the ex-ante baseline model to determine an appropriate baseline wattage.
- Verification of HVAC equipment: Equipment will be verified against the AHRI database.
- Categorize Building Types: The program data provided by the implementation contractor includes end user contact name, business name, and installation

address. This data will be used to categorize the facility type where the sold fixtures/lamps were installed. The facilities will be categorized according to the definitions provided in the AR TRM v7. The deemed Hours of Use (HOU) and Coincident Factors (CF) provided in the TRM for each facility will be used in the ex-post energy savings calculations.

- Gross annual energy savings, peak demand reduction, and lifetime energy savings will be determined through industry standard methodologies. The AR TRM methodologies will be followed when applicable, with assumptions replaced by verifiable known conditions.

Net-to-Gross Estimation (NTG)

The purpose of net savings analysis is to determine what portion of gross savings achieved by PSO customers is the direct result of program influence. As a result, evaluating the net effects of the price discounts requires estimating free ridership without non-program sales data. ADM will investigate the PSO Midstream Program's net-to-gross ratio (NTGR) separately for Lighting and Non-Lighting (HVAC).

Midstream Lighting NTG

ADM investigated the PSO Midstream Program's lighting net-to-gross ratio (NTGR) through both a survey of end-use customers as well as from a survey of participating lighting distributors. Based on survey responses, ADM used the end-user survey to calculate free ridership.

ADM reviewed the survey data from each avenue prior to completing the analysis. If there were evidence that the buyers were not able to speak to how much the program influenced their decision, either because they were unaware of the discounted price or could not provide responses to multiple questions on program influence (e.g., responded by saying "don't know"), then we would have used the distributor scores to estimate program influence. However, sufficient information was reported from the end-user survey to warrant its use in this analysis.

ADM used self-reported responses from a random sample of customers who have purchased efficient light bulbs during the current program year to estimate lighting discount free ridership.

The survey will aim to elicit information from which to estimate the number of bulbs that the customer would have purchased in the counterfactual scenario where the efficient light bulbs were not discounted. The survey effort will be conducted with a random sample of PSO customers through phone calls. The strength of this approach is that it also allows for further questioning regarding the fate of recently purchased bulbs (e.g., installed immediately, stored for future use, the location of installation, etc.). Survey respondents will be asked a series of questions to elicit feedback regarding influences on their light bulb purchasing decisions. Each respondent will then be assigned a free ridership score based on a consistent free ridership scoring algorithm. The scoring algorithm used is based on the methodology described in the AR TRM v7.0.

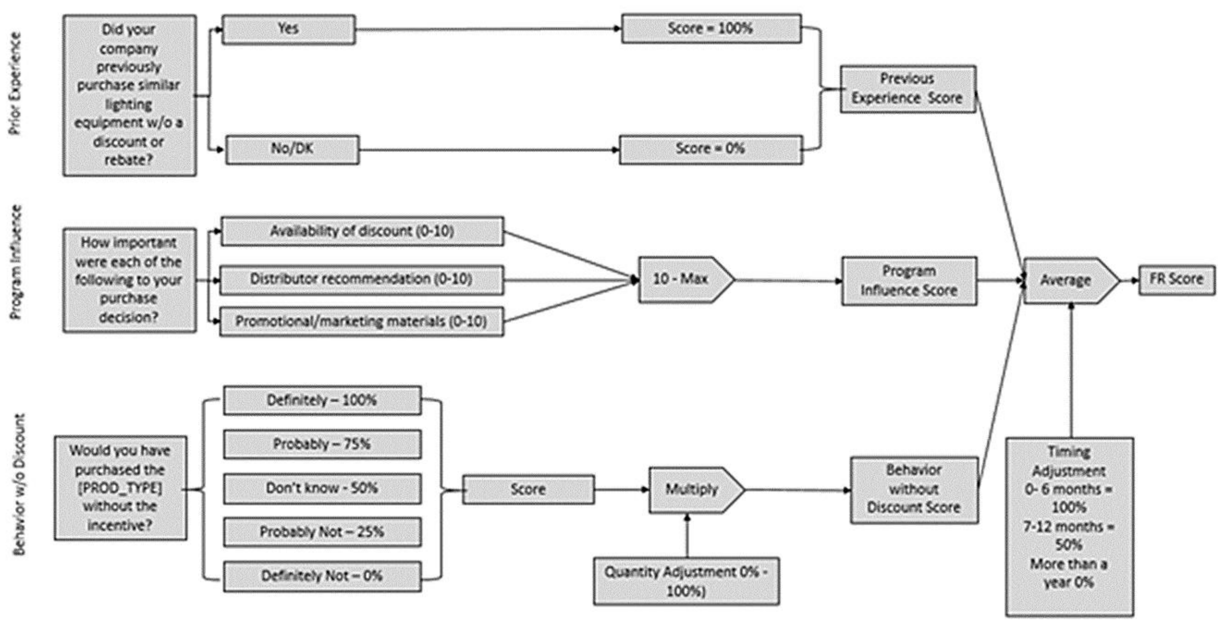
The final respondent net-to-gross score will be calculated as follows:

$$NTG = 1 - \text{Free ridership}$$

ADM will not assess spillover for the Midstream Lighting program for two reasons – there is limited spillover potential in a midstream program and the information required to calculate spillover would be burdensome and difficult for survey respondents to provide or estimate.

The free ridership scoring algorithm for light bulb purchases from the surveys is shown in Figure 3-13.

Figure 3-13: Free Ridership Scoring Algorithm



The flow diagram has three paths or branches. ADM will ask eight main questions to determine each respondent's free ridership score.

Prior Experience (first row): Two questions are used for prior experience:

- Prior to the purchase of the lighting, had your company purchased similar efficient lighting equipment?
- Did your company make any of those previous purchases without receiving a discount or rebate from PSO?

Program influence (second row): One question is used for influence/ importance:

- On a scale from 0 to 10, where 0 is “not at all important” and 10 is “very important”, how important was the following in your decision to purchase the [PROD_TYPE]?

Behavior without Discount (third row): There are five questions in this branch. One question is regarding customers’ behavior without a discount, there are two for the quantity adjustment, and two questions for the timing adjustment.

- Would you have purchased [PROD_TYPE] without the discount?
- Without the discounts from PSO, do you think you would have purchased the same amount, fewer, or more lamps?
- What percent of the lamps would you still have purchased if the discounts from PSO were not available?
- Did you purchase the [PROD_TYPE] earlier than you otherwise would have if the discount from PSO were not available? [DO NOT ASK TO NEW CONSTRUCTION PROJECT CUSTOMERS]
- When would you have purchased [PROD_TYPE] if the discounts from PSO were not available?

ADM asked customers that provide conflicting responses an open-ended question to clarify the role of the discount in their decision-making process. Additionally, to provide context, ADM will ask customers how they learned about the discount and if they knew about the discount before they made the decision to purchase the product (these two questions are not typically directly included in the free ridership scoring algorithm but also provide context when needed).

Midstream Non-Lighting NTG

ADM investigated the PSO Midstream HVAC Program’s net-to-gross ratio (NTGR) through both a survey of end-use customers as well as from a survey of participating HVAC distributors.

ADM reviewed the survey data from each avenue prior to completing the analysis. If there were evidence that the buyers were not able to speak to how much the program influenced their decision, either because they were unaware of the discounted price or could not provide responses to multiple questions on program influence (e.g., responded by saying “don’t know”), then we would have used the distributor scores to estimate program influence. However, sufficient information was reported from the end-user survey such that ADM calculated free ridership using only the end-user survey.

The methodology for end-user Midstream Non-Lighting free ridership is the same as Custom and Prescriptive and described in the Custom and Prescriptive Evaluation Methodology section.

Lifetime Energy Savings

Lifetime energy savings (kWh) is the product of annual energy savings (kWh) multiplied by the Effective Useful Life (EUL). The EUL considers the technical lifespan of the equipment as well as the change in energy savings over time. The EUL is determined by measure for each measure within each project of the evaluation sample. The EUL for prescriptive measures is sourced from the AR TRM v7.0. If a measure is not listed in the AR TRM, then a different industry standard reference, such as another technical reference manual is considered. For custom equipment, the EUL is determined based on the lifespan of the equipment or if that cannot be determined then the industry standard of 20 years is applied. Energy savings for any behavioral measures in the program is only granted one year of EUL.

Process Evaluation Methodology

The process evaluation was designed to research and document the program delivery mechanisms and collective experiences of program participants, partners, and staff. The process evaluation was designed to answer the following research questions:

- How was this program marketed? How effective were the marketing efforts?
- How well did PSO staff and distributors work together? Is there rebate processing, data tracking, and/or communication efficiencies that can be gained?
- Did the program implementation reflect its design? Are there underlying assumptions about program implementation and design that are being made about how the program will unfold? Are there ways to improve the design or implementation process?
- Were distributors satisfied with their experience? What was the level of satisfaction with the rebate amount, the application process, the rebated measures, and other aspects of program participation?
- What are PSO staff and implementation staff perspectives on the program? What are the reactions to program design choices that have been implemented?
- What do distributors like about the program? Why? What would they like to change about the program? Why?
- What share of projects are associated with specific distributors? How are savings distributed across them? Are there any differences in opinion between active and less active distributors?
- What types of buildings/facilities participated in the program? Could certain facility types be targeted more effectively?
- What customer barriers to participation do distributors see? How can these be mitigated?
- Were there any significant obstacles during the 2021 program year?

- Looking forward, what are the key barriers and drivers to program success within PSO's market?

To address these questions, ADM's PY2021 process evaluation activities included a review of program materials, program staff interviews, distributor interviews, and end-use customer surveys. Table 3-32 provides a summary of data collection activities for the process evaluation.

Table 3-32: Process Evaluation Data Collection Activities Summary

Data Collection Activity	Process Evaluation Research Objectives
Review Program Materials	Review any marketing materials, program procedure manuals, program websites, and other program documentation as it becomes available.
Program Staff Facilitated Discussion	Assess staff perspectives regarding the strengths, weaknesses, opportunities, and threats to program success.
Distributor Interviews	Investigate benefits of program participation, satisfaction with program training, feedback on the program provided marketing support and program direct marketing to customers, feedback on program materials and guidelines; information for calculation of a Net-to-Gross ratio, and satisfaction with program processes and the program overall.
End Use Customer Surveys	Gather data on participant knowledge and awareness of the program, motivation, business practices, satisfaction, reasons for participating, decision-making process, as well as data that will help to inform the calculation of a Net-to-Gross ratio.

3.1.5.4 Impact Evaluation Findings

Impact evaluation findings determine net annual energy savings and net coincident peak demand reduction. Gross energy impacts are assessed through M&V efforts on the total population of projects. The effects of free ridership are then applied to the population (on a project level basis) to determine program level net energy impacts.

Midstream Lighting Gross Impacts

The Midstream lighting program included 23,851 items sold with ex-ante energy savings of 2,074,161 kWh and ex-post savings of 2,247,470 kWh, resulting in a gross realization rate of 104%. The program channel also claimed a peak summer demand savings of 385.34 kW, with a calculated ex-post summer peak demand savings of 364.76, resulting in a realization rate of 95%. A summary of the program level savings is shown in Table 3-33.

Table 3-33: Summary of Midstream Lighting Savings

Reported kWh Savings	Verified kWh Savings	Gross kWh Realization Rate	Reported kW Savings	Verified kW Savings	Gross kW Realization Rate
2,074,161	2,247,470	108%	385.34	364.76	95%

ADM determined ex-post savings for this program through a review of the tracking database provided by the implementation contractor. We reviewed the database to ensure there were no input errors or repeat entries and used the data provided to determine quantities and wattages of each lamp type sold. The database was used to determine final ex-post annual energy savings and peak demand reduction savings. The database was also reviewed to determine quantity of lamps sold, distributor name, end customer name, lamp type, inducement amount, and sold lamp wattage.

A summary of savings by facility type can be seen in Figure 3-16. The facility type that contributed the most program savings was Lodging: Rooms. The facility type refers to all single room units of lodging facilities, including hotels, motels, and dormitories. The second largest contributing facility type was Lodging: Common Areas, this space type includes the common areas of each facility such as lobbies, hallways, and breakfast rooms not included in the Lodging: Rooms space type. The Lodging: Rooms space type contributed savings of 462,602 kWh, 22.5% of overall savings; while the Lodging: Common Areas space type contributed savings of 296,696 kWh, 14.4% of overall savings.

Figure 3-14: Reported kWh Savings by Facility Type

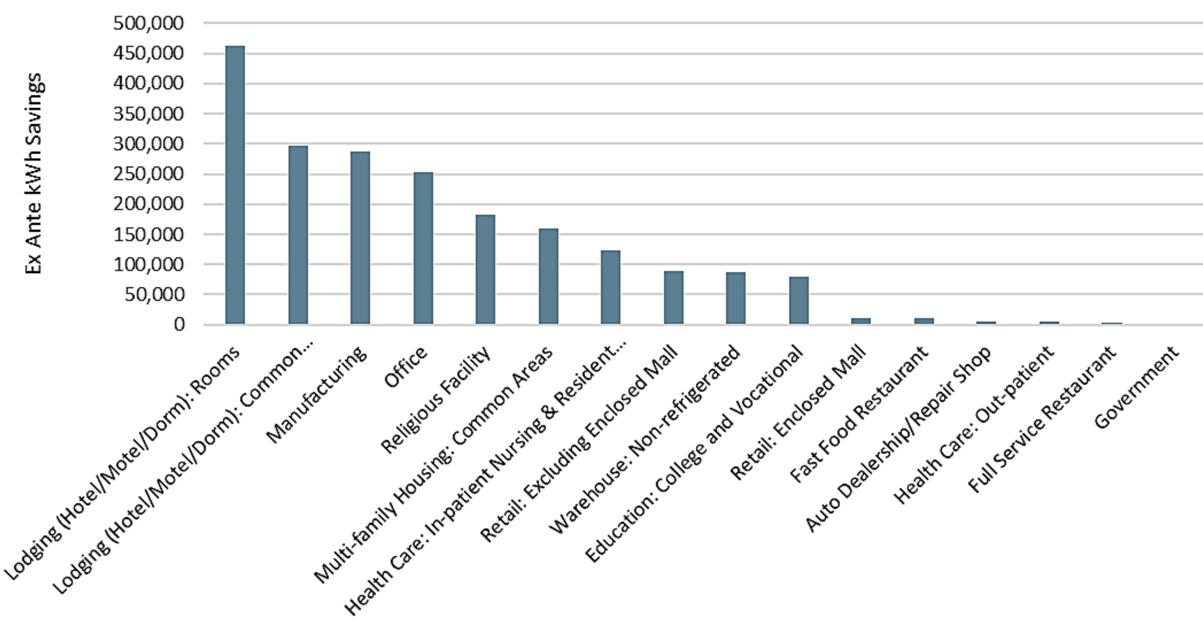
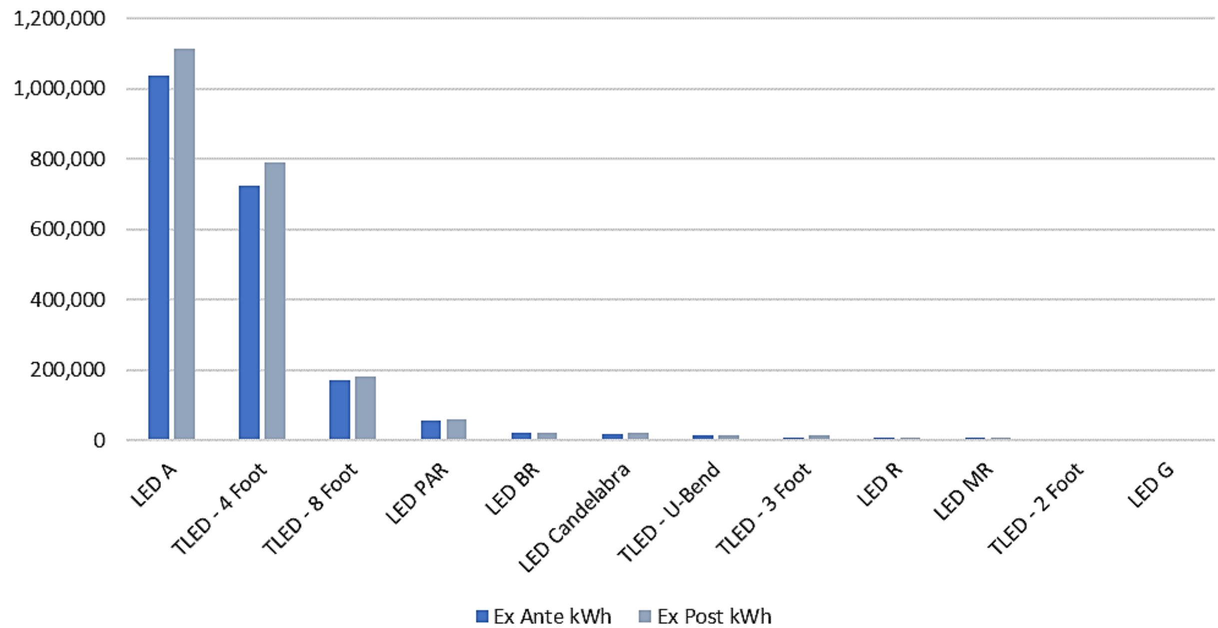


Figure 3-15 illustrates the relationship between ex ante and ex post savings. The differences in savings between the bulb types did not differ very much, with most of the difference being attributed to a difference in the applied interactive effects.

Figure 3-15: kWh Savings per Lamp Type



Discrepancies in the ex-ante and ex-post program savings can mostly be attributed to a difference in applied interactive effects between the two calculations. The ex-ante calculations utilized an energy interactive effect (IEF_e) of 1.00 and demand interactive effect (IEF_d) of 1.20 for all projects, whereas the ex-post calculations utilized a value of 1.07 and 1.10, respectively. The ex-post interactive effects were derived from a blend of facility types with expected HVAC system types.

The other instances attributing to the realization rate discrepancy are different utilized baseline wattages. ADM has built a baseline wattage table based on lumen output of each fixture type present in the program, based on the Mid-Atlantic TRM. The incidence of occurrence for projects with differing baseline wattages is 24 of the 176 projects (14%), of these projects, there is a range of realization rates from 54% to 206%.

Midstream Lighting NTG

ADM administered a phone survey to customers that purchased lighting through the PSO Midstream Lighting program. ADM sent 96 emails to 48 unique end-use customers and completed 22 surveys (46% response rate). The customers that ADM spoke with had purchased a variety of lighting types including LED Linear Lamps, A-Line Lamps, LED Recessed Trim Kits, PAR lamps, BR lamps, MR lamps and Candelabras. The 22 customers that ADM spoke with represent 40% of Midstream Lighting Program annual energy savings.

ADM used self-reported responses from customers who had purchased efficient lamps and fixtures to estimate free ridership at 72.44% for annual energy savings and 69.82% for peak demand reduction.

- Six respondents had free ridership scores of 33% or greater (representing 50% of the sample kWh savings). Free ridership is based on three categories, prior experience, program influence, and behavioral without a discount.
  - Prior Experience: Three of the six respondents were assigned 100% "Prior Experience" scores because they reported having similar experience purchasing energy efficient lighting without a discount or rebate from PSO.
  - Program Influence: Only one of the six respondents were assigned a "Program Influence" partial free ridership score, indicating that the availability of the discount, recommendation from the distributor, and any marketing material they viewed had little or no impact on their decision-making process.
  - Behavior: All six respondents stated they would have purchased this energy efficient lighting without the discount and were therefore assigned free ridership.
- Sixteen respondents had free ridership scores of 25% or less. Of these respondents six were scored as having 0% free ridership, one respondent scored a partial free ridership score between 1 and 4%, and the other nine scored between 5 to 18%.
- The six respondents with free ridership scores greater than 33% were the drivers in the determination of overall free ridership, representing 50% of the sample kWh savings.

See Table 3-34 and Table 3-35 for a summary of net savings impacts for the Midstream lighting program.

Table 3-34: Summary of Net kWh Savings - Midstream Lighting

Program Year	Gross Reported Savings kWh	Gross Verified Savings kWh	Gross Realization Rate	Gross Lifetime Savings kWh	kWh NTG Ratio	Net Verified Savings kWh	Net Lifetime Savings kWh
PY2021	2,074,161	2,247,470	108%	17,976,757	72.45%	1,628,292	13,024,160
PY2020	852,893	882,543	103%	9,056,595	80.14%	707,279	7,258,045

Table 3-35: Summary of Net kW Savings – Midstream Lighting

Program Year	Reported kW Savings	Gross Verified Savings kW	Gross Realization Rate	kW NTG Ratio	Net Verified Savings kW
PY2021	385.34	364.76	95%	69.82%	254.68
PY2020	162.38	159.94	98%	78.15%	124.99

Midstream Non-Lighting Gross Impacts

The Midstream Non-Lighting program involved the installation of 752 items over 230 projects consisting of unitary and split system air conditioners, air source heat pumps, and variable refrigerant flow heat pumps. The gross ex-post energy savings and demand reduction was 2,205,248 kWh and 418.50 kW, resulting in realization rates of 92% and 100%, respectively. A summary of the program level savings is shown in Table 3-36.

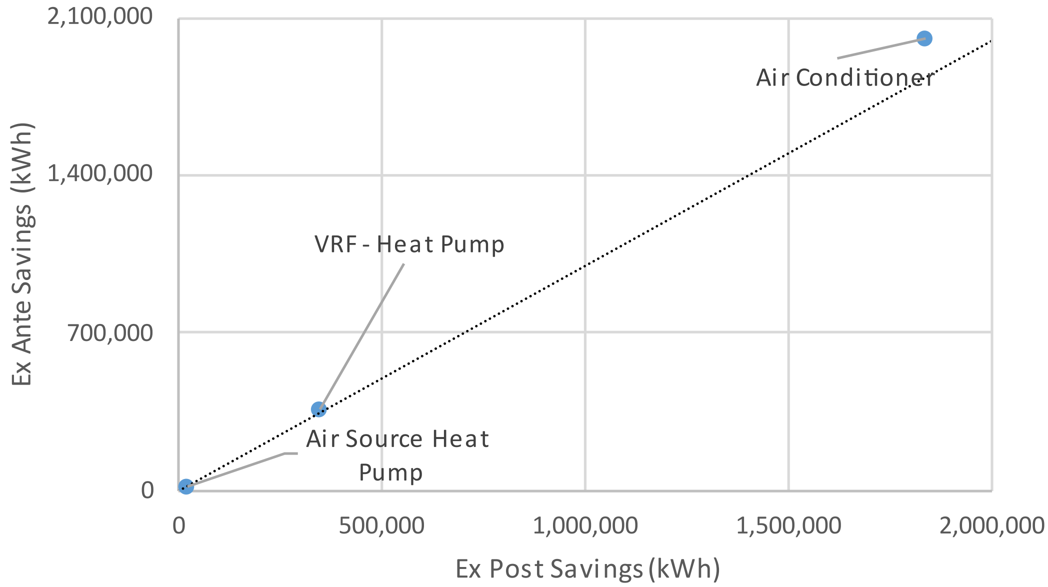
Table 3-36: Summary of Midstream Non-Lighting Savings

Reported kWh Savings	Verified kWh Savings	Gross kWh Realization Rate	Reported kW Savings	Verified kW Savings	Gross kW Realization Rate
2,388,672	2,205,248	92%	420.44	418.50	100%

ADM determined ex-post savings for the Midstream Non-Lighting Program using the program tracking data provided by the implementation contractor. The data was reviewed to identify and remove any input errors or duplicates prior to final analysis. Provided AHRI identification numbers were used to determine efficiency ratings of the installed equipment along with values determined from the Arkansas v7 Technical Reference Manual (TRM) and MidAtlantic v8 TRM.

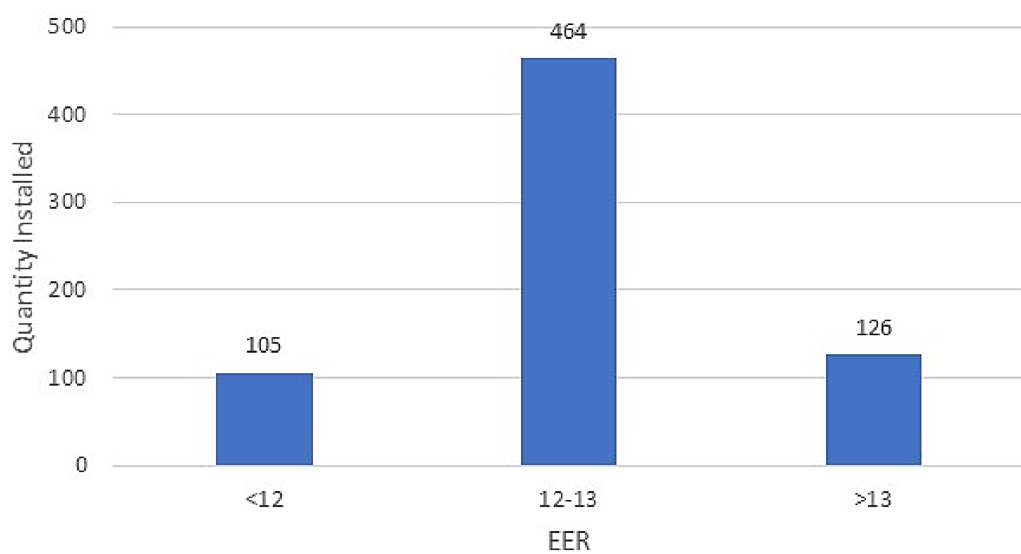
A summary of savings by equipment type is shown in Figure 3-16. The figure plots the ex-ante annual energy savings versus the ex-post annual energy savings for the installed equipment types. The “Air Conditioner” equipment type was the largest contributing equipment type with ex-ante annual energy savings of 2,006,780 kWh, 96% of the program savings. Total program savings nearly doubled compared to the previous year, with “Air Conditioner” savings growing by a factor of eight; as opposed to “VRF – Heat Pump”, which was reduced by a factor of twenty.

Figure 3-16: Ex-Ante Savings vs Ex-Post Savings (kWh) by Equipment Type



While the 12-13 EER range maintains a similar percentage of total units (61% in 2020 vs. 67% in 2021), the number of AC units installed with an EER rating greater than 13 showed the most growth, from 4% in 2020 to 18% in 2021. As time goes on, it would be expected that more efficient equipment will become available and accessible and this value to continue to grow in the future. A figure illustrating the quantities and EER ratings of installed AC units is shown in Figure 3-17.

Figure 3-17: EER Ratings of Installed AC Units



Generally, the savings discrepancies in the Midstream Non-Lighting analysis were due to a difference in AHRI-rated efficiencies of the installed equipment, as opposed to the nameplate efficiencies utilized in the ex-ante calculations. In some cases, this difference in efficiency rating warranted a shift in the baseline efficiencies based on values taken from the AR TRM, which greatly affected the savings realization rates.

The other discrepancy stemmed from a difference in effective full-load hours (EFLH) utilized in the ex-ante calculations. The ex-post calculator determines the EFLH by matching up the ZIP code of the project facility with a weather zone look-up of OK, matched to the AR TRM. The Ex-ante calculations strictly utilized Zone 8 for EFLH, whereas some projects were found to be in Zone 7 and Zone 9, causing the difference in EFLH.

Midstream Non-Lighting NTG

ADM administered a phone survey to customers that purchased equipment through the PSO Midstream Non-Lighting program. We were able to complete 10 survey responses of which all respondents reported the necessary information to determine free ridership. The customers that ADM spoke with all had purchased eligible air conditioners.

ADM used these self-reported responses from customers who had purchased eligible equipment to estimate net-to-gross ratios at 90.9% for verified annual energy savings and 96.8% for verified peak demand reduction, compared to 81.97% and 80.44% in 2020. Only three respondents reported free ridership in the subprogram, compared to two from last year’s survey. The difference being the savings contributions for projects associated with the respondents. Free ridership is applied as a percentage of each project’s annual energy savings and peak demand reduction. Free ridership may be applied at 33%, 66% or 100% of the project’s annual energy savings.

A partial free ridership score was reported for the three respondents with a free ridership score. All three respondents reported plans for the purchase of incentivized equipment, with two of them who had plans to complete the purchase regardless of any financial incentives. These two respondents were assigned scores of 66%, whereas the other respondent had a score of 33%.

Customer decision maker survey responses were also analyzed to estimate participant spillover effects. No respondents reported installing efficient equipment that met the attribution criterion and for which energy savings could be estimated; thus, no spillover was determinant. The gross kWh realization rate improved from 51% in 2020 to 93% in 2021. This is mostly due to the adjustment of ex ante calculations for VRF, where the measure-level realization rate improved from 31% in 2020 to 96% in 2021. See Table 3-37 and Table 3-38 for a summary of net savings impacts for the Midstream Non-Lighting Program.

Table 3-37: Summary of Net Annual Energy Savings - Midstream Non-Lighting

Program Year	Reported Savings kWh	Gross Verified Savings kWh	Gross Realization Rate	Gross Lifetime Savings kWh	kWh NTG Ratio	Net Verified Savings kWh	Net Lifetime Savings kWh
PY2021	2,388,672	2,205,248	92%	31,240,656	90.93%	2,005,289	28,407,933
PY2020	1,034,508	526,033	51%	6,461,359	81.97%	431,184	5,296,312

Table 3-38: Summary of Net Peak Demand Reduction – Midstream Non-Lighting

Program Year	Reported kW Savings	Gross Verified Savings kW	Gross Realization Rate	kW NTG Ratio	Net Verified Savings kW
PY2021	420.44	418.50	100%	96.79%	405.07
PY2020	76.82	73.79	96%	80.44%	59.35

Midstream Total Lifetime Energy Savings

Lifetime energy savings were determined for each equipment type or line item incentivized within each project. Lifetime energy savings are determined by multiplying verified annual energy savings with the effective useful life (EUL) from the associated TRM for the installed equipment type. Gross and net lifetime energy savings are provided in Table 3-39. Average EUL by measure classification is provided for reference.

Table 3-39: Midstream EUL's and Lifetime Energy Savings

Measure Classification	Average EUL	Gross Program Lifetime Energy Savings (kWh)	Net Program Lifetime Energy Savings (kWh)
Lighting	10	17,976,757	13,024,160
Non-Lighting	15	31,240,656	28,407,933
Total	**N/A**	**49,217,413**	**41,432,093**

3.1.5.5 Process Evaluation Findings

The process evaluation consisted of a participant survey, distributor interviews, and program staff interviews. ADM provided a detailed process evaluation memo to PSO after the completion of the 2021 program year.

Lighting End User Survey

ADM administered a survey via email and through its in-house survey team in August and September 2021 to customers that purchased lighting through the PSO Midstream Program. The survey gathered information regarding program awareness, decision-making, satisfaction, and the participation process.

ADM surveyed 23 end-use customers. ADM first attempted to gather participants' responses with an email invitation and two reminder messages. Subsequently, ADM's in-house survey team made follow-up phone calls to 60 customers. ADM invited 66 Channel participants to take the survey and 23 replied (response rate of 34%). Eight survey responses were collected via email invitation, and 15 were collected via follow-up phone call. Unless otherwise stated, the calculations, graphs, and tables in this process evaluation use the complete sample of respondents (n = 23).

Customers that responded to the survey confirmed purchasing LED linear lamps, A-Line lamps, BR lamps, MR lamps, and/or PAR lamps. All the survey respondents confirmed that they purchased the discounted LEDs for the business or organization they worked for, owned, or managed to retrofit or replace existing lighting, though one respondent (4%) mentioned some of the lighting was also installed at a new construction project. None of the survey-takers noted installing any of the discounted products outside of PSO territory.

- Thirty-five percent of respondents said that they learned about the discounted lighting from a distributor employee (30%) or marketing materials at the store (4%). Other respondents mentioned prior experience with the program (22%) or word-of-mouth information from a friend, relative, contractor, or colleague (22%), or PSO staff (4%). Seventeen percent of respondents could not recall how they had heard about the discounted lighting.
- All respondents said that a lighting distributor recommendation had been an important factor in their decision to purchase energy-efficient lighting.
- Eighty-six percent of respondents said that the availability of discounts was important in their decision to purchase energy-efficient lighting[26]
- Seventy percent of respondents said they had purchased similar energy-efficient lighting in the past and 47% of those respondents reported having purchased it without a discount.

Most of the survey respondents said that all the discounted lamps they purchased through the program had been installed, though some respondents mentioned they had not had an opportunity to install all the lamps yet. Table 3-40 displays the percent of the program discounted lamps respondents reported having installed currently. ADM will use this data to inform future program years.

[26] n=22. Rated the importance of the discounts a 7 or higher on a scale from 0 (not at all important) to 10 (very important)

Table 3-40: In-Service Rates for Discounted LED Lamps

Product Type	Percent of Lamps Installed	Sample size (n)
LED Linear Fixture(s)	94%	15
LED Linear Lamp(s)	93%	14
A-Line Lamp (s)	84%	4
BR Type Lamp(s)	85%	2
PAR Lamp(s)	100%	1

Lighting Distributor Interviews

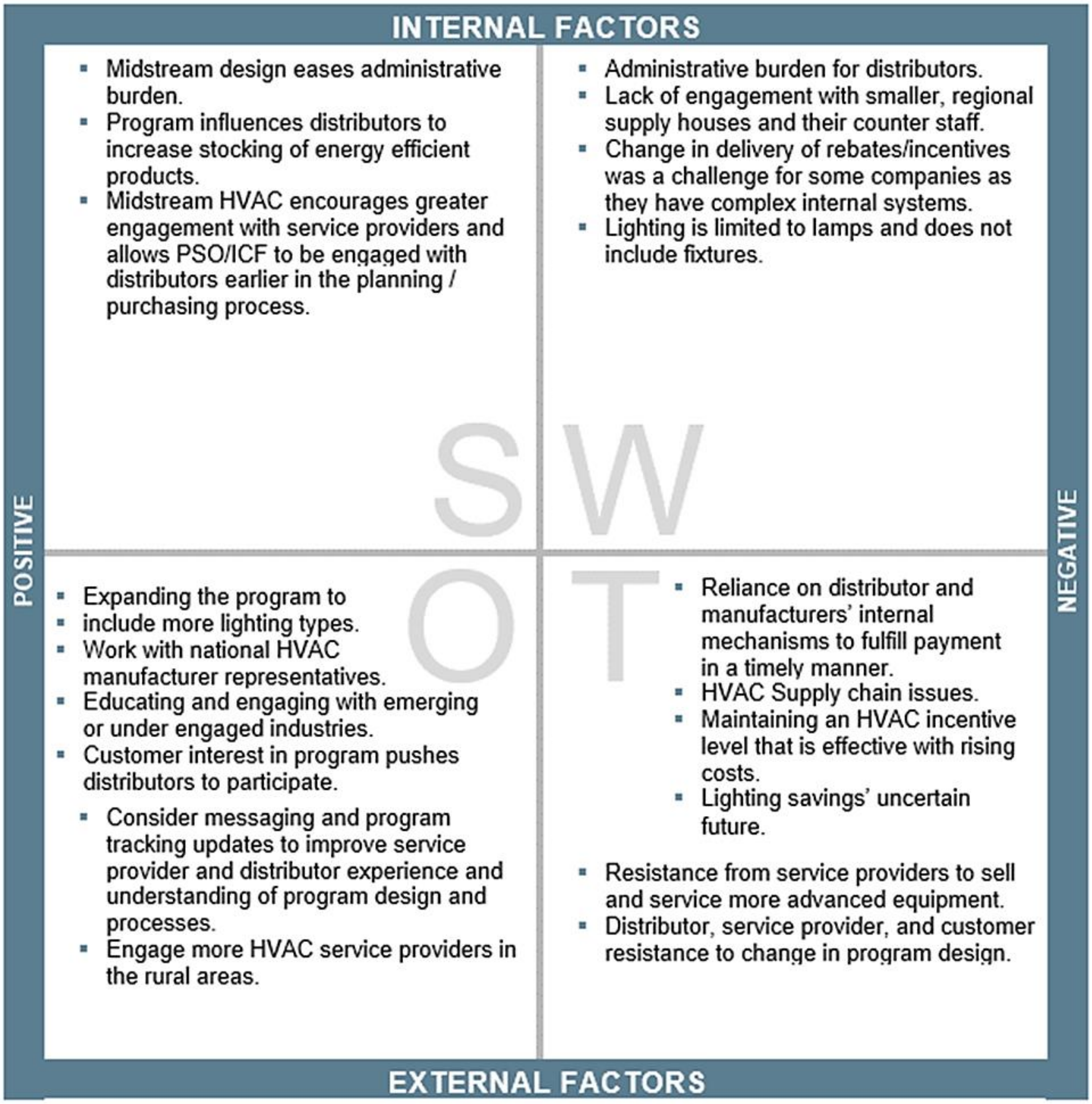
In September 2021 ADM interviewed two participating lighting distributors. The two distributors represented over 90% of Midstream Lighting Program annual energy savings. These interviews addressed Program awareness and distributors' reasons for participating, the Program training they received, the types of customers they serve and how they reach them, and aspects of their Program experience.

Program Staff Facilitated Discussion - SWOT Analysis

ADM researchers facilitated a discussion with PSO's program coordinator and ICF's account manager for the Midstream Program in October 2021. The purpose of the discussion was to investigate the Midstream Program's internal strengths and weaknesses as well as its external opportunities and threats (SWOT). This section provides the findings of the facilitated discussion conducted with PSO and ICF staff.

During the call ADM staff shared their computer screen via video call and took notes to ensure attendees' thoughts were accurately captured. After the discussion, ADM updated the SWOT matrix to synthesize the ideas shared during the facilitated discussion and subsequently reshared the updated matrix to solicit any additional questions, comments, or feedback to improve the diagram. Figure 3-18 illustrates a simplified version of the performed SWOT analysis.

Figure 3-18: PSO Midstream Program SWOT Analysis



The following summarizes key findings of the SWOT analysis of the Midstream Program:

- The Midstream team acknowledged distributor and service provider acceptance of the shift in program design as a challenge. The change in delivery of incentives was a challenge for some larger companies with complex internal accounting and payment systems. Additionally, at the beginning of the program there were some service providers and distributors that had been involved in other PSO programs that were reluctant to change. For example, there was some struggle to get service providers to fill out paperwork initially as they did not believe it was worth their time, especially if it was a "one-off" project. This resistance to change persists to an extent, and the contacts noted it as a threat, but limited to only some service providers and distributors.

- Program staff identified the lack of administrative burden for implementation staff and end-use customers as a key strength of the Midstream Program. Staff noted that the Midstream design reduces administrative burden for the implementation staff as well as for customers, compared to the Custom and Prescriptive Program. Despite the reduced burden for implementation staff and customers, the burden on distributors may be a weakness and the Program staff is continuously seeking to streamline the process.
- Midstream HVAC enables staff to engage with distributors in project planning. The Midstream design involves staff interaction with HVAC distributors, so they can "keep a pulse" on project preferences, bidding, timelines, and delays. This involvement enables staff to assess each project's need for incentives and potentially assess free riders.
- The Midstream design supports greater engagement with HVAC service providers. The program staff suggested that the Midstream program design has made it easier for service providers to participate. They acknowledged that some service providers have been reticent to participate, but once a service provider participates for the first time, perspectives tend to shift, and they understand the benefits and ease of participation.
- The program's reliance on distributors and manufacturers for payment processing is a potential threat to service provider satisfaction. Program staff stated that the service providers' satisfaction is dependent on distributors and manufacturers internal mechanisms to process payments in a timely manner.
- The limited range of eligible lighting measures in the Program is a weakness and opportunity for growth. Program staff noted that lighting is limited to lamps and does not currently include fixtures. Expanding the program to include more lighting types would enable more customers to participate and encourage more distributors to engage to a greater extent. Despite contacts acknowledging this opportunity, they also noted that this could threaten to "cannibalize other energy-efficiency programs' in the PSO portfolio.
- There are several opportunities to expand the program's reach. The contacts suggested that marketing directly to customers has proven to be an effective way to encourage distributors to participate, but there are additional outreach channels that may be successful. The contacts suggested marketing the program to or engaging with:
    - HVAC service providers in rural areas.

    - National HVAC manufacturing representatives. This could help the program increase participation from a higher level in a top-down manner.
    - Under-engaged and emerging industries, such as the marijuana grow industry. The Midstream team observed that there are many facilities being built with baseline HVAC equipment, without consideration for the opportunities for savings and incentives through Midstream HVAC
- Program staff mentioned four external roadblocks that may hinder future performance. These roadblocks include rising HVAC equipment costs coupled with supply chain issues, and an uncertain future for savings attributable to energy efficient lighting. The staff observed that rising equipment costs may make keeping effective incentive levels challenging. Additionally, the staff said that service providers' reluctance to sell and service more advanced HVAC equipment hinders the program's participation and future growth.

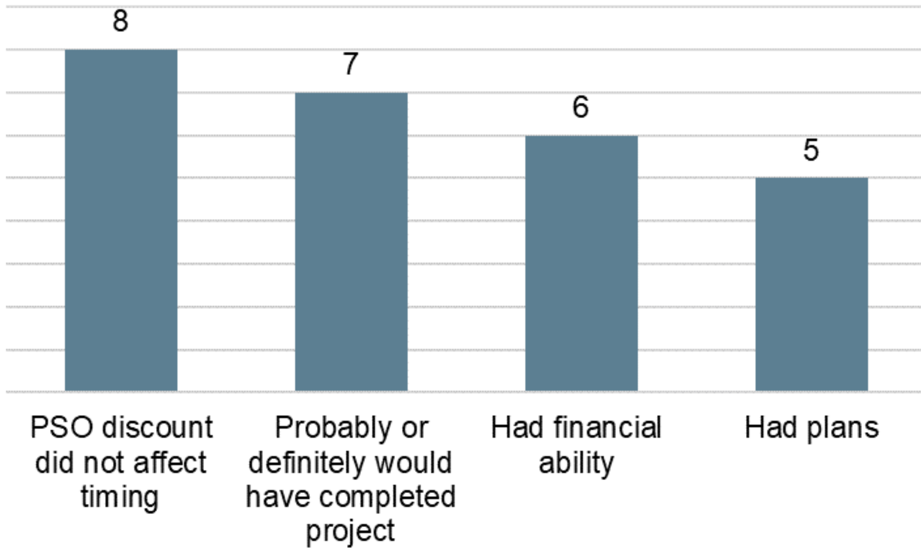
HVAC End User Survey

ADM administered a phone survey in August 2021 to customers that purchased HVAC equipment through the PSO Midstream Program. ADM surveyed 10 customers after attempting to contact 20 participants with 39 phone calls and 27 emails, for a completion rate of 50%. Unless otherwise stated, the calculations, graphs, and tables in this process evaluation use the complete sample of respondents (n = 10).

The nine respondents who were aware that PSO sponsored a discount on the HVAC equipment they purchased answered questions regarding their decision-making process. Six respondents said they purchased more efficient HVAC equipment because of the discount. And two said they probably would not have purchased the same energy-efficient HVAC equipment without the PSO-discount.

Figure 3-19 Midstream HVAC Customer Decision-Making displays the number of customers who had prior plans, would have done the project without the discount, and said the discount had affected the timing of their project. It also displays the number of customers that said they would have had the financial ability to complete the project without the discount.

Figure 3-19 Midstream HVAC Customer Decision-Making



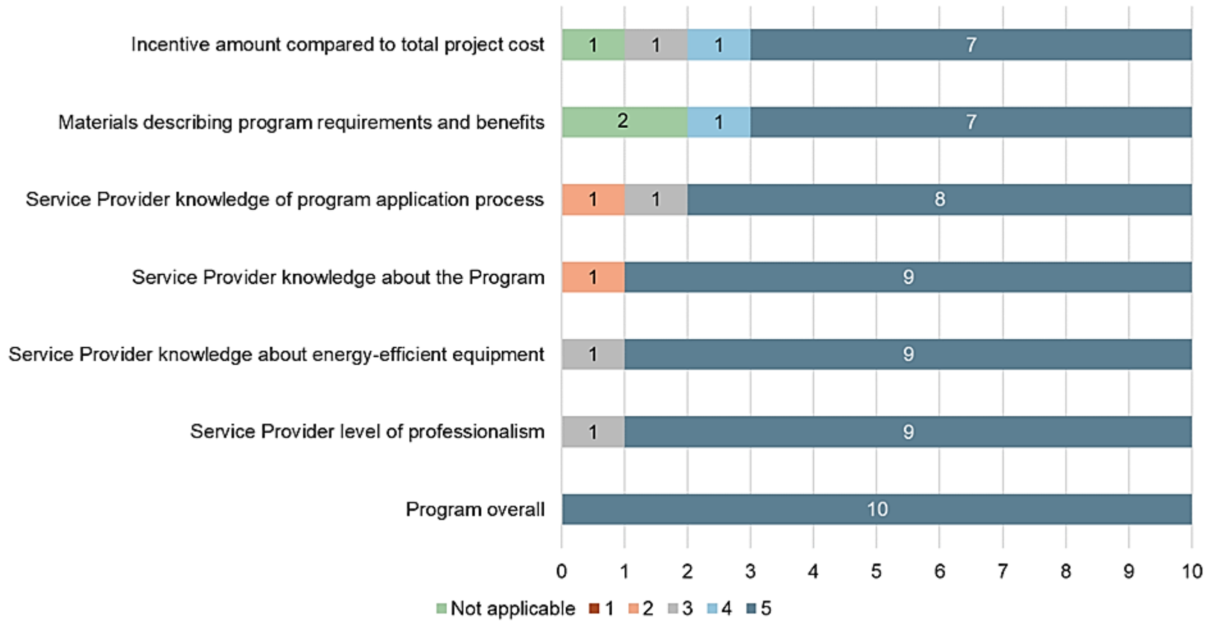
Six respondents said they purchased more efficient HVAC equipment because of the discount. And two said they probably would not have purchased the same energy-efficient HVAC equipment without the PSO-discount.

Seven respondents said they had previous experience with PSO energy-efficiency programs and six of these respondents said that it was important in their decision to complete the energy efficient HVAC equipment project through PSO's Midstream Program.[27]

All survey respondents said they were satisfied with the program overall and most indicated they were satisfied with their experience with their HVAC service provider (see Figure 3-20). Two customers suggested that the service provider they worked with could improve their understanding of program processes. One customer suggested that PSO should advertise the program to a greater extent. Another noted that they were interested in expanding the program to incentivize power generators. All respondents said they were satisfied with PSO as their electric utility.

[27] Rated the importance of their experience either as somewhat or very important.

Figure 3-20 Midstream HVAC Customer Satisfaction



HVAC Distributor Interviews

In September 2021, ADM interviewed 8 HVAC distributor contacts that participated in the PSO Midstream Program. These interviews addressed Program awareness, training, reasons for participating, stocking and sales of Program-qualified equipment, and other aspects of their experience in PY2021.

Seven of the contacts worked directly for HVAC distributors ("distributor representatives"). One stated that they were a consultant, and their company facilitated PSO Midstream HVAC projects by working with a distributor and end-use customers.

The contacts noted differing levels of marketing or outreach to promote Program-qualified units and the PSO Midstream Program. Seven of the contacts noted that their company used one or more strategy to sell Program-qualified units. Table 3-41 displays the strategies that contacts noted using to sell qualified units, as well as the number of contacts that said the Program had influenced them to use each strategy.

Table 3-41 Strategies Used to Promote Qualified Equipment

Promotion Strategy	Number of contacts that use strategy	Number of contacts influenced by Program to use strategy
Upsell contractors	5	4
Discuss the benefits of Program-qualified units with design professionals	4	2
Develop marketing or informational materials for service providers	3	3
Marketing of Program-qualified units	3	2
Conduct training workshops for contractors	1	1

3.1.5.6 SWOT Commercial Midstream Conclusions and Recommendations

This section presents findings from the process and impact evaluation and recommendations based on these findings.

Conclusions

- The Midstream subprogram more than doubled in participation and annual energy savings per participant from the previous year. An increase was expected as we return to normalcy from COVID-19, however, the previous year's program saw an increase despite the pandemic.
- Findings from ADM's facilitated discussion with PSO and ICF staff as well as lighting distributor interviews suggest there is an opportunity to expand Midstream lighting offerings to reach a larger segment of PSO's commercial customers as well as sell more efficient products.
- The program discounts act as motivation for most customers, but survey results suggest a portion of the Midstream lighting and HVAC customers would purchase energy efficient equipment without the program.
- There is an opportunity for program staff to increase coordination or collaboration with Lighting distributors. The lighting distributors mentioned two opportunities to increase program support:
  - Engagement with staff earlier in the year to ensure a timely launch.
  - Working with staff to ensure customers do not engage in "rebate shopping".
- Distributors indicate some frustration with the incentive process that may present an opportunity for improved program performance.

- External factors may play an increasing role in the program's future performance due to continued supply chain issues, increasing equipment costs, and federal requirements for baseline efficiency ratings.

Recommendations

- Re-evaluate the measures in the Midstream HVAC program guide. Water source heat pumps (WSHP) were included in the original program guide, however, there have been no WSHPs installed through the midstream program in the last three program years. There may be an opportunity to revise to the program guide to include a measure with greater demand.
- Consider the implementation of food service equipment for the Midstream program. Including both the Lighting and Non-Lighting programs, only 16 of the 575 completed projects were done at Fast Food or Full-Service Restaurants. Incentivizing food service equipment may draw more customers from these facility types and expose them to the Lighting and Non-Lighting portions of the program.
- Consider additional lighting product types, such as fixtures to enable a larger variety of businesses to participate. While this may erode the Custom and Prescriptive program, the efficiency gains through the midstream strategy may benefit the overall energy efficiency portfolio.
- Utilize interactive effects from the AR TRM based on heating and cooling types for Midstream Lighting projects.
- Differentiate 3-shift and 1 and 2-shift manufacturing facilities and utilize the corresponding deemed hours to get the most appropriate savings estimate.
- Consider ways to engage with HVAC service providers with outreach, training (both program and technology to increase comfort levels with new efficient technologies), or seminars create greater familiarity and willingness to promote the program and offer and service high efficiency equipment.
- Explore ways to foster greater engagement with the program, such as working with national HVAC manufacturer representatives, increasing outreach to rural distributor store branches, and directly targeting emerging or under-engaged industries.
- ADM has now collected multiple years of survey based ISR data. Consider incorporating this data as opposed to deemed values now that the sample size is significant.

3.2 Multifamily Program

ADM has completed an impact and process evaluation of PSO's Multifamily Program. The impact evaluation consists of verification of annual energy savings (kWh) and peak demand reduction (kW) with the inclusion of in-service rates, and net savings impacts. The process evaluation provides insights into program design and implementation.

3.2.1 Program Overview

The Multifamily Program is in its third year in the Public Service Company of Oklahoma (PSO) portfolio during program year 2021 (PY2021). The PY2021 reported Program savings were more than double the portfolio goal at 205%. While the Multifamily Program goal of serving 100 customers was the same as the previous year, the customers served increased from 112 to 129 customers. The 129 customers describe projects completed at participating facilities. PY2021 included 30 unique properties with 3,063 individual apartments receiving one or more energy efficiency measures offered by the Multifamily program. Program expenditures also exceeded the budget; however, the additional energy savings outweighed the additional cost. Table 3-42 below illustrates performance metrics for the Multifamily Program.

To be eligible for the Multifamily Program, the property must be composed of three or more dwelling units within the service territory. Energy efficiency equipment is eligible within dwelling units, in common areas, and in office spaces.

Table 3-42: Performance Metrics - Multifamily Program

Metric	PY2021
Number of Customers	3063
Budgeted Expenditures	$1,289,905.00
Actual Expenditures	$1,248,171.78
Energy Impacts (kWh)	
Projected Energy Savings	1,585,300
Reported Energy Savings	4,256,383
Gross Verified Energy Savings	4,354,603
Net Verified Energy Savings	3,694,145
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	313.40
Reported Peak Demand Savings	1,207.03
Gross Verified Peak Demand Savings	1,189.33
Net Verified Peak Demand Savings	1,177.44
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	3.62
Utility Cost Test Ratio	2.58

The Multifamily Program provides comprehensive energy efficient measures for qualifying Multifamily properties in the PSO service territory. The Program offers direct install measures (ENERGY STAR® LEDs, faucet aerators, and low-flow showerheads) at no cost to the participating Multifamily property. Tenant dwellings that receive direct install measures are eligible for an energy survey. The energy survey is turned into a report that compares the energy use of the property to similar properties in the neighborhood, recommends ways to be more energy efficient, and shows potential savings of energy upgrades. The Multifamily Program offers commercial energy efficiency measures in addition to the Residential measures. The Commercial measures include LED lamps and fixtures, air infiltration, ceiling insulation, duct sealing, HVAC system replacements, water heaters, ENERGY STAR® windows, ENERGY STAR® pool pumps, ENERGY STAR® washing machines, ENERGY STAR® dryers, vending machine controls, and ice machines.

The Multifamily Program combines the provision of financial inducements with access to technical expertise. The aim is to maximize Program penetration across a range of potential Multifamily customers. The Program has the following goals:

- Increase owner/operator awareness and knowledge of applicable energy-saving measures and their benefits.

- Increase the market share of Commercial-grade high-efficiency technologies sold through market channels.
- Increase the installation rate of high-efficiency technologies in Multifamily facilities by businesses that would not have done so absent the Program.

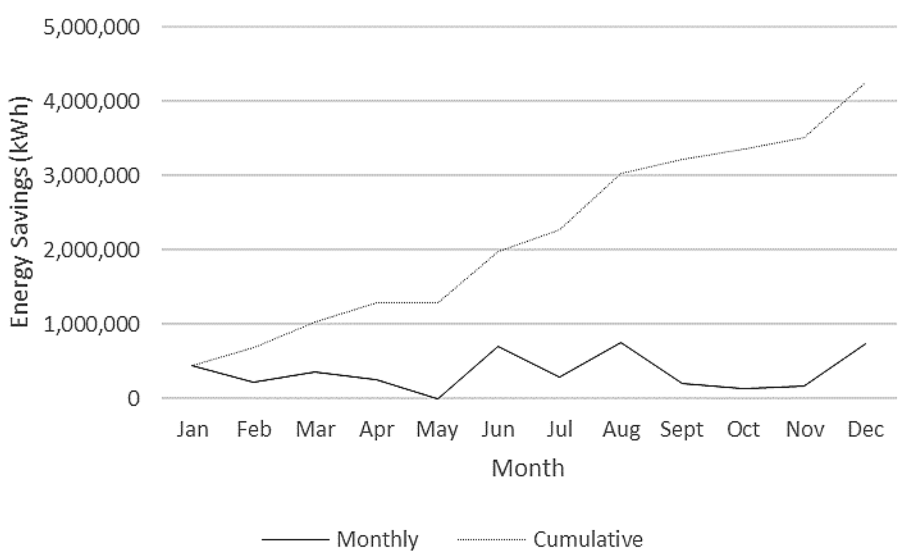
The Multifamily Program defines prescriptive rebate amounts to participating customers for some measures, including certain types of lighting, lighting controls, HVAC equipment, water-related equipment, and other equipment. The Multifamily Program pays rebates for custom projects (e.g., chillers) that do not fall into prescriptive measure categories on a per kWh and kW impact basis. Table 3-43 summarizes Multifamily Program activity by the percentage of reported savings by measure type.

Table 3-43: Percentage of Reported Savings by Measure Type

Measure Type	Percent of Program
HVAC	50.75%
Building Envelope	26.03%
Lighting	17.61%
Domestic Hot Water	5.33%
Appliances	0.28%

Participation in the Multifamily Program varied throughout the year. The initial effects of the pandemic impacted the program for the first few months. The largest projects, in terms of both savings and incentives were completed in June, August, and December, with a lull in projects during the other months. Figure 3-21 illustrates program activity throughout the year, including monthly and cumulative project savings.

Figure 3-21: Accrual of Reported Annual Energy Savings During the Program Year



Program participation and savings goals were exceeded, with both metrics having increased from the previous program year.

3.2.2 EM&V Methodology

This chapter provides an overview of the data collection activities, gross and net impact calculation methodologies, and process evaluation methodologies that ADM employed in the evaluation of the Multifamily Program.

Data Collection

Data collection activities for the evaluation consisted of a review of program materials, virtual verification visits, a facilitated discussion with program staff, service provider interviews, and interviews with participating owners/managers and tenants.

Program information and documentation was obtained for the census of projects within the program. Documentation included energy savings algorithms and inputs, project invoices, equipment specification sheets, and any available implementation documents such as inspection reports. ADM also acquired information on equipment from industry references such as the Air Conditioning, Heating, and Refrigeration Institute (AHRI) and the Design Lighting Consortium (DLC). PSO uses Sightline in conjunction with an SQL Server Reporting Services (SSRS) system as its central tracking and reporting system. Review and collection of this documentation is the desk review portion of the impact evaluation.

In lieu of on-site data collection due to safety protocols during the pandemic, ADM collected information virtually and confirmed measure installation with virtual site visits. Data collection activities included property owner/manager surveys, service provider interviews, and a program staff facilitated discussion. ADM collected on-site data, when possible, virtually. ADM did not deploy any monitoring equipment but gathered baseline conditions and efficient equipment conditions such as quantities, specifications, locations, and operating conditions. The property owner/manager surveys provided self-reported data for the net-to-gross (NTG) analysis as well as process evaluation input. Table 3-44 shows the achieved sample sizes for the different types of data collection activities utilized for this study.

Table 3-44: Sample Sizes for Data Collection Efforts

Evaluation Activity	Achieved Sample Size
Virtual Site Visit	6
Property Owner/Manager Survey	6
Facilitated Discussion with Program Staff	1
In-depth Interviews with Service Providers	2
Engineering Desk Review	Census

3.2.2.1 Gross Energy Impacts Methodology

ADM performed a census review of program tracking data to determine gross energy savings program results. ADM used the following steps to evaluate the Multifamily Program gross energy savings and peak demand reduction:

- Program tracking data was reviewed to determine the scope of the Program and to ensure there were no data issues such as duplicate entries or missing data.
- Periodic review of the program data was completed throughout the year, to reduce the risk of evaluation uncertainty through performing desk reviews of initial project data and providing commentary to PSO regarding the utilized methodologies of savings calculations.
- ADM conducted a detailed engineering desk review for each project completed in the Multifamily program. The desk review process includes a thorough examination of all project documents, including invoices, equipment cut sheets, pre, and post-inspection reports, and estimated savings calculators. The review process led to further requests for information and/or project documents for corresponding projects determined to have potential for savings realization discrepancies.
- ADM calculated verified gross savings impacts. The sources for deemed savings algorithms are the 2013 Oklahoma Deemed Savings Document, Arkansas Technical Reference Manual v.7 (AR TRM), and Mid-Atlantic Technical Reference Manual v.8 (Mid-Atlantic TRM).
- ADM used the data collected through virtual verifications and surveys to revise any savings calculations, as necessary. For example, if the reported savings calculations relied on operating hours for a given measure that was inaccurate based on the on-site verification and data collection, changes are made to reflect actual operating conditions more accurately.
- Net energy impacts are determined through survey results of property owners/managers to assess the impact of free ridership.

- Lifetime energy savings are determined through application of industry standard effective useful life (EUL) references by equipment type such as the AR TRM.

ADM used the algorithms in

Table 3-45 below to calculate annual energy savings, peak demand reductions, and lifetime energy savings for the Multifamily Program.

Table 3-45: References for Energy Savings Calculations

Measure	Methodology References
Air Infiltration	Arkansas TRM v.7.0, Section 2.2.9
Ceiling Insulation	Arkansas TRM v.7.0, Section 2.2.2
Duct Sealing	2013 OKDSD, Section 5
Faucet Aerators	Arkansas TRM v.7.0, Section 2.3.4
Heat Pumps	2013 OKDSD, Section 12
Low-Flow Showerheads	Arkansas TRM v.7.0, Section 2.3.5
ENERGY STAR® Refrigerator	Arkansas TRM v.7.0, Section 2.4.3
ENERGY STAR® Windows	2013 OKDSD, Section 6
Lighting Efficiency	Arkansas TRM v.7.0, Section 2.5.1.4
	Arkansas TRM v.7.0, Section 2.5.1.3
	Arkansas TRM v.7.0, Section 3.6.2
	Arkansas TRM v.7.0, Section 3.6.3
ENERGY STAR® Dryer	Mid-Atlantic TRM v8.0
ENERGY STAR® Washing Machine	Arkansas TRM v7.0 2.4.1
Water Heater	Arkansas TRM v7.0 2.3.1

3.2.2.2 Net-to-Gross Estimation (NTG)

To determine what portion of gross savings achieved by PSO customers is the direct result of program influence, we used net-to-gross estimation (NTG). ADM administered a survey to owners/managers of Multifamily properties to assess free ridership and spillover for the calculation of NTG. ADM reviewed the survey responses to assess the likelihood that participants were free riders. The free ridership methodologies used for determining what portion of a customer’s savings are attributable to the program varied by whether measures were direct install or non-direct install. A discussion of the two free ridership methodologies is below.

Free-Ridership (Non-Direct Install)

The property owner/manager survey questioned program participants to assess the program’s influence on the installation of Multifamily non-direct install measures. These include program measures besides lighting, faucet aerators, and low flow showerheads. The questions asked to program participants are:

- If they could afford to install the equipment without the financial support of the program.
- If they had plans to complete the project without program involvement.
- The likelihood of installing the equipment without the financial and informational support of the program provided for free; and
- The timing of the project in the absence of the program.

In this methodology, financial ability was a gateway value, in that if a participant did not have the independent financial ability to purchase energy efficient equipment absent an incentive, the other components of free ridership are not considered. The assessment of free ridership scores factored the other components of free ridership if the participant had financial capability. An overall free ridership score was calculated based on participant plans, a likelihood of installing the measure in the absence of the Program score, and a timing score.

ADM assessed prior plans to implement a measure using the responses to the following questions:

- Prior to learning about the program, did you have plans to implement the energy efficient measure?
- Did you have plans to specifically implement the energy efficient measure as opposed to a standard efficiency measure?

Respondents who indicated that they previously installed the measure at the property and had prior plans to implement the energy efficient measure are scored 1 on this component. The prior plans score for all other respondents was 0.

The estimation of free ridership incorporated the program's influence on the timing of the project in one of two ways. First, consistent with the Arkansas TRM definition of free ridership, respondents who indicated that the project would have been completed in more than one year if the program were not available are assigned a free ridership score of 0. The program's impact on timing modified the score for all other respondents in the follow ways.

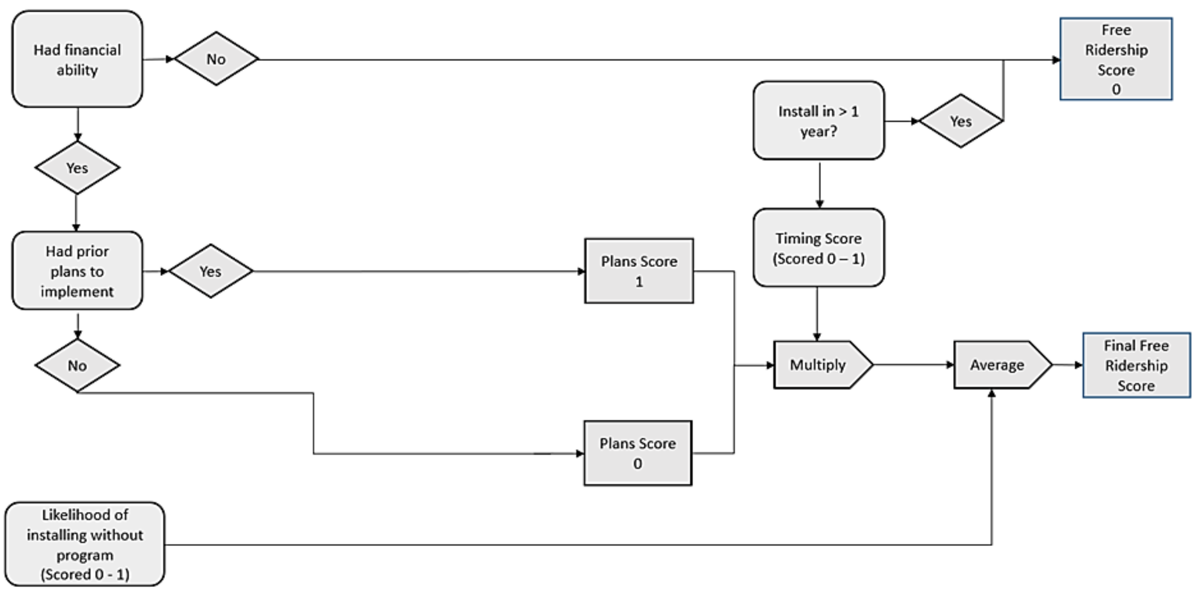
- If the respondent stated that they would have installed the measure in 6 months to one year, then the score is reduced by one-half; and
- If the respondent stated that they would have installed the measure at the same time or within 6 months of when the measure was initially installed, the score is not adjusted.

The respondents' stated their likelihood of installing a measure if the financial support was not provided or if the measure was not recommended through the energy survey. Respondents rated the likelihood of installing the measure on a scale of 1-4, where 1 means that they would not have installed the measure without the program and 4 means that they would have installed the measure without the program. The scoring of responses is as follows:

- 1 (Definitely would not have installed) = 0
- 2 (Probably would not have) = 0.25
- 3 (Probably would have) = 0.75
- 4 (Definitely would have installed) = 1
- 98 (Don't Know) =0 .5

A flow diagram of free ridership scoring of non-direct install measures is shown in Figure 3-22.

Figure 3-22: Non-Direct Install Scoring Flow Chart



Free-Ridership (Direct Install)

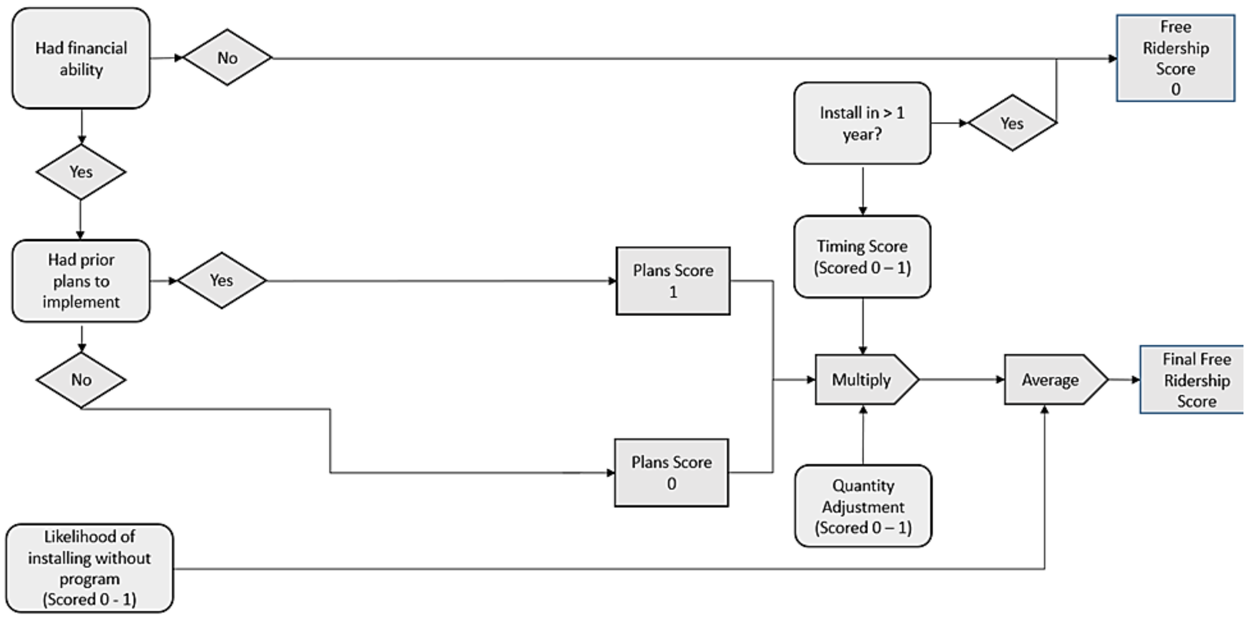
The approach to assess free ridership for direct install measures was like the approach used for non-direct install measures with the following differences:

- Re-wording questions based on direct-install versus incentive.
- An indication that a participant had previous direct install measures at the property in addition to stating that they had plans to install the measure before learning about the program.

- A quantity adjustment was applied because different numbers of direct install measures could potentially be installed at each dwelling in a property.

A flow diagram for free ridership scoring of direct install measures is shown in Figure 3-23.

Figure 3-23: Direct Install Scoring Flow Chart



Participant Spillover Methodology

To estimate participant spillover impacts, ADM asked participant survey respondents if they had purchased any additional items because of their experience with the program without receiving an incentive. Spillover is defined as the additional energy savings achieved by a participant because of the energy-efficiency programs influence.[28] Participants who indicated one or more energy efficiency purchases triggered logic to ask additional questions about what was purchased, and the number of units purchased to estimate the savings impact.

Additionally, to determine whether energy savings resulted from measures attributable to the program ADM asked the following questions:

- On a scale of 0 to 10, where 0 represents “not at all important” and 10 represents “extremely important,” how important was the experience with the program in your decision to purchase the items you just mentioned?

[28] The Uniform Methods Project. National Renewable Energy Laboratory (NREL). Chapter 17: Estimating Net Savings: Common Practices.

- On a scale of 0 to 10, where 0 represents “not at all likely” and 10 represents “extremely likely,” how likely would you have been to purchase those items if you had not participated in the Program?

ADM attributed savings to the program if the average of the first and 10 minus the second response if it was greater than 7.

Spillover Score = Average (SP1, 10-SP2)

3.2.2.3 Lifetime Energy Savings

Lifetime energy savings (kWh) is the product of annual energy savings (kWh) multiplied by the Effective Useful Life (EUL). The EUL considers the technical lifespan of the equipment as well as the change in energy savings over time. The EUL is determined by measure for each measure within each project of the evaluation sample. The EUL for prescriptive measures is sourced from the AR TRM v7.0. If a measure is not listed in the AR TRM, then a different industry standard reference, such as another technical reference manual is considered.

3.2.2.4 Process Evaluation Methodology

The process evaluation is designed to answer the following research questions:

- How did PSO market this program? Which marketing methods were most effective?
- What motivates owners/property managers to participate in the program? What barriers prevent participation?
- How well did PSO staff, service providers, implementation contractors, and property managers/owners work together? Is there rebate processing, data tracking, and/or communication efficiencies that can be gained?
- Did the program implementation reflect its design? Are there underlying assumptions about program implementation and design that are being made about how the program will unfold? Are there ways to improve the design or implementation process?
- Were property managers/owners satisfied with their experience? What was the level of satisfaction with the rebate amount, the application process, the rebated measures, and other aspects of program participation?
- Did property managers/owners find the energy survey of their property to be beneficial? If not, how could the survey be improved?
- What are PSO staff and implementation staff perspectives on the program? What are reactions to program design choices that have been implemented?

- What are key indicators of program success? Is the program achieving success? Do various stakeholders perceive the program to be successful?
- What types of multifamily properties participated in the program? Could certain facility types be targeted more effectively?
- Were there any significant obstacles during the 2021 program year?
- Looking forward, what are the key barriers and drivers to program success within PSO's market?

To address these questions, ADM's process evaluation activities included a survey of decisionmakers and interviews with service providers and program staff (facilitated discussion) to gain insight into program design and implementation. Table 3-46 details the data collection activities performed for this program's evaluation.

Table 3-46: Process Evaluation Data Collection Activities Summary

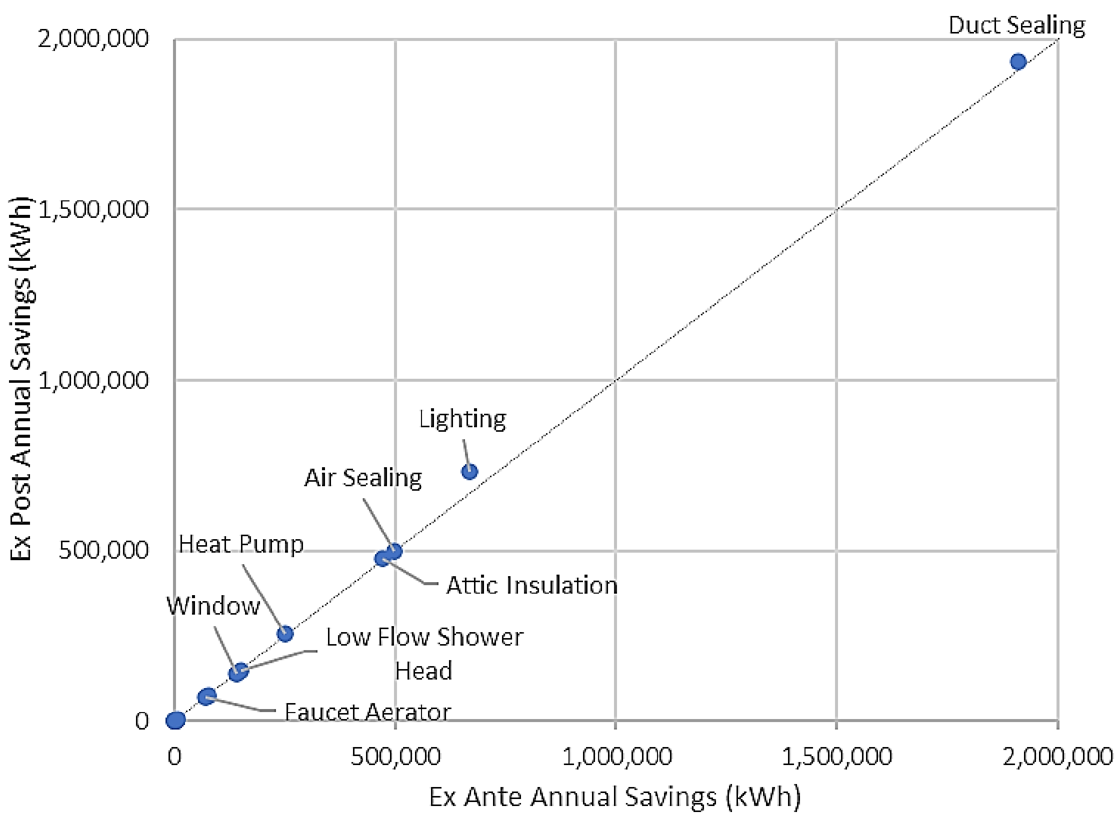
Data Collection Activity	Process Evaluation Research Objectives
Program Staff Facilitated Discussion	Discuss decisionmaker journey to create a common understanding of participation experience and identify key touchpoints to create a journey map.
Review Program Materials	Review program design or implementation materials, marketing materials, program procedure manuals, program websites, and other program documentation as it becomes available. This includes application forms, savings calculation spreadsheets, databases, and tracking systems to verify relevant information needed for the evaluation is being collected.
Property Owner/Manager Survey	Gather data on participant knowledge and awareness of the program, business practices, satisfaction, reasons for participating, decision-making process, as well as general attitudes and behaviors regarding energy efficiency, PSO's Multifamily program, and PSO as their utility.
Service Provider Interviews	Assessment of program changes, barriers to participation, satisfaction with program procedures and how it compares to other programs in the region; and assessment of program marketing materials, training, and communications with program staff.

3.2.3 Impact Evaluation Findings

Impact evaluation findings determine net annual energy savings and net coincident peak demand reduction. Net impact results are determined through the application of net-to-gross ratios applied to the verified gross energy impacts through evaluation activities. Gross energy impacts have been determined through a census desk review of all projects accompanied by data collection of surveys and site visit verification.

The Multifamily program in 2021 consisted of 17 main measure types spanning both direct install measures and non-direct install measures. A graphical representation of the relative contribution of measures to the overall Multifamily Program ex-ante savings (reported savings), ex-post savings (verified savings) and realization rates is in Figure 3-24. As shown in the figure, lighting and duct sealing are the measures with the largest impact on the program, with realization rates of 110% and 101%, respectively. Duct sealing can be attributed to 45% of program savings. The top contributing measures are labeled while measures with minimal impact are not labeled. Those not labeled include, water heaters, ENERGY STAR® washing machines, dryers, refrigerators, new construction lighting, and lighting controls.

Figure 3-24: Ex-Ante vs. Ex-Post Measure Level Energy Savings



The program level realization rate for gross annual energy savings is 102% with measure level variation from 51% to 110%. Table 3-47 details gross annual energy savings for each measure present in the program. Findings for measure types that deviated from ex-ante estimates are explained below.

Table 3-47: Verified Gross Annual Energy Savings by Measure

Equipment	Total Reported kWh	Total Verified kWh	kWh RR
Duct Sealing	1,909,312	1,934,131	101%
Lighting	667,448	732,271	110%
Air Sealing	498,366	498,366	100%
Attic Insulation	470,585	479,325	102%
Heat Pump	250,723	255,649	102%
Low Flow Shower Head	150,660	149,645	99%
Window	139,194	139,151	100%
Whole Building Approach	77,033	73,856	96%
Faucet Aerator	72,196	72,822	101%
ENERGY STAR® Refrigerator	6,465	6,410	99%
Water Heater	4,207	2,949	70%
New Construction Exterior > 5000 sq ft	3,996	3,996	100%
ENERGY STAR® Clothes Washer	3,861	3,861	100%
ENERGY STAR® Clothes Dryer	1,410	1,410	100%
Occupancy Sensor (Lighting)	436	430	99%
Air Conditioner	318	161	51%
Space by Space	172	172	100%
Total	**4,256,383**	**4,354,605**	**102%**

3.2.3.1 Measure Level Gross Annual Energy Savings (kWh)

ADM found no discrepancy in energy savings methodology for most of the energy efficiency measures in the program. For some of the measures with a difference in realization rate less than 2%, such as duct sealing heat pumps, and low flow showerheads, the reason for the discrepancy appears to be the ex-ante calculation of savings using the OKDSD, where the ex-post calculations utilized the AR TRM, per the program EM&V plan. Measures with realization rate factors where realization rates differed by more than 2% are listed below.

Retrofit Lighting

The annual energy savings realization rate for retrofit lighting measures is 110%. The interactive effects utilized for estimating energy savings were taken from the AR TRM, dependent upon the heating and cooling types of the facility. The difference in realization rate is due to the ex-ante calculation's application of the OKDSD interactive effects.

Attic Insulation

The annual energy savings realization rate for attic insulation is 102%. Both the ex-ante and ex-post calculations utilized the AR TRM for determining savings. The ex-ante used the default values associated with an efficient R-value of 38 in savings calculations, whereas the ex-post calculations determined savings per sq. ft. of installation by interpolating the reported R-value. The difference in the interpolated savings vs. the default is the reason for the discrepancy.

Whole Building Approach

The annual energy savings realization rate for this measure is 96%. The reason for discrepancy with this measure is due to the application of heating type-related interactive effects in the ex-post savings calculations. The ex-ante calculations appear to be using a savings interactive effect of 1.00 for all line items, whereas the ex-post was using interactive effects based on the heating and cooling condition of the project facility.

Faucet Aerator

The annual energy savings realization rate for this measure is 101%. A review of the ex-ante savings found that all line items were using a recovery efficiency (RE) rating of 1.00 and utilizing deemed values associated with weather zone 9 from the AR TRM. The ex-post calculations utilize a zip code lookup to determine weather zones and associated savings inputs, along with the default RE rating of .98.

ENERGY STAR® Refrigerator

The annual energy savings realization rate for this measure is 99%. This is the first instance of this measure present in the Multifamily program. Ex-post savings were determined using the inputs provided in the tracking data taken from Sightline. Review of the ex-ante savings values found that savings were being determined with different deemed values than reported. Along with a rounding error, where deemed inputs were being rounded to significant figures for the calculation of demand reduction.

Water Heater

Annual energy savings realization rate for this measure is 70%, with one line item attributing less than 1% of program savings. Like the Air Conditioner measure, this is the first instance of this measure in the Multifamily data set. All values for determining savings for the equipment were determined using the AR TRM, whereas the reported baseline efficiency doesn’t appear to match either the AR TRM or OKDSD.

Central Air Conditioner

The annual energy savings realization rate for this measure is 51% with one line item attributing less than 1% of program savings. This is the first instance of this measure present in the Multifamily program. The ex-ante tracking data appears to fit criteria of the

Room AC type from the OKDSD, while the installed unit is a central AC unit. Verified savings impacts are based on efficiency ratings from the AHRI directory, differing from the reported savings impact inputs.

3.2.3.2 Coincident Peak Demand Reduction (kW)

The overall realization rates for the peak demand reduction are 98%. The main difference in calculated peak demand reduction values is in the calculation for heat pumps. Other discrepancies were found in air conditioners, water heaters, and EnergyStar® dryers. Discrepancies in the calculation of heat pump kW is due to a difference in cooling capacity and EER values as determined by the AHRI certificates of installed heat pumps from the ratings listed in the tracking data. The discrepancies for water heaters and air conditioners are both covered under the discrepancy explanations in Section 3.2.3.1.

The peak demand reduction realization rate for ENERGY STAR® Dryers is 10%. The reason for the discrepancy in peak demand reduction was determined to be a magnitude error in the coincidence factor used in the ex-ante calculations. This was the same for last year's analysis. There were also realization rates of 46% and 70% for air conditioners and water heaters, respectively. The explanation for these discrepancies is the same as stated in Section 3.2.3.1. Demand reduction by measure is explained in Table 3-48.

Table 3-48: Verified Gross Peak Demand Reduction by Measure

Equipment	Total Reported kW	Total Verified kW	kW RR
Duct Sealing	445.96	444.8	100%
Lighting	351.62	350.92	100%
Heat Pump	93.41	77.13	83%
Attic Insulation	88.03	89.31	101%
Whole Building Approach	83.79	83.79	100%
Air Sealing	59.53	59.53	100%
Window	56.86	56.83	100%
Low Flow Shower Head	16.2	15.56	96%
Faucet Aerator	7.51	7.57	101%
Space by Space	1.5	1.5	100%
ENERGY STAR® Clothes Dryer	1.41	0.14	10%
ENERGY STAR® Refrigerator	1.2	0.93	78%
ENERGY STAR® Clothes Washer	0.91	0.91	100%
Water Heater	0.37	0.26	70%
Air Conditioner	0.3	0.14	46%
Total	**1,208.60**	**1,189.33**	**98%**

3.2.3.3 Net-To-Gross Estimation Impact Findings

ADM collected survey data to assign free ridership scores from property owners/manager as well as tenants. Free ridership has been determined based on the 6 self-claimed survey results of the property owners/managers, along with the results of last year's surveying (11 results) to add more data points in determining free ridership. One respondent was removed from the free ridership analysis as their financial ability to purchase the energy efficient equipment was dependent on energy efficiency financial incentives but not necessarily from PSO, resulting in a total of 16 results for calculation of free ridership.

Free ridership was found in relation to screw-in LED light bulbs, air sealing, attic insulation, windows, new construction lighting, water heaters, and ENERGY STAR® Refrigerators. Full free ridership was claimed in one instance, which included NC lighting, windows, air sealing, attic insulation, and water heaters. The combined overall free ridership score for the past two years for annual energy savings is 15.17% and 1.00% for peak demand reduction.

None of the Multifamily representatives that were asked questions regarding the installation of additional energy efficient improvements following program participation indicated program influence. Therefore, ADM found that there were no attributable participant spillover effects. The tables below summarize the results of the net savings analysis.

The NTG ratios are calculated as 1-free-ridership plus spillover. This results in a program level annual energy savings NTG of 84.8%. Results by measure classification are shown in Table 3-49 for annual energy savings and Table 3-50 for peak demand reduction.

Table 3-49: Multifamily Net Energy Savings

Program	Expected kWh Savings	Verified Gross kWh Savings	Free Ridership (kWh)	Verified Net kWh Savings	Net to Gross Ratio
Multifamily	4,256,383	4,354,603	660,458	3,694,145	84.8%
Total	**4,256,383**	**4,364,603**	**660,458**	**3,694,145**	**84.8%**

Table 3-50: Multifamily Net Peak Demand Savings

Program	Expected Peak kW Reductions	Verified Gross kW Reductions	Free Ridership (kW)	Verified Net kW Reductions	Net to Gross Ratio
Multifamily	1,208.60	1,189.33	11.89	1,177.44	99.0%
Total	**1,208.60**	**1,189.33**	**11.89**	**1,177.44**	**99.0%**

3.2.3.4 Lifetime Energy Savings

Lifetime energy savings were calculated by multiplying the annual energy savings by the effective useful life (EUL) from the corresponding AR TRM section. Lifetime energy savings and average EUL by measure type are shown in Table 3-51.

Table 3-51: Measure EUL's and Lifetime Energy Savings

Equipment	EUL	Gross Lifetime Savings (kWh)	Net Lifetime Savings (kWh)
Duct Sealing	18	34,814,356	29,534,096
Lighting	19	8,756,660	7,428,546
Air Sealing	11	5,482,026	4,650,572
Heat Pump	16	4,090,383	3,469,999
Windows	20	2,783,018	2,360,920
Low Flow Shower Head	10	1,496,451	1,269,486
Whole Building Approach (NC Lighting)	11	812,411	689,193
Faucet Aerator	10	728,217	617,769
Attic Insulation	20	526,759	446,866
ENERGY STAR® Refrigerator	17	108,964	92,438
ENERGY STAR® Washing Machine	14	54,054	45,856
New Construction Lighting - Exterior	11	43,956	37,289
Water Heater	13	38,332	32,519
ENERGY STAR® Dryer	14	19,746	16,751
Occupancy Sensor (Lighting)	8	3,441	2,919
Air Conditioner	19	3,058	2,594
Space-By-Space (NC Lighting)	11	1,892	1,605
Total		**59,616,428**	**50,574,461**

3.2.4 Process Evaluation Findings

ADM's process evaluation activities included a survey for property owners/managers, service provider interviews, and a facilitated discussion with program staff used to develop a customer journey map. ADM provided a detailed process evaluation memo to PSO after the completion of the 2021 program year.

3.2.4.1 Service Provider Perspectives

ADM interviewed the two primary service providers that participated in the PSO Multifamily Program. Respondents noted that participation in PSO's Multifamily Program has increased the volume of their home energy efficiency improvement projects. One respondent observed that the program's key strengths were that it helped property owners and managers reduce their utility costs and to increase their properties' value. Staff at both service provider organizations noted property owners and managers viewed the Program as an excellent opportunity to improve their buildings' and potentially extend equipment operating life.

3.2.4.2 Owner/Manager Survey

Overall survey-takers were satisfied with interactions with program staff, the quality of the contractor's work, the process of applying for the program and having equipment installed, performance of the equipment installed, wait time to receive services, and the quality of the contractor's work and the program overall. [29] Most respondents noted having recommended the program to someone else. All the decisionmakers said they were satisfied with PSO as their electric utility.

3.2.4.3 Customer Journey Map

ADM facilitated a discussion with program staff to support the development of a customer journey map for the program. A customer journey map is a graphic representation of how a customer or participant interacts with a program or product. Key customer touchpoints were categorized into five phases: awareness, planning, installation, quality assurance and post-installation, and feedback.

The discussion led to the conclusion that individual journey maps are necessary to differentiate between new construction and retrofit projects. Having two avenues complicates the process not only from the customer perspective but program staff as well. The customer journey map includes customer thoughts as obtained during surveying efforts. These can be thought of as Key Moments of Truth (KMOT) for the customer or decisionmaker. More detail on each phase of the customer experience for a retrofit project is presented in Figure 3-25.

[29] Rated their satisfaction a 4 or 5 on a scale from 1 (very dissatisfied) to 5 (very satisfied)

Figure 3-25: Multifamily Retrofit Decisionmaker Journey Map

PSO MULTIFAMILY PROGRAM

Customer Group: Retrofit multifamily decisionmakers (property managers, owners)

Objective: Create a common understanding of the participation experience, identify key touchpoints & opportunities for program improvement

	AWARENESS	PLANNING	INSTALLATION	QUALITY ASSURANCE & POST INSTALLATION	FEEDBACK
TOUCHPOINT	*Service Providers, ICF/PSO Staff, Word-of-Mouth, or Internet Search*	*ICF Program Staff or Service Provider*	*Service Providers or participating company staff*	*ICF Program Staff; third-party-verifier (TPV), participating customer staff*	*ICF Program Staff, participating company staff, ADM*
CUSTOMER ACTION	1. Receive outreach from PSO/ICF Staff or Service Providers *OR* 1. Research available rebates and no-cost measure improvements available through Program on internet *OR* 1. Learn about program from friend, colleague, family	1. Work with Program staff, service provider, and TPV (as required) to determine appropriate measures to implement. 2. Assist service provider with required program paperwork/intake form (as needed) *OR* 2. Complete program paperwork/intake form with Program staff guidance or assistance	1. Coordinate with service provider to complete Program installations/improvements *OR* 1. Have internal staff or service provider complete rebated/no-cost measure installations	1. Coordinate with TPV, contractor or ICF staff to complete any post-installation requirements a) Test-in/out for air and duct sealing and HVAC installs b) Visual verification for lighting measures 2. Receive payment (if applicable)	1. Complete decision-maker survey and site visits with ADM Associates
CUSTOMER THOUGHTS	• **My property needs improvements. (KMOT)** • Tenants are interested in improvements. • The property would be more attractive to potential tenants with improvements. • Improvements must meet company efficiency requirements. • Are there ways for me to get no cost or incentivized improvements for my property? • Is my property eligible for this program? • **Do I have the authority and ability to enroll my property? (KMOT)**	• **What is the out-of-pocket, upfront cost for each improvement type? (KMOT)** • Is financing available? • What are the participation requirements for each improvement type? • **How can making improvements reduce property bill costs? (KMOT)**	• How will I notify all tenants of the improvements? • How long will installation of program measures take? • Will it be a challenge to coordinate measure installation with the service provider?	• **Did the equipment that we installed qualify for the Program incentive as expected? (KMOT)** • Coordination with the contractor and ICF/PSO staff was well executed.	• I do not have time for a survey. • I am satisfied with improvements made through program, contractor, and overall program experience. • Can other properties we own or manage participate? • Can we complete additional upgrades at the participating property?

3.2.5 Conclusions and Recommendations

Evaluation of the Multifamily Program consisted of a process and impact evaluation to determine ex-post verified net energy savings estimates as well as assess achievement of the program's objectives. ADM found that the magnitude and estimation of annual energy savings and peak demand reduction exceeded projections. A summary of program level impacts is shown in Table 3-52 and Table 3-53.

Table 3-52: Summary of Program Level Annual Energy Savings Impacts (kWh)

Program	Reported Gross kWh Savings	Verified Gross kWh Savings	Realization Rate	Net-to-Gross Ratio	Verified Net kWh Savings
Multifamily	4,256,383	4,354,603	102%	84.8%	3,694,145

Table 3-53: Summary of Program Level Coincident Peak Demand Impacts (kW)

Program	Reported Gross kW Savings	Verified Gross kW Savings	Realization Rate	Net-to-Gross Ratio	Verified Net kW Savings
Multifamily	1,207.03	1,189.33	98%	99.0%	1,177.44

ADM developed the following conclusions from the evaluation findings.

- The program is driven by repeat direct participants as well as recruitment from service providers and word-of-mouth referrals from past participants. Decisionmaker survey responses suggest that the program's service providers and staff play a crucial role in recruiting participants. During the customer journey map facilitated discussion, the program staff confirmed that the awareness generated from their initial outreach in PY2019 had led to continued interest and awareness in PY2021 from multifamily property owners and managers.
- Duct sealing was the largest contributor with program savings (45% of program portfolio) with retrofit lighting a second. However, there is a diversification of lighting related measures that could be expanded on in the future (Lighting controls, NC lighting).
- Incentivized measures offered by the program have expanded from the previous year, but new additions to the program have minimal impact on program savings. There have been multiple measures that have appeared for the first time this year, and some from last year weren't present.
- Staff interviews indicate that the program was successfully marketed and promoted in 2021; however, findings from ADM's service provider interviews suggest that there is an opportunity to increase marketing and outreach collaboration efforts.

ADM offer the following recommendations for the Multifamily Program.

- Both service providers said the program has great potential, though one noted room for improvement and provided a recommendation worth noting:
- Provide a quarterly funding update. The service provider indicated that he had successfully marketed the program, but when interested properties contacted him, they were unable to participate because no funds remained.
- Focus on recruiting decisionmakers that have not participated in the past that would not otherwise invest in energy-efficient improvements. Recruitment of new participants will help the program continue its growth.
- Increase program funding to support the strong demand from Multifamily properties for energy efficiency improvements. Program budget was exceeded for the third year in a row. The budget may be hindering growth of the program as noted from service providers who had interested properties unable to participate due to no funds remaining.
- Evaluation and implementation teams work closely to ensure consistency and accuracy in M&V methodologies and program tracking data. Expansion of tracking data in these cases would improve program analyses, especially if new measure savings begin to contribute significantly to program savings.
- New measure additions to the program may require additional data fields, such as space type for new construction lighting (Space-By-Space).
- Include product category for ENERGY STAR® refrigerators to better determine savings.
- Ensure participating decisionmakers are engaging with the Program in the most holistic and inclusive manner possible (e.g., lighting, HVAC, and weatherization measures). Findings from decisionmaker surveys and review of program tracking data suggest participating properties may have additional opportunities for energy efficiency improvements.
- Change the interactive effects for lighting projects from OKDSD to the AR TRM to improve realization rates.
- Utilize interpolation as specified in AR TRM for calculations of attic insulation measures.
- Implement weather zones and associated savings inputs for faucet aerators rather than using minimum efficient values.
- Consider net-to-gross implications at the onset of a project's application. The risk of free ridership for a program increases when program participation is dominated by low volume high energy savings projects. ADM encountered a decisionmaker

in the survey effort who achieved financial means to purchase energy efficient equipment through a range of available incentives. It was unclear if additional incentives from PSO was necessary.

3.3 Home Weatherization Program

This chapter presents evaluation findings from the impact and process evaluation of the Home Weatherization's 2021 program year.

3.3.1 Program Overview

PSO's Home Weatherization Program objective is to generate energy savings and peak demand reduction for limited income residential customers through the direct installation of weatherization measures in eligible dwellings. The weatherization program provides no-cost energy efficiency improvements to PSO customers with household incomes of $50,000 or less a year. PY2021 performance metrics are summarized in Table 3-54.

Table 3-54: Performance Metrics – Weatherization

Metric	PY2021
Number of Customers	2,214
Budgeted Expenditures	$3,457,428
Actual Expenditures	$3,394,070
Energy Impacts (kWh)	
Projected Energy Savings	2,394,910
Reported Energy Savings	4,229,974
Gross Verified Energy Savings	4,227,635
Net Verified Energy Savings	4,227,635
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	1,145.82
Reported Peak Demand Savings	2,412.07
Gross Verified Peak Demand Savings	2,411.81
Net Verified Peak Demand Savings	2,411.81
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	2.97
Utility Cost Test Ratio	2.06

In 2021, PSO partnered with Titan ES and Revitalize T-Town (RTT) to deliver weatherization efficiency improvements:

- Titan ES is a home weatherization contractor that provides diagnostic energy assessments, customer education, and installation of weatherization measures to improve energy efficiency.
- RTT is a Tulsa based non-profit organization that provides a variety of home improvement services for limited income homeowners. The services provided by

RTT include program-sponsored energy efficiency improvements, as well as other repairs such, as roof repairs.

Through the Home Weatherization Program, participants received diagnostic energy assessments, which identify a list of cost-effective improvements such as air sealing, attic insulation, duct sealing, and water heater tank/pipe insulation. Table 3-55 shows measures installed through the program in 2021. Duct sealing made up the largest share of reported kWh savings and was the third most common measure type installed. In conjunction with attic insulation and air sealing, this makes up approximately 99% of the program savings. In 2020 the program expanded and added several measures intended for mobile homes (low flow showerheads, faucet aerators, advanced power strips, LED lightbulbs, and mobile home air infiltration). In 2021, the program continued to provide these measures (excluding advanced power strips). These measures made up about one percent of program savings.

Table 3-55: Summary of Measures Implemented

Measure	Number of Projects	% Share of Reported kWh Savings
Duct Sealing	1698	43%
Attic Insulation	1660	35%
Air Infiltration	1797	20%
Water Heater Jacket	86	<1%
Water Heater Pipe Insulation	893	<1%
Showerheads - Mobile	23	<1%
LED-Mobile	27	<1%
Faucet Aerators - Mobile	26	<1%
Air Infiltration - Mobile	29	<1%

PSO’s Home Weatherization Program serviced 2,214 households during the 2021 program year. Participants saved an average of 1,911 kWh. This compares to an average of an average of 2,111 kWh in 2018, 1,828 kWh in 2019, and 1,959 kWh in 2020. Titan ES was responsible for the installation of these energy efficiency measures at most of these homes (see Table 3-56).

Table 3-56: Homes by Agency

Agency	Number of Homes
Titan ES	2,181
RTT	33
Total	**2,214**

Participation in the Home Weatherization Program remained consistent throughout the year. Figure 3-26 displays the accrual of reported energy savings throughout 2021. This is a positive indication of a steady flow of energy efficiency projects throughout the implementation period.

Figure 3-26: Accrual of Reported kWh Savings During the Program Year

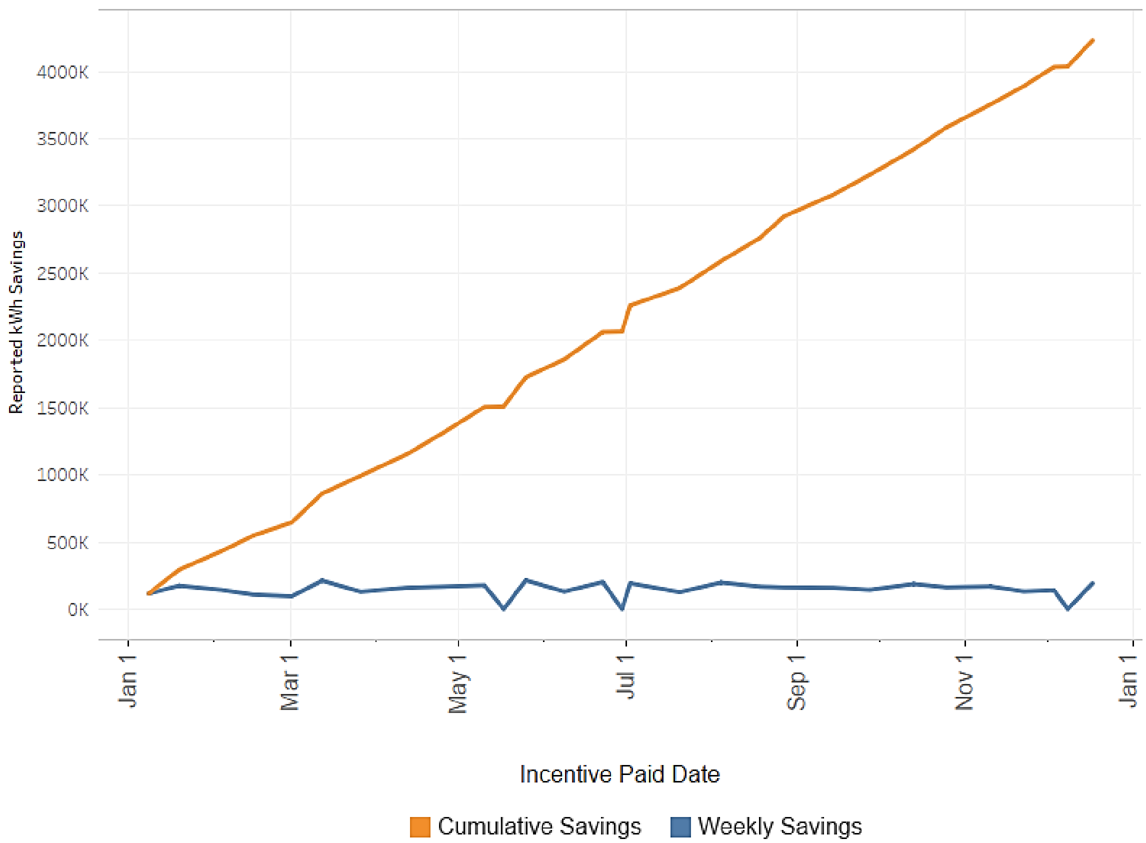
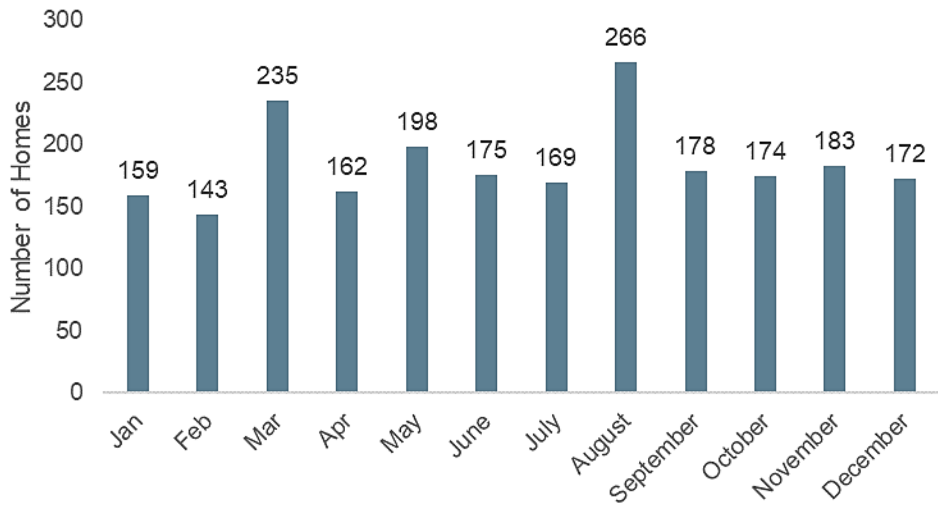


Figure 3-27 displays the number of homes invoiced each month. August had the highest number of homes invoiced. January and February had the fewest number of homes.

Figure 3-27: Number of Projects by Month



3.3.2 EM&V Methodologies

This section provides an overview of evaluation methods employed for the verification of energy impacts and reporting on program feedback. Impact evaluation methodologies included a review of program data and materials, data collection activities, gross and net impact calculation methodologies. Process evaluation activities included a participant survey and facilitated discussion with staff to explore the program's strengths, weaknesses, opportunities, and threats. The 2021 process evaluation component was designed to answer the following research questions:

- Has the underlying theory of how the program affects energy-saving behaviors changed since the previous years? If so, how and why?
- How have the program implementation and delivery changed, if at all since the previous program years? How are these changes related to previous evaluation results and how are they expected to change program impacts going forward?
- Did the program implementation reflect its current design? In what ways did it deviate and how did that affect program success?
- Do program utility and implementation contractor staff effectively coordinate to deliver the program?
- Are there ways to improve the design or implementation process?
- How do participants hear about the program? Are there any changes in how participants learn of the program as compared to the prior year?
- Were program participants satisfied with their experience? What was the level of satisfaction with the work performed, the scheduling/application process, and other

aspects of program participation? What are the perceived energy and non-energy benefits associated with the program?

- Were there any significant challenges or new obstacles during the program year?
- Looking forward, what, if any, are key barriers and drivers to program success within PSO's market?

3.3.2.1 Data Collection

Several primary and secondary data sources were used for the evaluation. Tracking data and supporting documentation for the program was obtained from SQL Server Reporting Services (SSRS). This tracking data was used as the basis for quantifying participation and assessing program impacts. Additional data was collected through phone surveys, photographic verification with participating customers, virtual verifications with the primary program contractor, and staff interviews. Table 3-57 summarizes the data collection activities and evaluation purpose.

Table 3-57: Data Collection

Data Collection Activity	Achieved Size	Evaluation Purpose
Virtual Ride-Alongs with Contractors	3	Measure and Installation Process Verification
Photo verification with participating customers	3	Measure and Installation Verification
Customer Surveys	103	Measure Verification, In-Service Rate, Customer Satisfaction
In-Depth Interviews with Program Staff	2	Assess staff perspectives regarding the strengths, weaknesses, opportunities, and threats to program success.

Participant Telephone Survey Sampling Plan

To provide program feedback, ADM conducted a phone survey of PY2021 Home Weatherization Program participants. We designed the survey's sample to be statistically representative of the program population and ensures accurate program insights. For this effort, our sample approach was designed to achieve a minimum 10% precision at a 90 percent confidence level (90/10).

For the calculation of sample size for survey completes, a coefficient of variation of 0.5 was assumed.[30] With this assumption, a minimum sample size of 68 participants was required, as shown in the following formula:

[30] The coefficient of variation, cv(y), is a measure of variation for the variable to be estimated. Its value depends on the mean and standard deviation of the distribution of values for the variable (i.e., cv(y) =

Equation 3-1: Minimum Sample Size Formula for 90 Percent Confidence Level

$$n_0 = \left(\frac{Z*CV}{RP}\right)^2 = (\frac{1.645*0.5}{0.10})^2 = 68$$

Where:

n_0	= minimum sample size
Z	= Z-statistic value (1.645 for the 90% confidence level)
CV	= Coefficient of Variation (assumed to be 0.5)
RP	= Relative Precision (0.10)

Although 68 was the minimum sample size, ADM conducted phone surveys with 103 participants across the service territory. The additional survey completes were obtained to increase the chance of survey participation in all areas the program impacted and to increase the chance of receiving feedback regarding all program measures.

Participant Telephone Survey Procedure

The participant survey informs the gross impact analysis by verifying the presence of reported tracking data measures. Respondents were asked to confirm whether they had received the reported measures. These responses were used to develop In-Service Rates (ISRs) that represent the portion of energy efficiency measures that were installed and are operational. The telephone survey questions also seek to evaluate customer satisfaction with individual measures, program stakeholders, and the program overall. Participants were given a $10 Walmart gift card for their time.

Additionally, program participants that receive direct install measures including LED light bulbs, faucet aerators, low flow showerheads, or water heater pipe insulation or jackets were asked if they were willing to send an email with photographic evidence of measure installation to further verify the installation of program measures. Section 3.3.3.1 provides details regarding the findings of ADM's survey efforts.

3.3.2.2 Gross Impact Methodologies

The methodology used to calculate energy (kWh) and demand impacts (kW) consisted of:

- **Verifying measure installation:** ADM calculates installation rates (ISR) by measure for a sample of program participants utilizing data from its participant telephone survey.

sd(y)/mean(y)). Where y is the average savings per participants. Without data to use as a basis for a higher value, it is typical to apply a CV of 0.5 in residential program evaluations.

- **Reviewing reported savings estimates for each measure:** ADM reviews program tracking data and reported savings calculations for all measures to review the accuracy of reported savings and provide an explanation of any savings discrepancies.
- **ADM calculates verified savings through an engineering desk review utilizing:**
  - Oklahoma Deemed Savings Document (OKDSD)
  - Arkansas Technical Reference Manual v7 (AR TRM)

A brief description of each measure's calculation methodology is identified in this section. Detailed measure level algorithms and deemed savings values utilized for the verified energy (kWh) and demand (kW) impact savings calculations are explained below.

Air Infiltration Reduction

ADM used the AR TRM to calculate energy and demand impacts of infiltration reduction measures. This measure involves sealing leaks in conditioned areas of the homes. This is achieved by installing door gaskets, door sweeps, foam sealing plumbing penetrations, and caulking around windows. Savings are calculated by multiplying the air infiltration reduction (CFM), with the energy savings factor corresponding to the climate zone and HVAC type. The air infiltration reduction estimate in CFM is obtained through blower door testing performed by the program contractor pre- and post-measure installation for each home serviced. Only homes with central AC (or room AC) cooling systems are eligible for the measure.

Mobile Home Air Infiltration Reduction

Like air infiltration reduction conducted on other homes, mobile home air infiltration involves sealing leaks from doors, windows, plumbing penetrations and other areas. As blower door tests are not feasible on mobile homes, ADM developed prescriptive-like savings from its 2018 air infiltration savings analysis which were calculated using the AR TRM.

Attic Insulation

This measure requires adding ceiling insulation above a conditioned area in a residential dwelling of existing construction to a minimum ceiling insulation value of R-38. Deemed savings values are calculated for each home in accordance with the AR TRM with scaled values. Additional detail regarding the AR TRM scaled values can be found in the report's Appendix G. Attic insulation deemed savings are listed based on the R-value of the baseline insulation and weather zone. Savings are calculated by multiplying the corresponding savings value by the square footage insulated.

Duct Sealing

This measure involves sealing leaks in ducts of the distribution system of homes with either central AC or a ducted heating system. ADM is using the OKDSD[31] in conjunction with the duct leakage reduction results to calculate measure savings. The duct leakage reduction estimate in CFM is obtained through duct blaster testing performed by the program contractor pre- and post-installation for each home serviced.

Pipe Insulation and Water Heater Jackets

The deemed savings for water heater jackets installed on electric water heaters are sourced from the OKDSD. The deemed savings for this measure depend on 1) insulation thickness and 2) water heater tank size.

Water heater pipe insulation involves insulating all hot and cold vertical lengths of pipe, plus the initial length of horizontal hot and cold-water pipe, up to three feet from the transition, or until wall penetration, whichever is less. The OKDSD specifies deemed values for energy and demand impacts of water heater pipe insulation measures. The deemed values can be found in the report's Appendix G.

Electric water heating is required for the installation of pipe insulation and/or water heater jackets.

Low Flow Showerheads

This measure consists of removing existing showerheads and installing low flow showerheads in homes with electric water heating. The baseline flow rate is 2.5 gallons per minute (gpm) and the efficient showerhead is 1.5 gpm which saves 3,246 gallons of water per year and has a ratio of 0.000104 peak kW demand reduction to annual kWh savings.

Faucet Aerators

This measure involves the retrofit of aerators on kitchen and bathroom water faucets. The deemed savings are per faucet aerator installed. The baseline faucet flow rate is 2.2[32] gallons per minute (gpm) and the efficient faucet aerators is 1.5 gpm.

Advanced Power Strips

This measure involves the installation of a 5 plug Advanced Power Strip (APS) that can automatically disconnect related equipment loads (i.e., speakers, video games, Blu-ray, etc.) depending on when the "master" device (i.e., television) is turned off. The baseline

[31] OKDSD calls for a SEER value of 13 be used in the algorithm. ADM utilized a SEER value of 11.5, which is the average of U.S. DOE minimum allowed SEER for new AC from 1992-2006 (10 SEER) and after January 2006 (13 SEER). This adjustment is not done across all programs, it is specific to home weatherization.

[32] Maximum flow rate federal standard for lavatories and aerators set in Federal Energy Policy Act of 1992 and codified at 2.2 GPM at 60 psi in 10CFR430.32

condition for this measure is the absence of an APS, where the devices are connected to a traditional power strip or wall outlet.

ENERGY STAR® Omni-Directional LEDs

This measure provides savings for replacing an inefficient lamp with an Omni-directional LED in residential applications. The replacement must be ENERGY STAR® qualified. ADM will use AR TRM v7.0 to assess savings and demand reduction for the installation of ENERGY STAR® Omni-Directional LEDs (9.5W).

3.3.2.3 Net-to-Gross Estimation

The Home Weatherization Program specifically targets customers with limited income, providing all services at no cost to the customer. It is likely that participating customers would not have funded the installed energy efficiency measures on their own. As a result, ADM assumed an NTG ratio of 100% for all measures.

3.3.2.4 Virtual Ride-Alongs with Contractor

ADM uses a visual verification software application (Streem) to perform virtual ride-alongs.[33] To use the service, ADM sends a link which the recipient can open through any internet browser on a smart phone. Once the recipient opens the link, the phone's camera is made accessible and allows the Streem user to take photos and videos and visit the recipient's setting in a virtual manner.

3.3.3 Impact Evaluation Findings

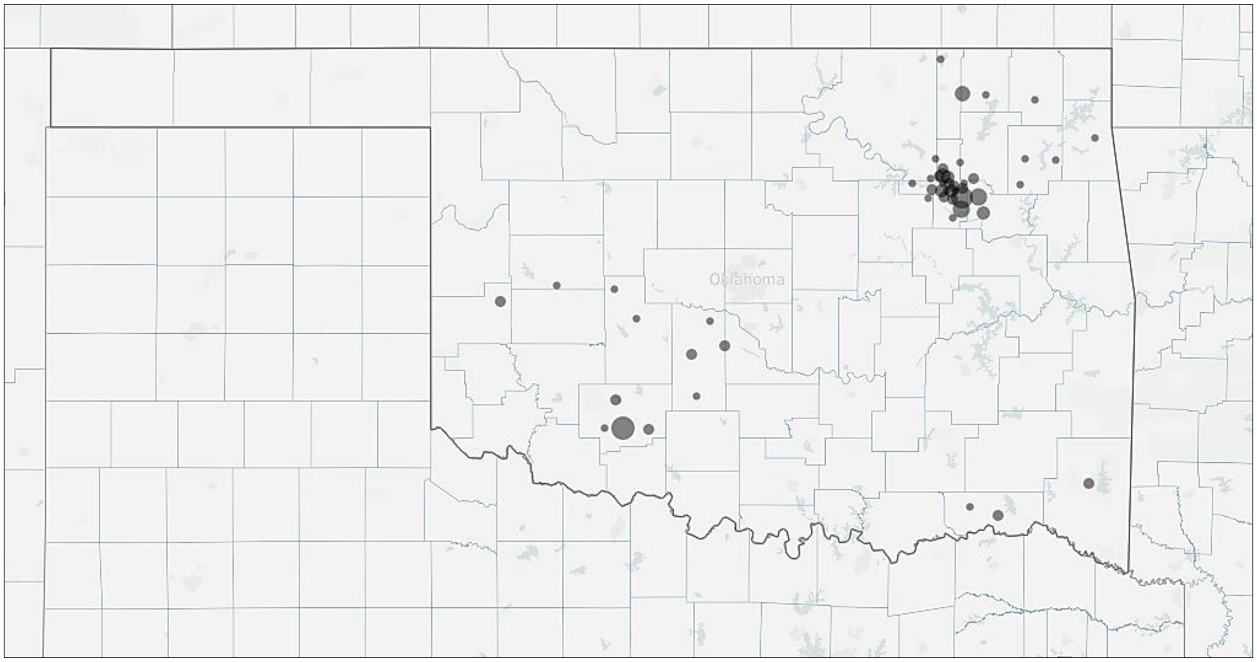
This section provides information on the impact evaluation findings for PY2021.

3.3.3.1 Participant Telephone Survey Findings

ADM completed phone surveys with program participants across the service territory. ADM's in-house survey team called 508 participants and completed 103 surveys (20% response rate). Survey responses represented 17 counties and 50 zip codes. Survey participants by zip code is shown in Figure 3-28. Each point represents a unique zip code. Larger points indicate more survey responses, with the sizes representing from 1 to 10 projects.

[33] ADM utilized Streem's visual verification software. More information about this software can be found here: https://streem.pro/

Figure 3-28: Number of Survey Participants by Zip Code[34]



3.3.3.2 Email Verification Findings

ADM asked phone survey respondents if they were willing to send photographic evidence to further verify participation. Three survey respondents that received water heater jacket installations through the program provided visual evidence of measure installation by sending an email to ADM with a photo attachment.

3.3.3.3 Virtual Ride-Along Findings

ADM conducted three virtual ride-along visits with Titan ES in June, July, and August 2021. The primary goal of the virtual ride-along visits was to verify contractor procedures and to visually verify the installation of major program measures (attic insulation, duct sealing, and air insulation).

On an initial video call the Titan ES crew supervisor showed ADM's field technician the areas that they intended to conduct air sealing or duct sealing on, as well as initial blower door test and duct leakage test results. The Titan ES supervisor also showed ADM the pre-condition of the ride-along homes' attics.

ADM ended the initial video call once we had observed the pre-condition of the home. Titan ES staff contacted ADM's field technician once work was completed to have a second post-improvement call. ADM's field technician observed Titan ES staff perform blower door and duct sealing tests and the Titan ES staff showed the ADM technician all

[34] Size of circle varies depending on the number of projects in each zip code (max = 10, min = 1)

the air seal measures installed as well as the attic insulation installed through the program.

For each of the ride-alongs, ADM noted the following pre- and post-conditions for each program measure:

- Air Sealing: ADM observed homes with gaps around doors, under sinks, and around pipes and windows before Titan ES performed improvements. After Titan ES staff completed their work, ADM observed weatherstripping around doors, foam sealant under sinks around pipes, and caulking around windows and doors.
- Duct Sealing- ADM noted gaps around registers and plenum holes prior to Titan ES conducting weatherization improvements. We noted signs of mastic and tape on ducts, plenums, registers and returns after weatherization was complete.
- Attic Insulation- ADM observed that the three homes had unevenly spread insulation at depths ranging from 3-6 inches. After Titan ES staff completed weatherization, ADM's field technician verified insulation evenly spread at depths from 14-16 inches.

During the ride-alongs the ADM technician observed test in and test out values for both blower door and duct blaster tests and took pre- and post-pictures of the measures performed. The results were as expected with all three homes.

3.3.3.4 Air Infiltration

A total of 88 customers were asked to confirm air infiltration improvements made through the program. Three customers did not recall receiving air infiltration improvements. Visually identifying caulking and/or sealing is not always apparent and as these respondents could not determine, their responses were considered inconclusive. Based on these findings, an ISR of 100% was applied.

ADM calculated the prescriptive savings values for each home and determined the total program level energy (kWh) and demand impacts (kW) savings for air infiltration as 865,920 kWh and 276 kW, respectively. The energy savings methodology for this measure is defined in the AR TRM. The required inputs are the results of the blower door test (CFM_{50} between pre-installation and post-installation) and an energy savings factor dependent on climate zone and HVAC system type. Algorithm inputs were confirmed through research, project documentation, and survey efforts. These inputs were found to be consistent with reported estimates. For mobile home air infiltration ADM found 14,746 kWh savings and 5.0 kW peak demand reduction. The program level realizations rates for air infiltration were 100% for kWh savings and kW peak demand reduction.

3.3.3.5 Attic Insulation

A total of 81 survey respondents were asked to confirm whether they had attic insulation installed. One respondent did not recall receiving this measure, so their response was considered inconclusive. One stated they had not received this measure. ADM requested verification of this measure's installation with the program implementer, however Titan ES was unable to contact this respondent and as a result, an ISR of 100% was applied for attic insulation.

ADM found proper use of the algorithms in the AR TRM for the calculation of energy savings. The total program level energy (kWh) and demand impacts (kW) savings for attic insulation were calculated to be 1,492,900 kWh and 1,336 kW, respectively. The savings methodology was consistent with ex-ante (reported) estimates. The program level realizations rate for attic insulation was 100% for kWh savings and kW peak demand reduction.

3.3.3.6 Duct Sealing

A total of 77 customers were asked to confirm duct sealing improvements made through the program. Five respondents did not recall receiving duct sealing. One stated they did not receive this measure. Visually identifying duct sealing is not apparent. Based on these findings, an ISR of 100% was applied.

ADM found proper use of the Oklahoma Deemed Savings Document (OKDSD) for reported savings in conjunction with the duct leakage reduction results to calculate measure savings. Additional detail can be found in the report's Appendix G. ADM calculated the prescriptive savings values for each home and determined the total program level energy (kWh) and demand impacts (kW) savings for duct sealing as 1,829,366 kWh and 790 kW, respectively. The program level realization rates for duct sealing were 100%.

3.3.3.7 LED Light Bulbs

Six survey respondents confirmed receiving LEDs through the program. These respondents reported receiving a total of 38 LED light bulbs. ADM utilized survey responses from 2020 and 2021 to calculate the ISR for this measure. Because of limited participation with this measure, we used responses from two year's surveys to calculate ISR. In 2020, thirteen respondents confirmed that 61 LEDs they received through the program were still installed. In 2021, five respondents confirmed all the LEDs were still installed. One respondent stated that none of the 6 LEDs they had received were currently still installed. An ISR of 94% was applied to the ex-post (verified) energy saving calculation (ISR=93/99).

ADM calculated the prescriptive savings values for each home and determined the total program level energy (kWh) and demand impacts (kW) savings for LEDs as 4,210 kWh and 0.6 kW, respectively. LED bulb calculations resulted in realization rates of 94% kWh and 94% for peak demand reduction. The reason for the less than 100% realization rate for kWh savings and kW peak demand reduction is due to the assigned ISR. This did not have a significant impact on program level realization rates as LED savings made up a small portion of total program savings (0.1%).

3.3.3.8 Water Heater Jackets and Pipe Insulation

ADM completed 48 verification surveys with customers that had water heater insulation installed in their homes through the program. Thirty-eight respondents were able to confirm installation of water heater jackets or pipe insulation. The remaining respondents, while unaware of the installation, appeared to have received the measure resulting in an ISR of 100%.

The deemed savings for water heater jackets installed on electric water heaters are sourced from the OKDSD. The deemed savings for this measure depend on 1) insulation thickness and 2) water heater tank size.

ADM calculated the prescriptive savings values for each home and determined the total program level energy (kWh) and demand impacts (kW) savings for water heater jackets and pipe insulation to be 5,848 kWh and 8,184 kWh, respectively. We calculated the demand reduction for water heater jackets and pipe insulation to be 0.4 kW and 2.6 kW, respectively. The program level realization rates for water heater jackets and pipe insulation were 100%.

3.3.3.9 Faucet Aerator(s)

Seven survey respondents were verified as receiving faucet aerators through the program. Of these respondents, three provided ISR information in ADM's survey. Two indicated the aerators were still installed, one indicated they had removed the aerators. The respondent that indicated they removed the aerators had received two and the other respondents received one each.

ADM utilized survey responses from 2020 and 2021 to calculate the ISR for this measure due to the quantity of responses representing 2021. In 2020, respondents confirmed 10 of the 12 aerators installed through the program were still installed. An ISR of 80% was applied to the ex-post energy saving calculation (ISR=12/15).

ADM used the AR TRM to determine savings for this measure and found the total savings attributable to faucet aerators to be 1,088 kWh and peak demand reduction to be 0.1 kW. Savings methodologies were consistent with the ex-ante estimates. We found a realization rate of 90% for peak demand reduction and 88% for kWh savings for this measure. The application of the ISR was the primary driver of the less than 100% realization rate, though another reason for realization rate that deviated from 100% is that

ADM utilizes weather zones to assign savings, while ex-ante tracking data uses 2019 Mobile Home memo values.

3.3.3.10 Low Flow Showerhead(s)

ADM confirmed with 5 survey respondents that they received showerheads through the program (a total of 7 showerheads). Four of these respondents confirmed that the low flow showerhead(s) they received through the program were still installed (6 showerheads). ADM utilized survey responses from 2020 and 2021 to calculate the ISR for this measure due to the quantity of responses representing 2021. In 2020, respondents confirmed 5 of the 8 aerators installed through the program were still installed. An ISR of 80% was applied to the ex-post energy saving calculation (ISR=11/15).

ADM used the AR TRM to determine savings for this measure and found the total savings attributable to low flow showerheads to be 5,372 kWh and peak demand reduction to be 0.6 kW. Savings methodologies were consistent with the ex-ante estimates.

We found a realization rate of 73% for peak demand reduction and kWh savings for this measure. The application of the ISR was the main driver of the less than 100% realization rate for low flow showerhead(s).

3.3.3.11 Impact Evaluation Summary

ADM utilized current prescriptive methodologies to determine annual energy savings and peak demand reduction. These gross energy savings were adjusted to account for in-service rates based on participant survey responses. ADM found consistent application of prescriptive methodologies with minor data issues. Realization rate risk was apparent for some measures in the application of in-service rates to gross savings. Table 3-58 displays the results.

Table 3-58: Home Weatherization In-Service Rates

Measure	Verified/Claimed	Number of Measures	ISR
Attic Insulation	Verified	79	100%
	Claimed	79	
Duct Sealing	Verified	71	100%
	Claimed	71	
Infiltration	Verified	85	100%
	Claimed	85	
WH Pipe Wrap/Insulation	Verified	38	100%
	Claimed	38	

Measure	Verified/Claimed	Number of Measures	ISR
LED Bulbs	Verified	93	94%
	Claimed	99	
Faucet Aerators	Verified	12	80%
	Claimed	15	
Low Flow Showerheads	Verified	11	73%
	Claimed	15	

Ex-post and ex-ante kWh and peak demand reduction by measure are shown in Table 3-59. As shown, the measures with the largest impact are air infiltration, attic insulation, and duct sealing. This is consistent with past years as the program attributed most of its savings to air infiltration, attic insulation, and duct sealing in 2018, 2019, and 2020 as well.

Table 3-59: Reported and Verified Energy Savings (kWh and Peak kW)

Measure	Reported Energy Savings (kWh)	Reported Peak Demand Savings (kW)	Verified Gross Energy Savings (kWh)	Verified Gross Peak Demand Savings (kW)	kWh Realization Rate	kW Realization Rate
Air Infiltration	865,920	276.26	865,920	276.26	100%	100%
Attic Insulation	1,492,900	1,335.90	1,492,900	1,335.90	100%	100%
Duct Sealing	1,829,366	790.35	1,829,366	790.35	100%	100%
Water Heater Jacket	5,848	0.43	5,848	0.43	100%	100%
Water Heater Pipe Insulation	8,184	2.60	8,184	2.60	100%	100%
Low Flow Showerheads (Mobile home)	7,326	0.77	5,372	0.56	73%	73%
LED (Mobile home)	4,482	0.66	4,210	0.62	94%	94%
Faucet Aerators (Mobile home)	1,203	0.13	1,088	0.11	90%	88%
Air Infiltration (Mobile home)	14,746	4.96	14,746	4.96	100%	100%
Total	**4,229,974**	**2,412.07**	**4,227,635**	**2,411.81**	**100%**	**100%**

3.3.4 Process Evaluation Findings

ADM's process evaluation activities included a participant survey and a facilitated discussion with program staff. ADM provided a process evaluation memo to PSO in

December of 2021 with detailed information on the facilitated discussion and participant survey.

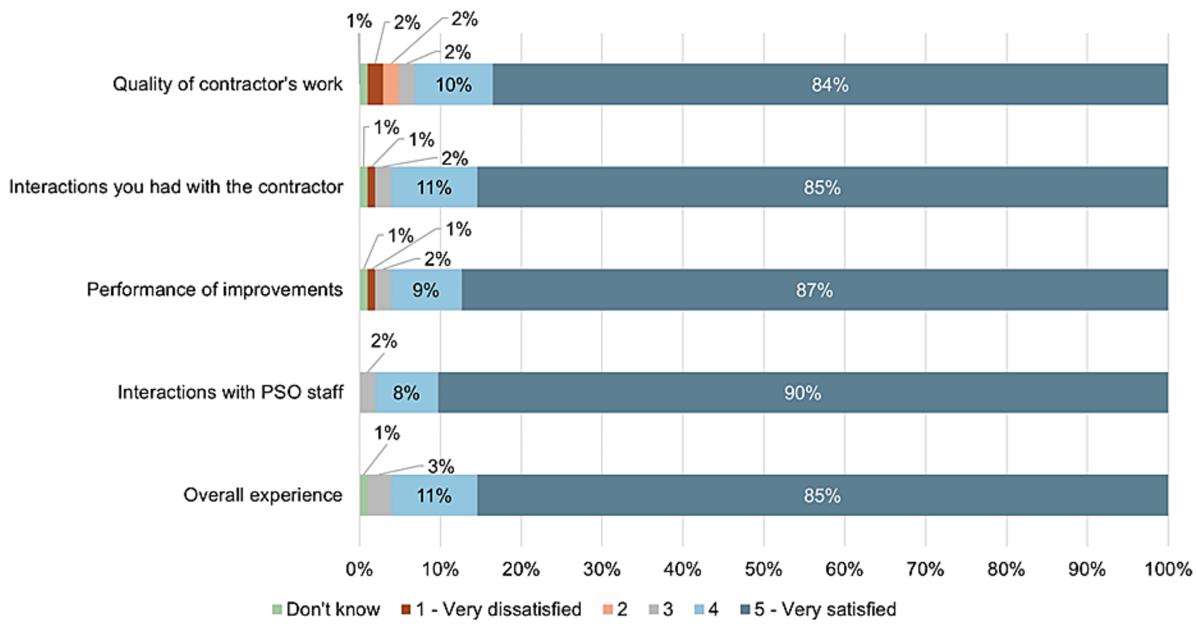
ADM's facilitated discussion with PSO and Titan ES staff took place in October 2021 and key findings included:

- The program is cost-effective and always meets energy savings goals. The program coordinator suggested good return-on-investment (ROI) is achieved by contracting with a local weatherization company and bundling improvements together.
- Program staff identified strong relationships and partnerships as a key strength of the program. Staff noted a strong working relationship between PSO and Titan ES that enables continuous improvement and flexibility in the program's approach as staff approach program design choices and implementation with a focus on solutions. The PSO program coordinator observed that the program's ability to cost split with gas companies allows them to reach more customers. She also said that partnerships with nonprofits allow the program to offer a larger spectrum of measures and improvements, though this is only available to a limited number of customers each year and nonprofits may take longer than Titan ES to offer services to customers.
- Discussion participants noted customer complaints as a weakness and "detractors" as a threat to continued program success. Customers sometimes misunderstand program offerings and limitations, and the program receives occasional complaints regarding the contractors' work quality, quantity, or communication. Discussion participants noted that program detractors may pose an external threat. They noted that some detractors do not publicize their negative perspective, though others broadcast their experience to PSO, other organizations (e.g., Better Business Bureau), and other customers or potential participants.
- Program staff identified customer education as a weakness or challenge. The discussion participants noted that it is a challenge to overcome skepticism of the program being offered for "free" or no-cost to customers. Additionally, discussion participants stated that educating customers regarding the program's offerings can be a challenge.
- There are opportunities to continue to enhance program reach and design. To address the potential threat of a diminishing pipeline of participants, the program coordinator suggested they may revisit past participant homes if participation in the program occurred at least 10 years ago and consider updating program qualifications such as income level, age of home, and home square footage. The contacts suggested incorporating additional measures or emerging technologies,

such as dusk to dawn LED light bulbs could help the program achieve additional savings.

Consistent with 2020, most survey respondents stated they were satisfied with the performance of the improvements that were made, the quality of the contractor's work, and the interactions they had with the contractor and PSO staff (Figure 3-29). Furthermore, nearly all survey respondents indicated satisfaction with their overall program experience[35] and said they were satisfied with PSO as their electric utility.[36]

Figure 3-29: Customer Satisfaction



Ninety-six percent of survey respondents were satisfied with their experience overall. However, 27% provided written feedback regarding the aspects of their experience they were not satisfied with or recommendations to improve the program or PSO services.

- Nine percent mentioned dissatisfaction with the quality or cleanliness of the contractor's work.
- Five percent noted an opportunity to improve communications from the contractor regarding Program improvements and the participation process.
- Four percent said they were interested in additional weatherization or efficiency-related improvements.
- Five percent were interested in additional PSO services or program offerings such as solar panels, AC tune-ups, Power Hours, or power line repairs.

[35] A rating of 4 (11%) or 5 (85%).
[36] A rating of 4 (13%) or 5 (84%).

Section 3.3.5 summarizes key findings from the process and impact evaluation of the Home Weatherization Program.

3.3.5 Conclusions and Recommendations

The following summarizes the key findings from the evaluation of the 2021 Home Weatherization Program.

- The program met its energy savings goals. Final program data indicated the program attained its savings goals and provides a beneficial service to PSO customers.
- Overall, reported and evaluated energy savings were consistent. The program had an overall realization rate of 100% and measure level realization rates at or close to 100% for the largest contributors to the program. The only measurable realization rate risk is in the adjustment of gross energy savings for In-Service Rates (ISR).
- PSO and Titan have a strong relationship, with open communication and a focus on continuous program improvement. Findings from the SWOT facilitated discussion indicates the staff have a common understanding of the program's strengths, weaknesses, opportunities, and threats.
- The program offers an easy, straightforward no-hassle service to low-income customers in PSO's territory. Customers indicated that signing up and scheduling for the Program is quick and easy. Survey findings also show that most customers are satisfied with the quality of the weatherization improvements and their experience with the program implementation contractor.
- Some customer skepticism and misunderstandings regarding the program persist. Findings from the facilitated discussion with Titan and PSO staff indicate that it is occasionally a challenge to overcome skepticism of the program being offered for "free" or no-cost to customers. Discussion participants also stated that educating customers regarding the program's offerings and limitations can be a challenge.
- Participant satisfaction is high. Most survey respondents were satisfied with the program overall, the measures they received, as well as with PSO as their electric utility. A very small portion of respondents voiced dissatisfaction with some aspect of their experience.
- There is an opportunity to bolster customer understanding of program improvements and the benefits of energy efficiency. About one-fifth of survey respondents said that they either had not received or did not recall receiving one or more improvement that the tracking data indicated they received. Furthermore,

less than half of survey respondents said the program contractor had spoken with them about ways to use less energy in their home.

The following recommendations are offered for continued improvement of the Home Weatherization Program:

- Add customer email addresses to the AEG/Sightline data tracking system. If customer email addresses were added to program tracking data it would enable ADM to conduct mixed-mode surveys, thereby expanding the survey efforts to additional participants and allowing more participants to provide feedback and potentially ease the administrative burden of surveying.
- Continue to consider ways to increase the pipeline of projects such as revisiting past participant homes and adjusting program qualifications. Program staff noted that there may be an opportunity to reassess and make weatherization improvements at past participants' homes. They also suggested revisiting the income level, age of home, and square footage eligibility requirements.
- Ensure focus remains on a holistic approach to home weatherization with the addition of emerging technologies or other improvements. Program staff noted that they had discussed adding additional improvement types to the program such as dusk to dawn LED light bulbs. They also noted possibly increasing participation for direct install measures.
- Verify customer awareness of home improvements and utilize platform to promote energy efficiency actions and behaviors. Implementation contractor staff can ensure all participants are aware of the measures being installed in their homes and the benefits of weatherization and energy efficiency.
- Continue to advertise the program to eligible PSO customers, focusing on highlighting program measures and improvement limitations. PSO Home Weatherization marketing and outreach can continue to promote educational material, ensuring customers understand the program's offerings and eligibility requirements.
- Consider review of program qualifications and the possibility of revisiting past participant homes. Qualifications that PSO could revisit include income level, age of home, and home square footage. Though the pool of eligible homes is not a current threat, this recommendation could help ensure a continuous, strong pipeline of projects.
- Consider additional measures and expand the installation of direct install measures to capture additional energy savings. In 2020 and 2021 the faucet aerator, low flow showerhead, LEDs, and advanced power strip measures had

limited participation. Additional measures such as dusk to dawn LED light bulbs could help the program achieve additional savings.

- Continue to align program tracking data ex-ante savings and peak demand reduction methodologies. ADM utilizes measure level reports and a summary report. To reconcile monthly and measure level savings these reports should align.

3.4 Energy Saving Products Program

3.4.1 Program Overview

PSO's Energy Saving Products (ESP) program seeks to generate energy and demand savings for residential customers through the promotion of a variety of energy efficient measures. The overall purpose of this program is to provide PSO residential customers financial incentives for purchasing products that meet high efficiency standards.

For PY2021, the ESP program consisted of retail price discounts for qualifying LED light bulbs, room air purifiers, advanced power strips, bathroom ventilation fans, water dispensers, spray foam, door sweeps and seals, room air conditioners, and air filters. The program also included distribution of free LEDs in partnership with food banks and local food pantries within the PSO service territory. Discounted LED bulbs, including the free LEDs distributed through local food pantries, made up approximately 76% of the reported energy savings for the PY2021 ESP program.

In PY2021 the ESP program also offered rebates from PSO for qualifying heat pump water heaters, clothes dryers, clothes washers, refrigerators, and level 2 electric vehicle chargers. This downstream portion of the program accounted for approximately 1% of the non-lighting reported energy savings realized through the program.

The actual number of participants in the ESP lighting component of the program is unknown, as upstream measure purchaser information is not tracked by participating retailers. However, a total of 249,162 packages of LEDs and 923,620 individual bulbs were discounted through participating retailers or distributed in partnership with local food pantries. The total number of all other verified upstream measures purchased through the ESP program was 86,428, while the total number of verified measures rebated through the downstream portion of the program was 2,613. Overall, the ESP program supported the purchase of over 1.0 million energy efficient measures during PY2021.

Table 3-60 provides a summary of program metrics for the 2021 program year. Program costs were $1,452,080. Reported annual energy savings exceeded program projections. Overall, gross verified energy savings developed through ADM's impact evaluation were higher than reported savings and reported demand reduction, representing a gross realization rate of 108% for savings and approximately 115% for demand reduction.

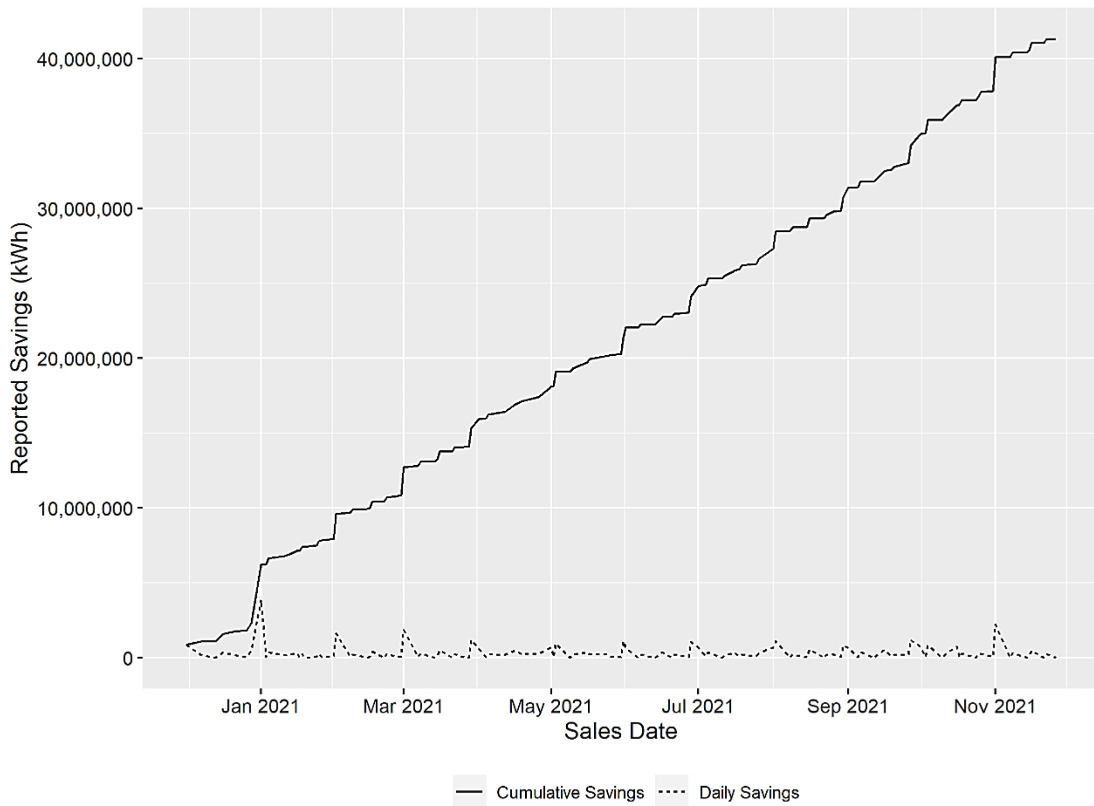
Table 3-60: Performance Metrics – Energy Saving Products Program

Metric	PY2021
Number of Known Participants[37]	2,155
Budgeted Expenditures	$1,645,022
Actual Expenditures	$1,452,080
Energy Impacts (kWh)	
Projected Energy Savings	32,801,227
Reported Energy Savings	41,780,315
Gross Verified Energy Savings	45,148,854
Net Verified Energy Savings	23,470,632
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	3,981.13
Reported Peak Demand Savings	7,810.61
Gross Verified Peak Demand Savings	8,946.97
Net Verified Peak Demand Savings	3,753.86
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	7.31
Utility Cost Test Ratio	6.49

Participation in the ESP program was mostly consistent throughout the 2021 program period. On the following page, Figure 3-30 shows the reported daily kWh savings and the cumulative reported kWh savings throughout the 2021 program year.

[37] The actual total number of customers that purchased an energy savings product is unknown. Instead, this table reports the count of unique customers that received rebates for qualifying downstream measures.

Figure 3-30: Accumulation of Reported Savings During the 2021 Program Year



3.4.2 EM&V Methodologies

The following section details the methodologies ADM used to verify retail sales, estimate energy, and peak demand impacts, and assess the performance for the Energy Saving Products program.

3.4.2.1 Data Collection

Several primary and secondary data sources were used for the evaluation. Tracking data and supporting documentation for the program was obtained from the program implementor. This tracking data was used as the basis for quantifying participation and assessing program impacts. Tracking data included the following information for each combination of retailer, model number, and discount level for upstream lighting:

- Package sales per week (program sales only)
- Original retail price
- Manufacturer/Retailer sponsored discounts (if any)
- PSO sponsored discounts
- Retail price, including all discounts

- Number of bulbs per package
- Rated wattage
- Rated lumens
- Rated lifetime (in hours)

Additional documentation including retailer agreements, retailer/manufacturer invoices, promotional event documentation, and general program materials were reviewed as part of the evaluation.

Primary data collection activities included an online general population survey, two surveys of downstream rebate participants, and interviews with program staff members. The general population survey was administered in two waves, one in the summer of 2021 (July) and a second during the fall of 2021 (October). The final sample size for each primary data collection activity is presented in Table 3-61 below.

Table 3-61: ESP Data Collection Activities

Data Collection Activities		N
General Population Survey		178
Downstream Rebate Participant Survey	Appliance Survey	152
	Electric Vehicle Level 2 Charger Survey	8
Program Staff Interview		2

There were three survey efforts conducted: a general population survey covering upstream purchases of discounted measures and two downstream rebate participant surveys; all three survey efforts were conducted online through emailed invitations. For the general population survey, a random sample of PSO's residential customers within Oklahoma were contacted via email and asked a variety of questions about recent purchases of energy efficient measures discounted via the upstream program. Because customer contact information is not tracked for marked-down measures in the upstream program, the methodology implemented provided a cost-effective way of reaching many potential program participants. The survey instrument employed several screening questions to determine whether respondents had (a) purchased measures discounted through the upstream program within the program year and (b) that those purchases had been made through participating retailers.

Twenty-six percent of the PSO customers contacted opened the e-mailed survey invitation (out of 3,526 individuals). Of these individuals, 178 participants qualified for the survey and completed it fully. For a disaggregation of qualifying survey responses by measure, see Table 3-62. The survey collected data on program awareness and insights into energy-saving product purchases for lighting and non-lighting measures in addition to data regarding measure satisfaction and household demographics.

Table 3-62: Measures Bought During 2021

Measure	Number of Eligible Respondents
LED Light Bulbs	167
Energy Saving Advanced Power Strips	53
Air Filters	47
Spray Foam, Door Seals, or Door Sweeps	21
ENERGY STAR® Room Air Conditioners	13
ENERGY STAR® Room Air Purifiers	7
ENERGY STAR® Bathroom Ventilation Fans	4
ENERGY STAR® Water Dispensers / Water Coolers	4

Note: the number of eligible responses column does not sum to 178 (the number of surveys completed) since surveyed customers could have purchased more than 1 discounted measure.

Customers that had received rebates for heat pump water heaters, clothes dryers, clothes washers, refrigerators, and electric vehicle chargers through the PSO ESP program were invited to participate in online surveys. Screening questions were asked to assess customer program awareness. Table 3-63 breaks down what types of appliances the survey respondents purchased.

Table 3-63: Rebated Measure Participants Contacted vs. Survey Responses

Rebated Equipment	Percent of Survey Respondents (n = 152)
ENERGY STAR® Refrigerator (only)	30%
ENERGY STAR® Clothes Washer (only)	27%
ENERGY STAR® Clothes Dryer (only)	9%
ENERGY STAR® Clothes Dryer and Clothes Washer	27%
ENERGY STAR® Clothes Washer and Refrigerator	3%
All three appliances	5%

Note: Percentage may exceed 100% due to rounding

To inform the process evaluation, ADM also conducted an in-depth interview with program staff at PSO and the implementation contractor. This interview provided insight into various aspects of the program and its organization, but also focused on changes to the program that occurred during 2021. Interviewees also discussed aspects of the program operations that they considered to be successful as well as the challenges faced over the course of the program year. These results, along with program feedback collected via the participant surveys, have been consolidated in a separate memo, the “2021 Process Evaluation Memo”.

3.4.2.2 Gross Impact Estimation Methodology: Upstream Program

This subsection summarizes the methods used to verify all measures as well as calculate gross energy savings and gross demand reduction for each measure. Further details, including specific savings algorithms for each calculation, can be found in Appendix G, G.1.3.

Lighting

Reported energy and peak demand impacts for the program were calculated using deemed per-unit impacts from the Oklahoma Deemed Savings Documents (OKDSD). For LEDs, the deemed savings algorithms came from the 2013 updated Deemed Savings Documents, which reflect baseline bulb wattage changes resulting from the Energy Independence and Security Act of 2007 (EISA). ADM’s evaluation consisted of: (1) verifying the quantity of program eligible measures that were discounted in-store, (2) reviewing the assumptions and inputs associated with the deemed savings values, (3) verifying that the deemed per-unit impacts were applied appropriately and (4) making appropriate adjustments for in-service rates, leakage, and cross sector sales.

Verification

For LED markdowns, ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number and type of package sold, bulbs per package, bulb lumens, bulb wattage, program and original retail pricing, retail location, and transaction period. This tracking data was compared to participating retailer/manufacturer invoices to verify the quantity of units sold and discounted through the program. The retailer/manufacturer invoices submitted to the program rebate processing center are based on actual sales transaction data from each retailer. Manufacturer invoices were also reviewed for the bulbs distributed through local food pantries.

Calculation of Gross Annual kWh Savings

For discounted LEDs, savings are realized when an inefficient lamp is replaced with an Omni-directional LED in residential applications. The replacement must be ENERGY STAR® qualified. The OKDSD specifies the algorithms for use in calculating energy and demand impacts of ENERGY STAR® LEDs. ADM utilized these algorithms with a modification to the hours of use per year (960.61 hours of use (HOU) per year). The modification of the hours of use was sourced from a benchmarking study performed in 2016.[38]

In-Service Rate Adjustments

The cost-effectiveness testing for the program requires calculating lifetime energy savings for purchased LEDs. Less efficient incandescent and EISA compliant halogen bulbs typically have rated lifetimes considerably lower than LEDs. Additionally, calculating lifetime energy savings requires an estimate of when the newly purchased bulbs are installed. The Deemed Savings Documents stipulate an in-service rate (ISR) of 97%, but this reflects the percentage of bulbs estimated to be installed eventually by the purchaser rather than immediately installed. Previous studies have found that immediate or first-year installation rates are generally lower, as some bulbs are shelved for later use.

To estimate a second year ISR, ADM asked survey respondents from the general population survey to estimate the number of purchased light bulbs they had purchased as well as the number that they had installed. It was then assumed that the full ISR of 97% is achieved within three years.[39] The second year ISR is assumed to be the average of the first-year ISR and the full ISR, reflecting an assumed linear rate of installation. The ISR only affects first and second-year savings as well as the discounting of energy and demand impacts for cost-effectiveness testing purposes. Annual savings estimates are unaffected.

Leakage Adjustments

Leakage refers to cross-territory sales that occur when program discounted bulbs are installed outside of PSO's service territory. When this occurs, the energy and demand impacts from the discounted bulbs are not realized within the territory that financially supported and claimed the savings. During program year 2019, ADM conducted a study to estimate leakage for each of the retailers in the program that will be used for EM&V analysis for program years 2019-2021.

Estimates of leakage were assessed using an approach that combined responses from the general population survey with a geo-mapping analysis using the following methodology:

- First, ADM developed a mapping of concentric circles (drive-times) surrounding each participating retailer. The initial modeling assumed the "reach" of a retailer is a 60-minute drive, which is then modified by the presence of an alternative sponsoring retailer (i.e., if a customer is within a 60-minute drive of two sponsoring retailers, it is assumed they purchased from the closest one). Non-participating

[38] ADM Hours of Use Memo, 2016.

[39] This three-year period for achieving the full ISR is recommended by the DOE Uniform Methods Project Residential Lighting Evaluation Protocol.

retailers are also included as alternative retailers within the construction of the drive-times. ADM use data obtained from InfoUSA[40] to create a comprehensive list of retailers by retailer type (e.g., Discount, Do-it-yourself, Mass Merchant) within the 60-minute drive-time area.

- Second, ADM used 2010 Census block data from Environmental System Research Institute (ESRI) to determine the proportion of the population that falls within each drive-time circle (from Step 1), as well as the proportion of the population that falls within the PSO Oklahoma (OK) territory and within the state of Oklahoma. Thus, for each drive-time circle and retail location, ADM determined the proportion of the population within the PSO OK territory, outside of PSO OK territory and within the state of OK, and outside of the state of OK.
- Third, a general population survey was used to assess the shopping habits of PSO customers. The results of this survey were used to assess the drive-time in miles that OK consumers accepted when shopping for products incentivized by the ESP program. This gauge of consumer behavior was used to modify the initial 60-minute drive assumption established in Step 1 by weighting drive-times according to customers' willingness to drive a maximum distance for a given retailer type. The approach uses a log transformation of the drive-times to smooth the data and estimates the cumulative percent via a second order polynomial regression.
- Fourth, for each drive-time, ADM calculates the relative propensity of the population within that drive-time to visit the store. This relies on the predicted cumulative percent of willingness to drive in step 3 above. The first drive-time of 0 to 5 minutes is assigned 100% relative propensity, since it is assumed, all customers making trips to stores are willing to drive the minimum distance. The relative propensity of the remaining drivetimes is the lag of one minus the predicted cumulative percent of willingness to drive.
- Fifth, the relative propensity is multiplied by each of the populations found in Step 2 above for each participating retailer. The populations from Step 2 are then summed for each retailer and three separate leakage values are computed. The first leakage rate measures leakage in state and out of PSO territory. This is measured by the sum of the adjusted population[41] that is within state and out of territory divided by the adjusted total population for a given retailer. The second leakage rate measures leakage out of state, which is given by the sum of the adjusted population out of state divided by the adjusted total population. The final

[40] https://www.infousa.com/lp/infousa/?mediacode=USAGAWS00471&bas_phone=800.868.5249&sfcid=7010d000001K9ERAA0&gclid=Cj0KCQiAq97uBRCwARIsADTziyYs_ck0OVKuaxW7dS4GJcCEJXeTMMfqXzeOjZwbpXuK5xmZ-0uOOkQaAvv7EALw_wcB

[41] Adjusted population is equal to the population multiplied by the relative propensity to visit the store.

leakage rate is the sum of the first two leakage rates and measures overall leakage out of PSO territory.

- Lastly, an overall leakage rate for the program is calculated by weighing the individual retailer leakage rates by the total number of bulbs sold for each retailer.

Further detail on this analysis can be found in a separate report entitled “2019 Lighting Sales Leakage Memo,” which is relevant for the entire program evaluation cycle (PY2019-PY2021). ADM found that PSO’s overall leakage rate was 8.4%; however, per UMP discussion[42], ADM will rely only on the calculated out-of-state leakage rate, 0.2%, as neighboring utility territories in Oklahoma also offer incentivized bulbs and incented bulbs likely cross both in and out of the neighboring service territories.

Cross Sector Sales Adjustments

ADM used estimated annual hours of use (HOU) of 960.61 (as described in Calculation of Gross Annual kWh Savings). This reflects an average daily HOU of 2.63 times 365.25 days per year. While this is within the range of HOU estimates from previous studies[43] of residential lighting use, it likely underestimates HOU for bulbs that are installed in non-residential buildings. The higher annual HOU for bulbs in non-residential savings implies a shorter expected useful life for the bulbs (in years). The period in which the savings occur affects the applicable baseline wattage and discount factor for cost-effectiveness savings. ADM used responses from the general population survey to estimate the percentage of purchased bulbs that are installed in non-residential facilities. For these bulbs, HOU were estimated to be 3,253 based on EUL stipulations for integrated-ballast CFLs from the Arkansas TRM.[44] A corresponding coincidence factor (CF) of 0.55 is assumed. This has the effect of increasing annual energy savings and peak demand reduction for the percentage of bulbs estimated to be installed in non-residential settings.

Non-Lighting Measures

Savings calculations for non-lighting measures are outlined in the sections below. The detailed algorithms can be found in Appendix G, G.1.3.

ADM’s evaluation consisted of (1) verifying the quantity of program eligible measures that were discounted in-store, (2) reviewing the assumptions and inputs associated with the

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[42] The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures: Chapter 6, Section 5, page 26.

[43] The DOE Uniform Methods Project Residential Lighting Evaluation Protocol summarizes nine recent studies with HOU estimates ranging from 1.5 to 2.98 hours per day. See: http://energy.gov/sites/prod/files/2013/11/f5/53827-6.pdf.

[44] Table 362: Estimated Useful Life by Lamp Type found in the Arkansas TRM v6.1 states the weighted-average annual operating hours for integrated-ballast CFLs as 3,253. See http://www.apscservices.info/EEInfo/TRM6-1.pdf.

deemed savings values and (3) verifying that the deemed per-unit impacts were applied appropriately.

Air Filters

Deemed savings for air filters were not available in the OKDSD, so the Texas TRM was used to calculate savings.[45]

Verification

For air filters (AF), ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number and type of Air filters sold, program and original retail pricing, retail location and transaction period.

Advanced Power Strips

Due to data differences between the program tracking data and the OKDSD, deemed kWh and peak demand kW savings values for advanced power strips (APS) were referenced using the Arkansas TRM v7.0[46] instead of OKDSD.

Verification

For APS, ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number of APS, program and original retail pricing, retail location, and transaction period.

Calculation of Gross Annual kWh Savings

The PSO ESP program provided rebates for Tier 1 APS only. Deemed savings were calculated for Tier 1 by average complete system as the type of installation was unknown.

Bathroom Ventilation Fan

Deemed kWh and peak demand kW savings values for bathroom ventilation fans (BVF) were unavailable in the OKDSD; however, the Illinois TRM v7.0 has established deemed kWh savings and peak kW demand values that were used for this analysis.[47]

Verification

For BVF, ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number of BVF sold, program and original retail pricing, retail location and transaction period.

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[45] Texas Technical Reference Manual, version 6.0 volume 2: Residential Measures, November 7, 2018. Section 2.2.1, pg. 2-57 – 2-63.

[46] Arkansas Technical Reference Manual, version 7.0 volume 1: EM&V Protocols, *prepared by* The Independent Evaluation Monitor, *approved in Docket* 10-100-R, August 31, 2017. Section 2.4.4, pg. 182-189.

[47] Illinois Statewide Technical Reference Manual for Energy Efficiency, version 7.0 volume 3: Residential Measures, September 28, 2018. Section 5.3.9, pg. 124-126.

Room Air Conditioners

The Arkansas TRM v7.0 has established deemed kWh savings and peak kW demand values that were used for this analysis.[48]

Verification

For room air conditioners (RAC), ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number, and type of RAC sold, cooling capacity, equivalent full-load cooling hours, program and original retail pricing, retail location and transaction period.

Room Air Purifiers

Deemed kWh and peak demand kW savings values for room air purifiers were unavailable in the OKDSD; however, the Illinois Technical Reference Manual (TRM) v7.0 has established deemed kWh savings and peak kW demand values that were used for this analysis.[49]

Verification

For room air purifiers (RAP), ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number and type of room air purifier sold, Dust CADR, program and original retail pricing, retail location, and transaction period. This tracking data was compared to participating retailer/manufacturer invoices to verify the quantity of units sold and discounted through the program. The retailer/manufacturer invoices submitted to the program rebate processing center are based on actual sales transaction data from each retailer.

Calculation of Gross Annual Energy Savings and Peak Demand Reduction

Gross annual energy savings for discounted room air purifiers were calculated using the algorithm from the Illinois TRM v7.0.

Water Dispensers

Deemed kWh and peak demand kW savings values for water dispensers (WD) were unavailable in the OKDSD; however, the Pennsylvania TRM has established deemed kWh savings and peak kW demand values that were used for this analysis.[50]

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[48] Arkansas Technical Reference Manual, version 7.0 volume 1: EM&V Protocols, *prepared by* The Independent Evaluation Monitor, *approved in Docket* 10-100-R, August 31, 2017. Section 2.1.10, pg. 73-75.

[49] Illinois Statewide Technical Reference Manual for Energy Efficiency, version 7.0 volume 3: Residential Measures, September 28, 2018. Section 5.1.1, pg. 6-8.

[50] Pennsylvania Technical Reference Manual, June 2016. Section 2.4.9, pg. 164-165.

Verification

For WD, ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number, and type of WD sold, type of storage, program and original retail pricing, retail location and transaction period.

Weatherization Measures: Spray Foam, Door Seals, and Door Sweeps

The Pennsylvania TRM's Interim Measure Protocol for Weather Stripping has established kWh savings and peak kW demand values that were used for this analysis.[51]

Verification

For these weatherization measures (WM), ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number, and type of WMs sold, program and original retail pricing, retail location and transaction period.

3.4.2.3 Gross Impact Estimation Methodology: Downstream Program

Clothes Dryers

Deemed kWh and peak demand kW savings values for clothes dryers (CD) were unavailable in the OKDSD; however, the Illinois TRM v7.0 has established deemed kWh savings and peak kW demand values that were used for this analysis.[52]

Verification

For CD, ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number and type of CD sold, dryer type, vented/ventless, voltage, drum size, automatic termination controls, program and original retail pricing, retail location, and transaction period.

Clothes Washers

The AR TRM v7.0 has established deemed kWh savings and peak kW demand values that were used for this analysis.[53]

Verification

For clothes washers (CW), ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number and type of

[51] Addendum document to the 2016 Pennsylvania TRM for weather stripping, caulking, and outlet gaskets.
[52] Illinois Statewide Technical Reference Manual for Energy Efficiency, version 7.0 volume 3: Residential Measures, September 28, 2018. Section 5.1.10, pg. 45-48.
[53] Arkansas Technical Reference Manual, version 7.0 volume 1: EM&V Protocols, *prepared by* The Independent Evaluation Monitor, *approved in Docket* 10-100-R, August 31, 2017. Section 2.4.1, pg. 165-170.

CW sold, fuel type, program and original retail pricing, retail location and transaction period.

Electric Vehicle Chargers

For Level 2 electric vehicle chargers (EVC), ADM used a saving algorithm co-developed with the implementor.

Verification

For EVCs, ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number, and model of EVCs sold, program and original retail pricing, retail location and transaction period.

Heat Pump Water Heaters

ADM checked heat pump water heater (HPWH) model numbers listed in the program tracking system against ENERGY STAR® databases to verify that each HPWH distributed in 2021 was ENERGY STAR® certified and assigned the correct capacity and efficiency ratings.

Deemed kWh savings values for HPWH were unavailable in the OKDSD; however, they were available in the Arkansas TRM v7.0.[54] The variables that affect deemed savings are the following: storage tank volume, HPWH Energy Factor (EF), HPWH installation location (conditioned vs. unconditioned space) and weather zone. Weather zones were based on established zones in Arkansas. Similar weather zones have been established in Oklahoma that are commiserate with the numbered weather zones in Arkansas.

Refrigerators

The AR TRM v7.0 has established deemed kWh savings and peak kW demand values that were used for this analysis.[55]

Verification

For refrigerators (FR), ADM reviewed the program tracking database consisting of retailer transaction data. Important fields included: item description, number and type of FR sold, program and original retail pricing, retail location and transaction period.

[54] Arkansas Technical Reference Manual, version 7.0 volume 1: EM&V Protocols, *prepared by* The Independent Evaluation Monitor, *approved in Docket* 10-100-R, August 31, 2017. Section 3.3.1, pg. 357-368.

[55] Arkansas Technical Reference Manual, version 7.0 volume 1: EM&V Protocols, *prepared by* The Independent Evaluation Monitor, *approved in Docket* 10-100-R, August 31, 2017. Section 2.4.3, pg. 174-181.

3.4.3 Net-to-Gross Estimation

3.4.3.1 Lighting

Program measures will be separated into two categories for net-to-gross estimation. Two participating locations have an assumed net-to-gross (NTG) ratio of 100%.

- For LEDs distributed through local food pantries, the NTG ratio is assumed to be 100%. For the 25,008 LED packages (100,032 bulbs) distributed through local food banks, the 100% net-to-gross ratio is assumed because customers do not shop for the lighting products at these locations but rather, they are simply offered LEDs without prompting. Individuals who received LEDs through the food banks are also more likely to represent low-income customers, potentially limiting their ability or willingness to purchase high efficiency lighting products. Overall, the LEDs giveaways represent just over 10% of reported gross energy savings from the ESP program lighting component.
- For the LED packages distributed through Dollar General, the 100% net-to-gross ratio will be assumed because the retailer has specifically stated that they "would not stock any ENERGY STAR® LEDs in the absence of the program."

For LEDs discounted at any other participating retail stores, ADM will estimate free ridership as described throughout the rest of this section.

Determining the net effects of the in-store retail discounts requires estimating the percentage of energy savings from efficient lighting purchases that would have occurred without program intervention. Ideally, participating retailers could provide light bulb sales data for non-program time periods and/or from similar non-program retail locations. This data would provide adequate information from which to calculate the lift in LED sales attributable to the program price markdowns. However, retailers are reluctant to release sales data for this purpose, and non-program sales data was not made available to ADM.

As a result, evaluating the net effects of the price discounts requires estimating free ridership without non-program sales data. Several methodologies have been used in similar evaluations across the country, all of which have certain advantages and disadvantages. For this evaluation of the PY2021 ESP program lighting component, ADM developed two separate estimates of free ridership, each using a different methodology. Table 3-64 provides a summary of the methodologies and their relative advantages and disadvantages. Details regarding each methodology are provided in Table 3-64.

Table 3-64: Free Ridership Estimation Methodologies – Advantages and Disadvantages

Methodology	Advantages	Disadvantages
General Population Survey	▪ Allows for a more truly random sample than intercept surveys. ▪ Allows for discussion of bulbs post-installation. ▪ Large sample size more cost-effective than intercept surveys.	▪ Relies on customer self-reporting of purchase decision making. ▪ Potential for recall bias is higher than intercept surveys (discuss purchases over the past six months). This may also affect whether the respondent purchased program bulbs. ▪ Potential for bias in scoring algorithm.
Consumer Demand Model	▪ Estimate is developed from actual sales data, eliminating potential biases that customer self-report data can exhibit.	▪ The model is estimated using program sales data only. While the model may fit program sales data well, it is possible that it does not predict sales levels at non-program prices well.

Survey Based Methodology

The first methodology is based on self-report surveys with a sample of customers aimed at understanding decision making for light bulb purchases. The goal of these surveys is to elicit information from which to estimate the number of bulbs that the customers would have purchased in the counterfactual scenario where LEDs were not discounted. Self-report survey methods for determining free ridership are generally recognized as susceptible to certain biases and error. This may be especially true for upstream price markdown programs, where the counterfactual scenario of regular retail prices may be difficult to explain or grasp. The self-report methodologies also rely on specific scoring algorithms, which may bias the free ridership estimates if they do not accurately reflect the customer decision making process. This evaluation relies on self-report survey data from two surveying efforts:

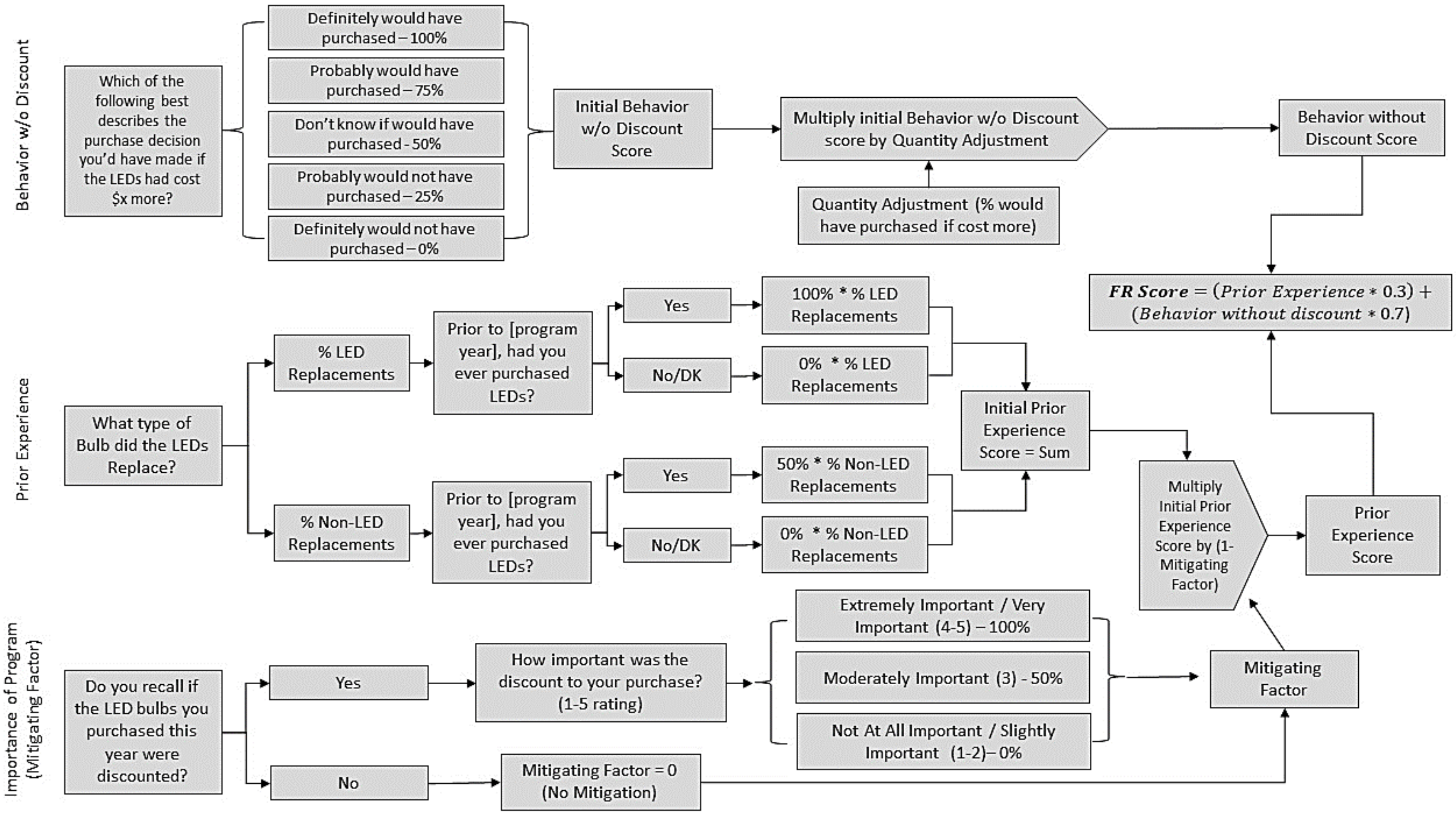
- The survey-based effort for calculating free ridership was conducted using emails from a sample of randomly selected residential customers. The strength of this approach is the ability to obtain a random and relatively large sample size cost-effectively. It also allows for further questioning regarding the fate of recently purchased bulbs (e.g., installed immediately, stored for future use, location of installation, etc.). The biggest drawback to the approach is the potential for respondent recall bias. For example, it may be difficult to get accurate responses to questions about the number of bulbs the respondent recently purchased and whether they were discounted through the program.

Survey respondents were asked a series of questions to elicit feedback regarding influences on their light bulb purchasing decisions. Each respondent was then assigned a free ridership score based on a consistent free ridership scoring algorithm. The free ridership scoring algorithm developed for the survey instruments is shown in Figure 3-31.

The “behavior without discount” scoring is the primary determinate of respondents’ free ridership scores. This section asked whether the respondent would have purchased the same light bulbs if they had cost the regular retail price. This may be a question that is particularly prone to social desirability bias – the tendency to respond in a manner that might be viewed favorably by others. For this reason, a consistency check was performed. In the survey, each respondent was asked to state light bulb characteristics that are important to them when choosing between available options. If a respondent lists price as the most important characteristic, but then goes on to indicate that they would have still purchased efficient options at full retail price, their response will be eliminated from the data population.

When responses from the general population survey were compiled, each response had equal weight in estimating the average free ridership level for the program.

Figure 3-31: Free Ridership Scoring for LEDs



Non-Survey Based Methodology

The second estimate of free ridership was developed through the estimation of a price response model which was used to predict sales levels in the absence of the program. The program tracking data included package and bulb sales for each retailer, by model number and week.[56] For each retailer and model number combination, original retail price and program price data were available. As program price discounts and/or retailer original pricing changed throughout the year, the tracking data was updated, allowing for the comparison of same-bulb sales under slightly different pricing conditions. Price effects are the main program tool for encouraging the purchase of high efficiency lighting choices. However, there are also regular promotional events sponsored by PSO within participating retail locations. The dates, location, and duration of in-store promotional events were also tracked, allowing for estimation of their effects on sales levels as well. The final price response model is used to estimate a free ridership as described in the equation below:

Equation 3-2: Estimation of Free Ridership

$$Free\ ridership\ ratio = \frac{\sum_i^n (E\left[Bulbs_{NoProgram_i}\right] * kWh_i)}{\sum_i^n (E\left[Bulbs_{Program_i}\right] * kWh_i)}$$

Where:

$E\left[Bulbs_{NoProgram_i}\right]$ = the expected number of bulbs of type, i, purchased given original retail pricing (as predicted by the model).

$E\left[Bulbs_{Program_i}\right]$ = the expected number of bulbs of type, i, given program discounted pricing (as predicted by the model).

kWhi = the average gross kWh savings for bulb type, i.

The price response modeling approach is advantageous in that it is built upon actual sales data from participating retailers (as opposed to relying on consumer self-report surveys). There are, however, several limitations for the approach. Most importantly, non-program sales data is unavailable for inclusion in the model. As a result, the modeling of price impacts may fit program sales data well, but it is uncertain whether those price effects apply well to prices outside of program ranges. Additionally, the lack of non-program sales data means that for many bulb types and time ranges, the available sales data lists zero sales. These “zeroes” in most cases do not actually represent zero sales, but rather a lack of information because program pricing was not in effect for a given bulb during a given week. This presents a challenge in modeling the sales data using typical time-series

[56] Most bulb sales were recorded on a weekly basis. However, some retailer/manufacturer partners reported bulb sales bi-weekly or monthly. To produce weekly sales estimates for these bulbs, the bi-weekly sales were divided by two and monthly sales were divided by four. While this may not be entirely accurate over a given timespan, it is a reasonable assumption in the absence of weekly data.

or panel data methods. Additionally, during the sales period analyzed there was only pricing variation for a subset of bulb models, limiting the ability of the model to predict price response effects in a robust manner. Finally, there are likely variables that affect sales levels for LEDs that are not captured by the program tracking data; thus, there is a risk of omitted variable bias in addition to the inherent amount of error from statistical modeling.

Spillover and Market Effects

It is worth noting that none of the methodologies used to estimate program free ridership include estimates of spillover or market effects. Spillover refers to savings that occur because of program influences on customers but for which an incentive or rebate is not given. In the context of a program for LED price markdowns, the following examples illustrate potential sources of spillover:

- Participant spillover: a customer who purchases program discounted bulbs is influenced to install additional (non-rebated) energy efficiency measures or change their energy usage behavior because of their program experience.
- Nonparticipant spillover: a customer notices PSO sponsored discounts or receives educational resources from an in-store promotional event. While they do not ultimately purchase program discounted bulbs, their interaction with the program encourages them to install other (non-rebated) energy efficiency measures or change their energy usage behavior.

Market effects refer to changes in market structure or market actor behavior due to program influence that results in non-incentivized adoption of energy efficiency measures. In the context of a program for LED price markdowns, the following examples illustrate potential sources of market effects:

- Market pricing related effects: it is possible that the program sponsored discounts for certain lighting products cause downward pressure on prices for competing products (non-program bulbs). The competing products could potentially be LEDs at participating retailers or non-participating retailers. If pricing for these competing products is lowered in response to program discounts and a corresponding increase in purchases (and installations) occurs, then there may be additional savings attributable to program influences.
- Market manufacturing/stocking effects: it is possible that the program sponsored incentives caused bulb manufacturers and retailers to adjust their lighting product offerings. To the extent that the program causes lesser efficiency bulbs to be displaced with higher efficiency bulbs at the manufacturer/retailer level, there may be additional savings attributable to program influences.

It is likely that some combination of these effects increases the savings attributable to the ESP lighting portion of the program. However, there is also reason to believe these effects may be small overall. Participant and non-participant spillover typically occurs through customer education. The ESP program component does include regular in-store promotional/educational event, but the number of customers reached relative to overall program sales is likely small. Additionally, the promotional events usually provide information designed to encourage customers to participate in other PSO energy-efficiency programs, which would not constitute spillover if these customers ultimately did participate and receive a rebate. The implementor's field team educates customers regarding the incentives provided in the PSO ESP program; however, these are not explicitly quantified and therefore cannot provide reliable estimates of spillover.

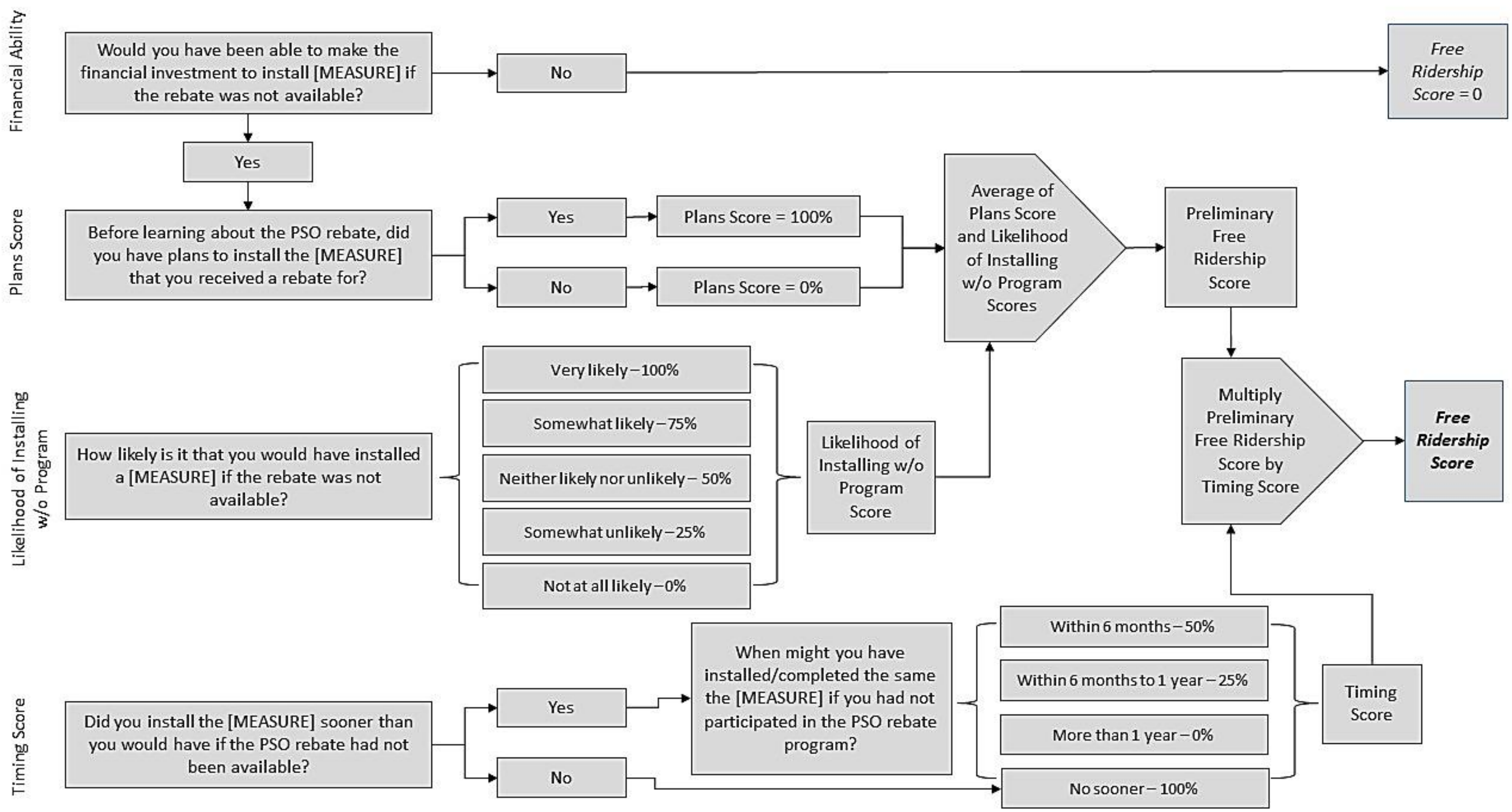
Market effects may exist to some extent but disaggregating the PSO program influences from other influences such as technological advances and other lighting discount programs across the country is difficult. The current ESP program component covers a substantial share of the bulbs sold in the PSO service territory, with no immediate plans for discontinuing the price markdowns.

Overall, it should be noted that spillover and market effects likely remain a minor factor, and the net-to-gross estimate developed in this evaluation should be considered with these omitted effects in mind.

3.4.3.2 Non-Lighting Measures

For upstream measures (discounted at the retail level), ADM sought to determine NTG ratios based on survey data gathered from the general population survey. However, since there were not enough survey responses from the PY2021 survey to represent a statistically significant sample for each measure, ADM aggregated survey responses from the entire portfolio cycle. All surveys administered by ADM contained questions aimed at assessing the decision-making processes of PSO customers participating in the program. The goal of these survey questions was to elicit information that could be used to estimate the number of customers that would have purchased the more efficient measure in the counterfactual scenario (i.e., where the energy efficient measure was not discounted). A series of questions on participants' financial ability to implement the measure without program incentives, plans to purchase the measure before learning of the program discount or rebate, the likelihood of purchasing the measure in the absence of the program, and the impact of the program on the timing of the purchase were asked. These questions were used to calculate free ridership following the logic shown in Figure 3-32 on the following page.

Figure 3-32: Free Ridership Scoring for non-LEDs



For advanced power strips, air filters, and weatherization measures, there were statistically significant sample sizes when surveys from the entire portfolio cycle were combined. For these three measures, survey data from the PY2019, PY2020, and PY2021 general population surveys were combined to calculate average measure-level free ridership scores, shown on the following page in Table 3-65. For room air conditioners, room air purifiers, water dispensers, and bathroom ventilation fans, there were not enough survey responses across the evaluation cycle to compile statistically significant samples. For these measures, ADM calculated a weighted average free ridership score of 0.52 from the evaluation cycle average free ridership scores of all non-LED upstream measures (Table 3-65). ADM used the weighted average free ridership score to calculate the NTG ratio used for room air conditioners, room air purifiers, water dispensers, and bathroom ventilation fans.

Table 3-65: Survey Responses and Free-Ridership Scores: Upstream Measures

Measure	Survey Responses				Evaluation Cycle Average Free Ridership	Net-to-Gross Score for PY2021
	2019	2020	2021	Total		
Advanced Power Strips	62	5	7	74	0.24	0.76
Air Filters	12	59	20	91	0.73	0.27
Weatherization Measures	43	92	-	135	0.56	0.44
Room Air Conditioners	9	15	5	29	0.48	0.48
Bathroom Ventilation Fans	5	5	1	11	0.37	0.48
Water Dispensers	-	3	1	4	0.48	0.48
Room Air Purifiers	-	3	-	3	0.12	0.48
Weighted Average					**0.52**	

For downstream measures, ADM determined free ridership based on responses gathered from the downstream rebate survey and the EV charger survey. However, since there were not enough survey responses from either survey in 2021 to represent statistically significant survey samples for each measure, ADM aggregated survey responses from the entire portfolio cycle to determine measure-level free ridership scores. For clothes dryers, clothes washers, and refrigerators the survey responses from PY2019-PY2021 represented statistically significant samples and were used to calculate the scores presented Table 3-66 below.

For EV chargers, ADM was able to gather 10 survey responses, representing 29% of program participants during the evaluation cycle. Due to the scarcity of empirical data from other sources, ADM views the survey responses gathered to be the most accurate representation of PSO customer free ridership available for rebated EV chargers and therefore will use the survey-based free ridership score (Table 3-66).

Table 3-66: Survey Responses and Free-Ridership Scores: Downstream Measures

Measure	Survey Responses				Evaluation Cycle Average Free Ridership	Net-to-Gross Score for PY2021
	2019	2020	2021	Total		
Clothes Dryers	19	58	67	144	0.54	0.46
Clothes Washers	64	110	106	280	0.52	0.48
Refrigerators	57	65	60	182	0.53	0.47
Electric Vehicle Chargers	1	1	8	10	0.31	0.69

For heat pump water heaters, there was only 1 survey response from the evaluation cycle, so ADM will continue to use a NTG score based on ComEd's Appliance Rebates Program Evaluation Report (a stipulated NTG ratio of 0.86) as was done for PY2019 and PY2020.[57]

3.4.4 Impact Evaluation Findings

This section reports findings from the impact evaluation of the ESP program.

3.4.4.1 Lighting Gross Energy Savings and Peak Demand Impact

The tracking data compiled by the implementor and provided through AEG for the ESP program lighting component identified a total of 224,154 packages of LEDs were discounted through participating retail stores (2,199 of which were packages of LEDs included with fixtures). An additional 25,008 packages of LEDs were distributed free-of-charge through local food banks. Table 3-67 shows the reported quantities and impacts of measures discounted or distributed free-of-charge through the ESP program during PY2021.

Table 3-67: Reported Measure Quantities and Impacts – Lighting Only

Distribution Type	Measure Type	Package Quantity	Bulb Quantity	Reported kWh	Reported kW
Retail Discounts	Directional LEDs (with fixture)	2,199	4,231	212,088	31.67
	Directional LED	43,991	154,196	6,194,715	924.98
	Omni-directional LED	177,964	665,161	21,415,304	3,197.71
Food Bank	Omni-directional LED	25,008	100,032	3,131,822	467.64
Totals		**249,162**	**923,620**	**30,953,928**	**4,622.00**

[57]http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY8_Evaluation_Reports_Final/ComEd_Appliance_Rebates_PY8_Evaluation_Report_2016-12-09.pdf

Verification

To verify the types and quantities of distributed measures, ADM performed a census review of all retailer/manufacturer invoices for LED sales. This review found that 1 LED discounted through the program was not eligible to receive energy efficiency savings[58]; as a result, no verified kWh savings and no kW reduction were attributed to this item. As a result, the verified quantity of LEDs decreased by 298, for a total of 923,322. This review also verified that the reported quantity of light bulbs sold through retail stores and distributed free-of-charge through local food pantries matched exactly with the invoices that PSO paid.

ADM also reviewed the program tracking database to determine if energy and demand impacts were correctly calculated according to the Oklahoma Deemed Savings Document algorithms for each LED type. For PY2021, ADM calculated verified energy and demand impacts based on OKDSD but used an adjusted value for hours of use (960.61 hours). ADM found that for all light bulbs, reported impacts were calculated in accordance with the deemed savings algorithms. Each program eligible bulb was checked to determine the correct bulb wattage and ensure the correct lumen output and baseline wattage was applied. The discrepancies identified through the database review required adjustment for the actual wattages and/or baseline wattages used in the calculation of energy and demand impacts for some bulbs.

Table 3-68 provides the estimated impact each of these adjustments had over reported kWh savings. ADM identified 53 LED models in the program tracking data that significantly differed[59] from the calculated savings. Many of these differences are due to parameters such as wattage, baseline wattage, or lumens being reported differently from the verified values in the ENERGY STAR® database. There are also many instances of omnidirectional bulbs that appear to use Tier 2 baseline wattages for the savings calculations instead of Tier 1.

Table 3-68: Gross kWh Savings Adjustments – Lighting Only

Model Number	Lamp Category	Watts		Lumens		Baseline Watts		Energy Savings (kWh)	
		Reported	Verified	Reported	Verified	Reported	Verified	Reported	Verified
LED11813G-3	Decorative	4	4	300	350	25	45	18.8	36.7
93129230	Decorative	8.5	5.5	500	500	45	45	32.6	35.3
93129133	Decorative	4	4	300	320	25	45	18.8	36.7
LED11400G-2	Directional	15	13	1250	1050	72	72	51	52.8
LED11404G-2	Directional	15	13	1250	1050	72	72	51	52.8

[58] The reported Energy Star® Model number 93129471 was not found in the ENERGY STAR® LED database
[59] The table does not include models with very small discrepancies that are likely a result of rounding issues.

Model Number	Lamp Category	Watts		Lumens		Baseline Watts		Energy Savings (kWh)	
		Reported	Verified	Reported	Verified	Reported	Verified	Reported	Verified
LED11698G-3	Directional	8.5	8	665	650	65	65	50.5	51
LED11809G-3	Directional	8.5	8	665	650	65	65	50.5	51
LED11810G-3	Directional	8.5	8	665	650	65	65	50.5	51
TPAR38-1503025FH25-12DE26-1	Directional	19	13.5	1200	1200	72	72	47.4	52.3
TPAR38-1503040FH25-12DE26-1	Directional	19	13.5	1200	1200	72	72	47.4	52.3
93128619	Directional	7	7	500	600	45	65	34	51.9
93128619	Directional	7	7	600	600	45	65	34	51.9
93128137	Directional	13	13.5	900	900	65	65	46.5	46.1
93128138	Directional	13	13.5	900	900	65	65	46.5	46.1
93128621	Directional	13	15	1200	1300	72	72	52.8	51
93128575	Directional	13	15	1200	1300	72	72	52.8	51
93128616	Directional	13	15	1200	1300	72	72	52.8	51
41054	Directional	10.5	11	700	850	65	65	48.8	48.3
67615	Directional	10	10	800	800	43	65	29.5	49.2
67607	Directional	6	7	480	500	29	45	20.6	34
A20BR3065WESD26	Directional	9	8	665	680	65	65	50.1	51
A20BR3065WESD36	Directional	9	8	665	680	65	65	50.1	51
A20BR3065WESD56	Directional	9	8	685	700	65	65	50.1	51
LED12357A-2	Directional	14	15	1100	1070	72	72	51.9	51
LED12357B-2	Directional	14	15	1100	1070	72	72	51.9	51
LED12357	Directional	14	15	1100	1070	72	72	51.9	51
LED12355C	Directional	15	15.5	1070	1100	72	72	51	50.5
LED12357C	Directional	15	15.5	1070	1100	72	72	51	50.5
LED11819H-2	Omnidirectional	5.6	5.5	450	450	29	29	20.9	21
LED11820H-2	Omnidirectional	5.6	5.5	450	450	29	29	20.9	21
LED11821H-2	Omnidirectional	5.6	5.5	450	450	29	29	20.9	21
LED11822G-3	Omnidirectional	9	9.5	800	800	43	43	30.4	30
LED11823G-3	Omnidirectional	9	9.5	800	800	43	43	30.4	30
LED11824G-3	Omnidirectional	9	9.5	800	800	43	43	30.4	30
93122484	Omnidirectional	8	10	800	800	43	43	31.3	29.5
93122485	Omnidirectional	8	10	800	800	43	43	31.3	29.5
93122536	Omnidirectional	8	10	800	800	43	43	31.3	29.5

Model Number	Lamp Category	Watts		Lumens		Baseline Watts		Energy Savings (kWh)	
		Reported	Verified	Reported	Verified	Reported	Verified	Reported	Verified
93122537	Omnidirectional	8	10	800	800	43	43	31.3	29.5
93121845	Omnidirectional	13	10.5	1100	1100	53	53	35.8	38
93121900	Omnidirectional	13	10.5	1100	1100	53	53	35.8	38
93122666	Omnidirectional	17	13.5	1600	1600	72	72	49.2	52.3
93122667	Omnidirectional	17	13.5	1600	1600	72	72	49.2	52.3
93122480	Omnidirectional	5	6	450	480	29	29	21.5	20.6
93122482	Omnidirectional	5	6	450	480	29	29	21.5	20.6
1004511049	Omnidirectional	9	9.5	665	800	65	43	50.1	30
B7A19A40WESD14	Omnidirectional	13	5.7	1000	460	72	29	52.8	20.8
B7A19A40WESD14	Omnidirectional	5.7	5.7	460	460	45	29	35.2	20.8
LED11820G-2	Omnidirectional	5.5	5.6	450	450	29	29	21	20.9
LED11821G-2	Omnidirectional	5.5	5.6	450	450	29	29	21	20.9
LED11822F-3	Omnidirectional	9.5	9	800	800	43	43	30	30.4
LED11823F-3	Omnidirectional	9.5	9	800	800	43	43	30	30.4
LED11824F-3	Omnidirectional	9.5	9	800	800	43	43	30	30.4
LED12623	Omnidirectional	8.5	9	665	800	65	43	50.5	30.4
LED13186	Omnidirectional	5.6	5.5	450	450	29	29	20.9	21
LED12613	Omnidirectional	4	9	300	800	25	43	18.8	30.4

In-Service Rate Adjustments

To calculate program cost effectiveness, an average of the first year ISR from the general population survey, 75%, and the full year ISR of 97% was assumed (86%). This does not affect annual kWh savings estimates, as it was assumed that 97% of the bulbs are installed within three years based on the stipulations in the deemed savings documents.[60]

Leakage Adjustments

Leakage refers to cross-territory sales that occur when program discounted bulbs are installed outside of PSO’s service territory. When this occurs, the energy and demand impacts from the discounted bulbs are not realized within the territory that paid for and claimed the savings. For PY2019-2021, ADM conducted an appraisal study and

[60] Calculating cost-effectiveness requires an estimation of when the bulbs are installed to correctly discount future year savings. The cost-effectiveness estimates for the ESP program presented in this report assume that 85% of the bulbs are installed within the first year. By the third year, it is assumed that 97% of bulbs are installed, based on the deemed savings document. For the second year, 91% are assumed to be installed (a linear interpolation of years one and two).

estimated out-of-state leakage to be 0.2%, which corresponds to a reduction of approximately 61,762 kWh and 9.22 kW.

Cross Sector Sales Adjustments

An adjustment to gross impacts was made to account for the proportion of program bulbs estimated to be installed in non-residential settings, where HOU and CF are typically higher than residential sockets. The general population survey included a question related to cross sector sales. Respondents who indicated they had purchased LEDs in the past eight months were asked: “Were any of the LEDs you purchased in the past eight months installed in a business or commercial setting?” Of the 132 LED purchasers who responded to this question, 2 indicated that they installed bulbs in a non-residential setting[61]. Those 2 participants reported installing a total of 10 LEDs in non-residential settings, which represents 1.52% of all LEDs described by survey participants. The resulting non-residential allocation is therefore 0.74%.

The estimated cross-sector adjustment derived from the general population survey is within the range of values that previous evaluations of residential lighting markdown programs have estimated. A meta-analysis conducted in 2015 of 23 evaluation reports found cross-sector sales estimates ranging from 0.0% to 18.7%, with various methodologies used.[62] The average non-residential allocation estimate from these studies was 6.7%. In 2021, only 1.52% of survey respondents (2 participants) installed light bulbs in a commercial setting. Since this is too small of a sample size to accurately calculate cross-sector sales estimates, ADM utilized the 5.0% non-residential allocation estimate from the average of the intercept and RDD surveys from PY2015.

To account for cross-sector sales, the verified gross savings methodology developed by ADM uses weighted values for hours of use (HOU) and coincidence factor (CF). For commercial bulbs, ADM set HOU to 3,253 hours and used a CF of 0.55. These variables were weighted at 5.0%, while the residential adjusted HOU of 960.61 and CF of 0.09 were weighted at 95%. Following this method, ADM estimates that cross-sector sales increase program savings by 3,684,706 kWh and similarly increase demand reduction by 1,178.40 kW.

[61] This does not include one respondent that answered this question was removed from this calculation for being an extreme outlier.

[62] Strom, M., Russell, C., Wilson-Wright, L., Hoefgen, L., NMR Group, Inc., Bruchs, D., Ward, B., and Cadmus (2015) Massachusetts Residential Lighting Cross-Sector Sales Research Memorandum. *Last accessed:* October, 2019; *Accessed via*: http://ma-eeac.org/wordpress/wp-content/uploads/Residential-Lighting-Cross-Sector-Sales-Research-Memo.pdf

Final Verified Gross Savings Estimates

Without considering leakage and cross-sector sales adjustments, the initial verified gross energy savings estimates for the ESP program were 30,877,396 kWh. The initial verified gross peak demand reduction estimated was 4,610.59 kW. These results were determined by summing together the measure level initial verified gross energy savings and peak demand savings calculated using the methodologies stipulated in the Oklahoma Deemed Savings Documents. Table 3-69 on the following page compares reported and verified impact estimates for this program component following the verification review.

Table 3-69: ESP Program Impact Findings – Initial Gross Verified Lighting Savings Only

Distribution Type	Measure Type	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	Directional LEDs (with fixture)	4,231	212,088	212,088	31.67	31.67
	Directional LED	153,898	6,194,715	6,303,729	924.98	941.27
	Omni-directional LED	665,161	21,415,304	21,229,757	3,197.71	3,170.01
Food bank	Omni-directional LED	100,032	3,131,822	3,131,822	467.64	467.64
Total		**923,322**	**30,953,928**	**30,877,396**	**4,622.00**	**4,610.59**

After considering leakage and cross-sector adjustments, annual energy savings for the ESP program were estimated to be 34,500,341 kWh and verified peak demand savings were 5,779.76 kW. The application of the leakage and cross-sector adjustments is presented in Table 3-70.

Table 3-70: ESP Program Impact Findings – Leakage and Cross-Sector Adjusted Gross Verified Lighting Savings

Distribution Type	Measure Type	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	Directional LEDs (with fixture)	4,231	212,088	236,973	31.67	39.70
	Directional LED	153,898	6,194,715	7,043,366	924.98	1,179.96
	Omni-directional LED	665,161	21,415,304	23,720,713	3,197.71	3,973.88
Food bank	Omni-directional LED	100,032	3,131,822	3,499,289	467.64	586.22
Total		**923,322**	**30,953,928**	**34,500,341**	**4,622.00**	**5,779.76**

3.4.4.2 Air Filter Gross Energy Savings and Peak Demand Impacts

ADM's review of program tracking data identified that a total of 14,213 qualifying air filters were sold at participating retail stores during the 2021 program year. Table 3-75 shows the reported quantities and impacts of air filters through the ESP program during PY2021.

Table 3-71: Reported Measure Quantities and Impacts – Air Filters

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Retail Discounts	Air Filters	14,213	746,344	2,579.98

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for air filters sold through the program. This review found that all air filters were assigned the correct kWh and kW savings in the program tracking data. Any differences in total verified savings and demand reduction are attributable to differences in rounding.

Final Verified Gross Savings Estimates

Table 3-72 compares reported and verified impact estimates for air filters rebated through the program in 2021. The total verified energy savings for all Air filters was calculated to be 746,353 kWh and the verified demand impact was 2,579.99 kW.

Table 3-72: ESP Program Impact Findings – Air Filters

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	Air filters	14,213	746,344	746,353	2,579.98	2,579.99

3.4.4.3 Advanced Power Strip Gross Energy Savings and Peak Demand Impact

ADM's review of program tracking data identified that a total of 11,824 qualifying advanced power strips (APS) were sold at participating retail stores during the 2021 program year. Table 3-73 shows the reported quantities and impacts of APS through the ESP program during PY2021.

Table 3-73: Reported Measure Quantities and Impacts – Advanced Power Strips

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Retail Discounts	APS	11,824	989,669	112.33

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for APS sold through the program. This review found that all Air filters were assigned the correct kWh and kW savings in the program tracking data.

The APS were sold as an upstream component, making it difficult to assess whether customers were installing APS correctly. To account for this, ADM applied an ISR of 0.5.

Final Verified Gross Savings Estimates

Table 3-74 compares reported and verified impact estimates for APS discounted through the program in 2021. The total verified energy savings for all APS was calculated to be 989,669 kWh and the verified demand impact was 112.33 kW. ADM found no discrepancies between the reported and verified impact findings.

Table 3-74: ESP Program Impact Findings – Advanced Power Strips

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	APS	11,824	989,669	989,669	112.33	112.33

3.4.4.4 Bathroom Ventilating Fan Gross Energy Savings and Peak Demand Impact

ADM's review of program tracking data identified that a total of 961 qualifying bathroom ventilation fans (BVF) were sold at participating retail stores during the 2021 program year. Table 3-75 shows the reported quantities and impacts of BVF through the ESP program during PY2021.

Table 3-75: Reported Measure Quantities and Impacts – Bathroom Ventilating Fans

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Retail Discounts	BVF	961	26,410	3.28

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for BVF sold through the program. This review found that one model was assigned incorrect savings values in the tracking data (shown in Table 3-76).

Table 3-76: Bathroom Ventilating Fans Savings Discrepancies

Model Number	Number in Program	Reported kWh	Verified kWh	Reported kW	Verified kW
AERN110DCSL	21	38.6	27.4	0.0048	0.0034

Final Verified Gross Savings Estimates

Table 3-77 compares reported and verified impact estimates for BVF rebated through the program in 2021. The total verified energy savings for all BVF was calculated to be 26,331 kWh and the verified demand impact was 3.27 kW.

Table 3-77: ESP Program Impact Findings – Bathroom Ventilating Fans

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	BVF	961	26,410	26,331	3.28	3.27

3.4.4.5 Clothes Dryer Gross Energy Savings and Peak Demand Impacts

ADM's review of program tracking data identified that a total of 629 clothes dryers (CD) were rebated during the 2021 program year. Table 3-78 shows the reported quantities and impacts of CD through the ESP program during PY2021.

Table 3-78: Reported Measure Quantities and Impacts – Clothes Dryers

Distribution	Measure	Reported Quantity	Reported kWh	Reported kW
Downstream Rebates	CD	629	101,520	13.63

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for CD sold through the program. This review found that 1 CD discounted through the program was not eligible to receive energy efficiency savings[63]; as a result, no verified kWh savings and no kW reduction were attributed to this item. In addition, two models were assigned incorrect savings values in the tracking data (shown in Table 3-79).

Table 3-79: Clothes Dryers Savings Discrepancies

Model Number	Number in Program	Reported kWh	Verified kWh	Reported kW	Verified kW
TWB120 WP	1	148.78	265.31	0.0200	0.0356
TWF160 WP	1	148.78	265.31	0.0200	0.0356

The remaining difference in energy savings is attributed to the way that the company assigned savings to washer and dryer combination units. ADM assigned each combination unit savings for both the washer component and the dryer component, resulting in a higher number of verified clothes dryers than was reported in the tracking data. Thirteen combination units were listed as clothes washers in the program tracking data, but will also receive dryer savings, increasing the total quantity of verified clothes dryers to 641.

[63] Model Number DEL7000V was not found in the ENERGY STAR® Efficient Products database.

Final Verified Gross Savings Estimates

Table 3-80 on the following page compares reported and verified impact estimates for CD rebated through the program in 2021. The total verified energy savings for all CD was calculated to be 103,012 kWh and the verified demand impact was 13.83 kW.

Table 3-80: ESP Program Impact Findings – Clothes Dryers

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Downstream Rebates	CD	641	101,520	103,012	13.63	13.83

3.4.4.6 Clothes Washer Gross Energy Savings and Peak Demand Impact

ADM's review of program tracking data identified that a total of 1,093 clothes washers (CWs) were rebated during the 2021 program year. Table 3-81 shows the reported quantities and impacts of CWs through the ESP program during PY2021.

Table 3-81: Reported Measure Quantities and Impacts – Clothes Washers

Distribution	Measure	Reported Quantity	Reported kWh	Reported kW
Downstream Rebates	CWs	1,093	162,963	38.50

Verification

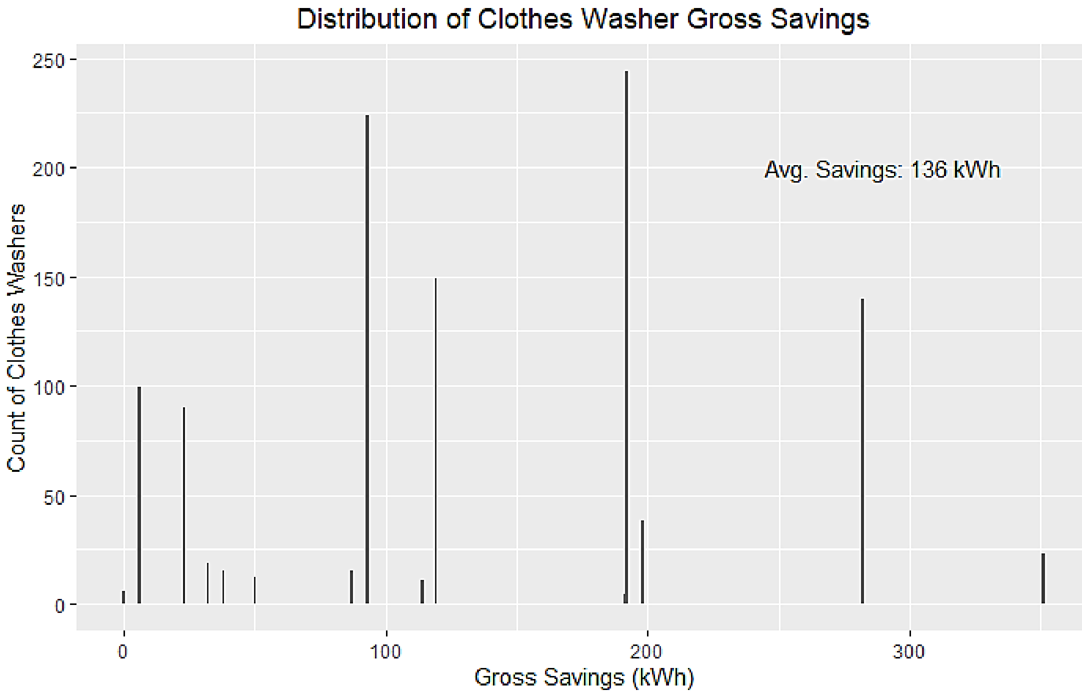
To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for CWs sold through the program. This review found that 4 CWs discounted through the program were not eligible to receive energy efficiency savings[64]; as a result, no verified kWh savings and no kW reduction were attributed to these models. The remaining difference in energy savings is attributed to the way that the company assigned savings to washer and dryer combination units. ADM assigned each combination unit savings for both the washer component and the dryer component, resulting in a higher number of verified CWs than was reported in the tracking data. Twelve combination units were listed as clothes dryers in the program tracking data, but will also receive CWs savings, increasing the total quantity of verified clothes washers to 1,101.

For all remaining CWs in the program, ADM's verified gross savings for clothes washers align with reported savings. However, to account for clothes washer configurations with negative savings (e.g., scenarios in which top load clothes washers replace front load clothes washers and gas is the primary fuel source in the home for end uses such as water heating and dryers), ADM calculated a weighted average savings per clothes washer. For this exercise, CWs with potentially negative savings were assigned savings

[64] Models DVG45R6300V, DVG60M9900V, WM3470HWA, and WTW8500DCSDB were not found in the ENERGY STAR® Efficient Products database.

values of 0 kWh and demand reduction values of 0 kW. The overall distribution of verified CW savings for PY2021 is plotted in Figure 3-33. ADM determined a deemed savings value of approximately 136 kWh and a deemed demand reduction value of 0.032 kW per CW.

Figure 3-33: Distribution of Clothes Washer Savings



Final Verified Gross Savings Estimates

Table 3-82 compares reported and verified impact estimates for clothes washers rebated through the program in 2021. The total verified energy savings for all CWs was calculated to be 149,890 kWh and the verified demand impact was 35.41 kW.

Table 3-82: ESP Program Impact Findings – Clothes Washers

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Downstream Rebates	CWs	1,101	162,963	149,890	38.50	35.41

3.4.4.7 Electric Vehicle Charger Gross Energy Savings and Peak Demand Impacts

ADM's review of program tracking data identified that a total of 23 qualifying electric vehicle chargers (EVC) were rebated through the program during the 2021 program year. Of these, 2 EVC were installed to support the charging of 2 electric vehicles. Table 3-83 shows the reported quantities and impacts of EVC through the ESP program during PY2021.

Table 3-83: Reported Measure Quantities and Impacts – Electric Vehicle Chargers

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Downstream Rebates	EVC	23	6,487	0.50

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for EVC rebated through the program. This review found that all EVC were assigned the correct kWh and kW savings.

Final Verified Gross Savings Estimates

Table 3-84 compares reported and verified impact estimates for EVC rebated through the program in 2021. The total verified energy savings for all EVC was calculated to be 6,487 kWh and the verified demand impact was 0.50 kW.

Table 3-84: ESP Program Impact Findings – Electric Vehicle Chargers

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Downstream Rebates	EVC	23	6,487	6,487	0.50	0.50

3.4.4.8 Heat Pump Water Heater Gross Energy Savings and Peak Demand Impact

ADM's review of program tracking data identified that a total of 7 heat pump water heaters (HPWHs) were rebated during the 2021 program year. Table 3-85 shows the reported quantities and impacts of HPWHs through the ESP program during PY2021.

Table 3-85: Reported Measure Quantities and Impacts – Heat Pump Water Heaters

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Downstream Rebates	HPWH	7	30,641	2.69

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for HPWHs sold through the program. This review found that 1 HPWH discounted through the program was not eligible to receive energy efficiency savings[65]; as a result, no verified kWh savings and no kW reduction were attributed to this model. In addition, a slight difference in the savings attributed to the single HPWH in the program, which may be due to differences in weather zone mapping or methodology.

[65] Natural gas fueled HPWH are not included in this program, therefore model number NPE-240A2 was not eligible.

Final Verified Gross Savings Estimates

Table 3-86 compares reported and verified impact estimates for HPWHs rebated through the program in 2021. The total verified energy savings for all HPWHs was calculated to be 24,605 kWh and the verified demand impact was 2.16 kW.

Table 3-86: ESP Program Impact Findings – Heat Pump Water Heaters

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Downstream Rebates	HPWH	6	30,641	24,605	2.69	2.16

3.4.4.9 Refrigerator Gross Energy Savings and Peak Demand Impacts

ADM's review of program tracking data identified that a total of 844 refrigerators (RF) were rebated during the 2021 program year. Table 3-87 shows the reported quantities and impacts of RF through the ESP program during PY2021.

Table 3-87: Reported Measure Quantities and Impacts –Refrigerators

Distribution	Measure	Reported Quantity	Reported kWh	Reported kW
Downstream Rebates	RF	844	45,917	6.69

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for RF sold through the program. This review found that 4 RF discounted through the program were not eligible to receive energy efficiency savings[66]; as a result, no verified kWh savings and no kW reduction were attributed to these models. This review also found that found that 2 RF were reported with incorrect savings values. The discrepancies for these line items are detailed in Table 3-88.

Table 3-88: Refrigerator Savings Discrepancies

ENERGY STAR® Model Number	Number in Program	Reported kWh (per Unit)	Verified kWh (per Unit)	Reported kW (per Unit)	Verified kW (per Unit)
FFHT1425V*	1	122	38	0.0178	0.0055
EFR100-B-BLACK	1	25	74	0.0036	0.0108

[66] Models LFXS26993S, LTCF20020W-00, RS27T5200**, and RS27T5200SR were not found in the ENERGY STAR® Efficient Products database.

Final Verified Gross Savings Estimates

Table 3-89 compares reported and verified impact estimates for RF rebated through the program in 2021. The total verified energy savings for all RF was calculated to be 45,568 kWh and the verified demand impact was 6.64 kW.

Table 3-89: ESP Program Impact Findings – Refrigerators Only

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Downstream Rebates	RF	840	45,917	45,568	6.69	6.64

3.4.4.10 Room Air Conditioner Gross Energy Savings and Peak Demand Impacts

ADM's review of program tracking data identified that a total of 2,497 qualifying room air conditioners (RAC) were sold at participating retail stores during the 2021 program year. Table 3-90 shows the reported quantities and impacts of RAC through the ESP program during PY2021.

Table 3-90: Reported Measure Quantities and Impacts – Room Air Conditioners

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Retail Discounts	RAC	2,497	153,791	266.17

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for RAC sold through the program. This review found that the small discrepancy between reported energy savings and verified energy savings can be traced to rounding differences.

Final Verified Gross Savings Estimates

Estimates for RAC rebated through the program in 2021. The total verified energy savings for all RAC was calculated to be 153,790 kWh and the verified demand impact was 266.17 kW. Table 3-91 compares reported and verified impact estimates for RAC rebated through the program in 2021.

Table 3-91: ESP Program Impact Findings – Room Air Conditioners

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	RAC	2,497	153,791	153,790	266.17	266.17

3.4.4.11 Room Air Purifier Gross Energy Savings and Peak Demand Impact

ADM's review of program tracking data identified that a total of 1,040 room air purifiers (RAP) were sold at participating retail stores during the 2021 program year. Table 3-92 shows the reported quantities and impacts of RAP through the ESP program during PY2021.

Table 3-92: Reported Measure Quantities and Impacts – Room Air Purifiers

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Retail Discounts	RAP	1,040	535,720	61.17

Verification

To verify the types and quantities of distributed measures, ADM performed a census review of all retailer/manufacturer invoices for RAP sales. This review found that 1 RAP model discounted through the program was not eligible to receive energy efficiency savings[67]; as a result, no verified kWh savings and no kW reduction were attributed to this model. There were 234 RAPs with this model number listed in the program tracking data, resulting in a decrease of the verified quantity to 806 RAPs.

Final Verified Gross Savings Estimates

Table 3-93 compares the total reported and verified impact estimates for this program component. The total verified kWh value for all RAP measures was calculated to be 375,898 kWh and the verified demand impact was 43.18 kW.

Table 3-93: ESP Program Impact Findings – Room Air Purifiers

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	RAP	806	535,720	375,898	61.17	43.18

3.4.4.12 Water Dispenser Gross Energy Savings and Peak Demand Impacts

ADM's review of program tracking data identified that a total of 690 qualifying water dispensers (WD) were sold at participating retail stores during the 2021 program year. Table 3-94 shows the reported quantities and impacts of WD through the ESP program during PY2021.

[67] Model FAP-CO3-A2 was not Energy Star Certified during the program year 2021. This model was removed from the ENERGY STAR® Database in November 2020.

Table 3-94: Reported Measure Quantities and Impacts – Water Dispensers

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Retail Discounts	WD	690	334,457	37.42

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for WD sold through the program. This review found that all WD were assigned the correct kWh and kW savings.

Final Verified Gross Savings Estimates

Table 3-95 compares reported and verified impact estimates for WD rebated through the program in 2021. The total verified energy savings for all WD was calculated to be 334,457 kWh and the verified demand impact was 37.42 kW.

Table 3-95: ESP Program Impact Findings – Water Dispensers

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	WD	690	334,457	334,457	37.42	37.42

3.4.4.13 Weatherization Measure Gross Energy Savings and Peak Demand Impacts

In the context of this report, “weatherization measures” (WMs) include door seals, door sweeps, and spray foam. These three measures are discussed collectively in this report as ADM used the same savings algorithm to evaluate them. ADM’s review of program tracking data identified that a total of 4,221 door seals, 3,277 door sweeps, and 47,939 cans of spray foam were sold at participating retail stores during the 2021 program year. Table 3-96 shows the reported quantities and impacts of WMs through the ESP program during PY2021.

Table 3-96: Reported Measure Quantities and Impacts – Weatherization Measures

Distribution	Measure	Total Quantity	Reported kWh	Reported kW
Retail Discounts	Door Seals	4,221	166,096	1.43
Retail Discounts	Door Sweeps	3,277	128,949	1.11
Retail Discounts	Spray Foam	47,939	7,397,424	63.71
WM Total		**55,437**	**7,692,468**	**66.25**

Verification

To verify the types, quantities, and savings associated with distributed measures, ADM performed a census review of the program tracking data for all WMs sold through the program. Any discrepancies between ADM's verified savings and the reported savings are tied to discrepancies in rounding.

Final Verified Gross Savings Estimates

Table 3-97 compares reported and verified impact estimates for WMs rebated through the program in 2021. The total verified energy savings for door seals was calculated to be 166,091 kWh, for door sweeps energy savings was calculated to be 128,946 kWh, and for spray foam, energy savings was calculated to be 7,397,416 kWh. Overall, ADM calculated the verified energy savings for WMs to be 7,692,453 kWh and the verified demand impact for WMs to be 66.31 kW.

Table 3-97: ESP Program Impact Findings – Weatherization Measures

Distribution	Measure	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW
Retail Discounts	Door Seals	4,221	166,096	166,091	1.43	1.44
Retail Discounts	Door Sweeps	3,277	128,949	128,946	1.11	1.11
Retail Discounts	Spray Foam	47,939	7,397,424	7,397,416	63.71	63.76
Total		**55,437**	**7,692,468**	**7,692,453**	**66.25**	**66.31**

3.4.4.14 Summary of Impact Evaluation Findings

Table 3-98 on the following page provides a detailed summary of ADM's impact evaluation findings for all measures included in the ESP program in 2021. Overall, the program's realization rates (RR) were high, with a RR of 108% for the gross verified energy savings and a RR 115% for the gross verified demand impact.

Table 3-98: Summary of Impact Evaluation Findings

Distribution Type	Measure Type	Verified Quantity	Reported kWh	Verified kWh	Reported kW	Verified kW	RR kWh	RR kW
Non-LED Retail Discounts	AF	14,213	746,344	746,353	2,579.98	2,579.99	100%	100%
	APS	11,824	989,669	989,669	112.33	112.33	100%	100%
	BVF	961	26,410	26,331	3.28	3.27	100%	100%
	RAC	2,497	153,791	153,790	266.17	266.17	100%	100%
	RAP	806	535,720	375,898	61.17	43.18	70%	71%
	WD	690	334,457	334,457	37.42	37.42	100%	100%
	WMs	55,437	7,692,468	7,692,453	66.25	66.31	100%	100%
Non-LED Retail Discount Subtotals		**86,428**	**10,478,859**	**10,318,951**	**3,126.60**	**3,108.67**	**98%**	**99%**
LED Retail Discounts	LED	923,322	30,953,928	34,500,341	4,622.00	5,779.76	111%	125%
LED Retail Discount Subtotals		**923,322**	**30,953,928**	**34,500,341**	**4,622.00**	**5,779.77**	**111%**	**125%**
Downstream Rebates	CD	641	101,520	103,012	13.63	13.83	101%	101%
	CW	1,101	162,963	149,890	38.5	35.41	92%	92%
	EVC	25	6,487	6,487	0.5	0.5	100%	100%
	HPWH	6	30,641	24,605	2.69	2.16	80%	80%
	RF	840	45,917	45,568	6.69	6.64	99%	99%
Downstream Rebate Subtotals		**2,613**	**347,528**	**329,562**	**62.01**	**58.54**	**95%**	**94%**
Program Totals		**1,012,363**	**41,780,315**	**45,148,854**	**7,810.61**	**8,946.97**	**108%**	**115%**

3.4.5 Net-to-Gross Estimation Results

The NTG analysis for the ESP program was conducted using the methodologies outlined in Section 3.4.2. The results of this analysis are summarized below.

3.4.5.1 Lighting Free Ridership Estimate from General Population Survey

ADM evaluators analyzed survey responses from 167 customers who participated in the general population survey and reported purchasing discounted LEDs from participating retailers during the program year. The responses from 128 of these customers were fully validated for use in calculating free ridership.[68] Calculated scores from the survey responses are presented on the following page in Table 3-99.

[68] Responses were removed if surveyed participants did not respond to all pertinent questions or if the responses did not pass consistency checks relevant to their responses. For example, if a survey participant

Table 3-99: General Population Survey Free-Ridership Estimate

Year	Respondent Type	N	Prior Experience Score	Behavior without Program Score	Free Ridership Estimate	Mitigating Factor
2021	LED Purchasers	128	0.36	0.56	0.497	-0.095

The average free ridership score for all 128 respondents was 49.7%. This is 14.7% higher than the free ridership level estimated from the same survey in PY2020.

3.4.5.2 Lighting Free Ridership Estimate from Price Response Model

Free ridership was also estimated using an econometric price response model that estimates the effect of program discounts and promotional events on bulb sales. Coefficients from the model were used to predict sales quantities at regular retail pricing and with an absence of program promotional events. The difference in model predictions for sales quantities under program and non-program conditions produces an estimate of free-rider (or naturally occurring) bulb sales. Multiplying the free-rider bulb sales quantities by SKU specific deemed gross savings estimates results in the final estimate of free-ridership. Due to the uncertainty in the analysis and the strength of the general population survey, ADM will use the results of the general population survey to express free ridership for the program.

3.4.5.3 Lighting Net-to-Gross Ratio

The discussion above outlines the results of two efforts to understand the level of attribution appropriate for the energy savings resulting from the lighting bulb sales through the ESP program. The methodology dependent on the general population survey resulted in an estimate of free ridership of 49.7%. This free ridership score exceeds free ridership determined in 2020 (38.6%).

3.4.5.4 Final Net-to-Gross Ratio

The measure level net-to-gross ratios are calculated as 1 - *estimated free ridership*.[69] The final net-to-gross ratios and associated net savings for each measure in the ESP program are shown in Table 3-100. Note that LEDs distributed through the food bank giveaways and sold at Dollar General are assumed to have a net-to-gross ratio of 1.0.

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indicated that price was the most important factor in their purchasing decision, but later indicated that they would have purchased the items regardless of the incentive discount, the response would no longer qualify for use in the free-ridership calculations.

[69] This is sometimes referred to as a net-of-free-ridership ratio, as it excludes any estimation of spillover or market effects.

Table 3-100: Verified Gross and Net Impacts – ESP Program

Measure Type		Gross Verified kWh	Gross Verified kW	NTG	Net kWh	Net kW
Directional LED		7,280,339	1,219.66	0.503	2,963,098	496,40
Omni-directional LED	Other Retailers	19,597,510	3,891.64	0.503	7,976,187	1,583.90
	Dollar General	4,123,203	82.24	1.000	4,123,203	82.24
	Food Bank	3,499,289	586.22	1.000	3,499,289	586.22
Air Filters		746,353	2,579.99	0.269	200,769	694.02
Advanced Power Strips		989,669	112.33	0.761	753,138	85.48
Bathroom Ventilation Fans		26,331	3.27	0.480	12,639	1.57
Clothes Dryers		103,012	13.83	0.459	47,283	6.35
Clothes Washers		149,890	35.41	0.478	71,647	16.93
Electric Vehicle Chargers		6,487	0.50	0.694	4,502	0.35
Heat Pump Water Heaters		24,605	2.16	0.860	21,160	1.86
Refrigerators		45,568	6.64	0.468	21,326	3.11
Room Air Conditioners		153,790	266.17	0.480	73,819	127.76
Room Air Purifiers		375,898	43.18	0.480	180,431	20.73
Water Dispensers		334,457	37.42	0.480	160,539	17.96
Weatherization Measures		7,692,453	66.31	0.437	3,361,602	28.98
Total		**45,148,854**	**8,946.97**	**0.577**[70]	**23,470,632**	**3,753.86**

3.4.5.5 Lifetime Savings

For LED measures, there are two different ways in which lifetime savings were calculated. For directional LEDs, lifetime savings for all measures are calculated by simply multiplying the ex-post (verified) energy savings values by the expected useful lifetime (EUL) of the measure. For omnidirectional bulbs, an additional step is needed.

The EUL of an LED is 20 years[71], but in 2023 the way in which savings are calculated for omni-directional LEDs will change. In 2023 omnidirectional bulbs will begin using tier 2 baseline wattages as part of their savings calculations, which will have a significant impact on savings for this measure[72]. To take that into account, lifetime savings were calculated by adding together Tier 1 and Tier 2 lifetime savings values. Tier 1 energy savings were calculated by taking the ex-post savings from this year multiplied by two years (the number of years from 2021 to 2023). Tier 2 savings were calculated by multiplying what

[70] Total NTG Represents an average NTG weighted by measure-level gross verified savings.
[71] Per the OKDSD.
[72] This is following the Arkansas TRM version 8 guidelines recommending that Tier 2 baselines are used starting in 2023.

the ex-post savings would have been for this year had tier 2 baselines been used, by 18 years (20 years minus the 2 years used in the tier 1 savings calculation). Table 3-101 shows the Tier 1 and Tier 2 lifetime savings values for LED measures.

Table 3-101: Lifetime Savings, LED Measures -- ESP Program

Measure Type		Tier 1 Annual kWh	Tier 1 EUL (years)	Tier 1 Lifetime Savings (kWh)	Tier 2 Annual kWh	Tier 2 EUL (years)	Tier 2 Lifetime Savings (kWh)
Directional LED		7,280,339	20	145,606,780	N/A	0	0
Omni-directional LED	Other Retailers	19,597,510	2	39,195,020	7,460,746	18	134,293,420
	Dollar General	4,123,203	2	8,246,406	139,037	18	2,502,667
	Food Bank	3,499,289	2	6,998,578	1,073,768	18	19,327,816

For all measures other than LEDs, lifetime savings for all measures are calculated by simply multiplying the ex-post energy savings values by the expected useful lifetime (EUL) of the measure. Table 3-102 shows the lifetime savings values for all non-LED measures. On the following page, Table 3-103 shows the total lifetime savings values for the program.

Table 3-102: Lifetime Energy Savings, Non-LED Measures – ESP Program

Measure Type	Gross Verified kWh	EUL (years)	Total Lifetime Savings (kWh)
Air Filters	746,353	0.17	126,880
Advanced Power Strips	989,669	10.00	9,896,690
Bathroom Ventilation Fans	26,331	12.00	315,972
Clothes Dryers	103,012	13.00	1,339,156
Clothes Washers	149,890	14.00	2,098,460
Electric Vehicle Chargers	6,487	10.00	64,870
Heat Pump Water Heaters	24,605	10.00	246,050
Refrigerators	45,568	17.00	774,656
Room Air Conditioners	153,790	10.50	1,614,795
Room Air Purifiers	375,898	9.00	3,383,082
Water Dispensers	334,457	10.00	3,344,570
Weatherization Measures	7,692,453	15.00	115,386,795

Table 3-103: Total Lifetime Energy Savings – ESP Program

Measure Type		Total Lifetime Savings (kWh)
Directional LED		145,606,780
Omni-directional LED	Other Retailers	173,488,440
	Dollar General	10,749,073
	Food Bank	26,326,394
Air Filters		126,880
Advanced Power Strips		9,896,690
Bathroom Ventilation Fans		315,972
Clothes Dryers		1,339,156
Clothes Washers		2,098,460
Electric Vehicle Chargers		64,870
Heat Pump Water Heaters		246,050
Refrigerators		774,656
Room Air Conditioners		1,614,795
Room Air Purifiers		3,383,082
Water Dispensers		3,344,570
Weatherization Measures		115,386,795
Total		**420,553,164**

3.4.6 Process Evaluation Findings

ADM's process evaluation activities included participant surveys, an interview with the PSO Program manager, and an interview with the implementation team. ADM provided a portfolio level process evaluation memo to PSO after the completion of the 2021 program year. The following summarizes the key finding from the process evaluation of the ESP program.

- Program staff have been successful in executing and growing the program over the evaluation cycle. According to program staff, they have been meeting and/or exceeding their goals every year. The program offers customers a variety of products and supports awareness of the incentives PSO sponsors. The customer portal has improved the rebate application process and reduced barriers to rebate turnaround time. The improvements have allowed increased customer satisfaction.
- Most program participation is concentrated around Tulsa, Lawton, Broken Arrow, and Owasso. Most of the measures were purchased within the service territory but

it mainly concentrated in four cities. The program also has a small online presence and currently offers no online marketplace. Program staff stated they will explore ways to increase sales in rural territories by engaging with local small businesses (e.g., family-owned businesses). They also plan to promote more limited time offers on specific measures and increase awareness of heat pump water heater technology.

- The program benefits from a strong educational and partnership component. Staff shared that their program field representatives educate customers and retail sales associates about energy efficiency in general, energy efficiency appliances, and energystar.gov. The partnerships with retail stores have also allowed the program field representatives to display point-of-purchase (POP) materials, thus increasing utility attribution. Program staff's partnership with Belo for marketing campaigns has improved marketing efforts and program outreach. The program has also increased its footprint on social media. Other partnerships include collaborations with ENERGY STAR® and the food bank.
- Decreased lighting sales and retailers going out of business were identified as potential threats to program success. Staff discussed the decrease in lighting sales that occurred during the first several months of the pandemic. Although the program staff indicated their sales are currently at pre-pandemic levels, they have continued to experience some supply chain issues. Staff are also concerned with the possibility of retailers going out of business. Finally, program staff identified a lack of technology for processing rebates using the current point-of-sales tracking system at many small businesses located within the service territory. These small businesses may also be struggling to participate in program due to labor shortages or administrative burden.

3.4.6.1 Upstream Measures

The following highlights findings affecting all the upstream measures component of the program.

- The top measures purchased by survey respondents for PY2021 were LED light bulbs, advanced power strips, and air filters. Although most survey respondents purchased one type of ESP measure (64%), almost a quarter of the sample purchased more than one type of ESP measure. For example, of the customers who purchased LEDs from a participating retailer, 67% indicated they purchased additional energy saving measures in 2021.
- Although many of the survey respondents purchased their measures from program qualifying retailers, some measures were purchased from non-participating stores. While most survey participants reported buying LED light bulbs from participating retailers, 51% of the surveyed customers who purchased air filters and 87% of

surveyed customers that purchased advanced power strips did not buy the products from a participating retailer in 2021.

- Most of the survey respondents were unaware the measures had been discounted from their normal pricing. Of the customers who purchased LEDs, 14% were aware the lighting measures were discounted. Many survey respondents who bought other measures stated they had not known the items had been discounted.
- The coronavirus pandemic has increased the amount of time people stay at home during PY2021 and many customers have not taken new actions to save energy during this time. Most participants (57%) indicated the time they spend at home greatly increased since the onset of the pandemic. As a result, 53% percent of survey respondents noticed a change in electricity consumption since the start of the coronavirus pandemic, compared to 32% who did not, and 15% who were unsure or preferred not to respond. Respondents indicated they had not changed the ways they try to save on energy because of the pandemic (46%) compared to 42% who have made some changes. Of these participants (n = 63), some participants indicated they turn off lights or unplugged items when not in use.

3.4.6.2 Downstream Measures

The following highlights findings affecting all the downstream measures component of the program.

- Customers who completed the downstream measure survey most commonly receive clothes washer rebates, followed by clothes dryer rebates, and refrigerator rebates. Most survey respondents (57%) first learned about the PSO rebate when they made the appliance purchase, while 37% learned of the rebate before they made the purchase. Many customers researched the measures online (39%), consulted a retailer (38%), or read a consumer magazine or website (19%). Participants most stated they were motivated to participate in the program to replace an existing appliance, saving money on energy bills or to protect the environment/combating climate change were also common reasons provided.
- Half of the survey respondents (50%) reported that it took three to four weeks to receive their downstream rebate. Further analysis indicates the longer people waited for the rebate, the less satisfied they were with the rebate application process. However, most people appeared to be satisfied with the rebate amount despite waiting for the rebate to arrive. Respondents also stated they were satisfied with the product they decided to purchase and install. Survey participants who purchased clothes washers reported the highest levels of satisfaction followed by those who bought refrigerators. Most survey participants (92%) were satisfied with the quality of appliances and equipment available through the program and the application process (80%).

- Downstream survey respondents were impacted by the coronavirus pandemic in 2021. Forty-five percent of participants indicated the time they spend at home greatly increased because of the pandemic. Almost half (46%) of survey respondents have noticed a change in their electricity consumption since the start of the coronavirus pandemic compared to 39% who did not see any changes.
- Most EV charger survey respondents (88%) purchased the level 2 charger to charge a new electric vehicle and the remaining bought the charger to replace an existing level 1 charger. Eighty-eight percent learned about the rebate through the PSO website, and one learned about the rebate through word-of-mouth (13%). Six out the eight respondents indicated they were using their new measure to charge a fully electric vehicle that does not use gasoline.
- EV charger survey participants stated that they either used the level 2 charger once a day (25%), a few times a week (50%), or once a week (25%). Only two of the eight respondents are using their Wi-Fi enabled software to schedule charging, while the remaining never have set-up the scheduling system. Seven of the eight participants said they never use public charging stations and only one uses them less than once a week.
- EV charger survey participants indicated they were satisfied with different aspects of the EV charger rebate program. All respondents are very satisfied with the level 2 charger they purchased. Additionally, 63% stated they were very satisfied with the program, followed by 38% who stated they were satisfied with the program overall. Fifty percent of respondents were somewhat or very satisfied with the application form and submission process compared to 50% who stated they were somewhat dissatisfied. Regarding the rebate, 88% stated they were satisfied with the rebate amount and 51% were satisfied with the timeliness of receiving the rebate.
- EV charger survey respondents were impacted by the coronavirus pandemic in 2021. Most participants indicated their electricity consumption has increased (75%) and have been spending more time at home (75%) since the start of the pandemic. Yet, regarding whether participants have changed the way they save on energy, the responses were split 50% each. Three participants shared that either cooling or heating systems are on more since the pandemic. Finally, most EV charger program participants reported (75%) the pandemic had not affected their ability to participate in PSO energy-efficiency programs.
- Program staff identified some impediments to program success relating to EV charger awareness. Within the program's EV charger component, there is a lack of access to contractors with knowledge in EV charger installation. Additionally, there continues to be a general lack of understanding of EV chargers with retail sales representatives and ratepayers. To improve the EV charger offering, staff

will brainstorm a strategy to offer a list of contractors who specialize in EV charger installations to participants. They also plan to increase the EV market in coming years through collaborations with other programs (e.g., Power Hours) and proposing time-of-day (TOD) tariffs.

3.4.7 Conclusions and Recommendations

The following summarizes the key findings from the evaluation of the Energy Saving Products Program.

- The verified net annual energy savings for PY2021 is 26,050,906 kWh, and net peak demand reduction is 4,244.54 kW. The lighting free ridership score increased significantly in 2021 compared to 2020. This was identified both through the population of program participants who completed the general population survey and was supported by the free ridership estimates calculated through the price response model.

ADM recommends the following are considered to support the continued improvement and development of PSO's ESP program:

- Explore new strategies for encouraging rural customers to participate in ESP offerings. In addition to program staff reaching out to small businesses, future bridging models designed to encourage participation in historically underserved, rural sectors of the PSO service territory could include networking and advertising with rural community organizations as well as local contractors and tradespeople. Marketing strategies could also consider advertising program rebates and discounts through municipal, or co-op print newsletters to engage with rural customers that may not have regular interaction with online advertisements.
- Increase signage that indicates the PSO-sponsored savings. Most surveyed customers were not aware of the discounts they received through the ESP program. Testing different approaches to the in-store signage may improve customer awareness of the program, retailer permitting.
- Encourage customers to continue purchasing multiple upstream measures. Cross-advertising discounts on multiple energy efficient measures in-store may continue to encourage the number of customers that purchase multiple upstream measures during the program year. For example, signage located near discounted light bulbs or air filters that advertises weatherization measure discounts (i.e., spray foam, door seals, and door sweeps) and where those discounted products can be found in the same store could encourage further customer engagement with the program.
- Consider marketing strategies that highlight how energy efficient appliances can help customers save energy during the pandemic. Nearly half of all surveyed customers expressed they have been spending more time at home and noticing

the impact on their energy bills. Marketing appliance rebates to offset some of the increase in consumption while spending more time at home could provide a relevant, engaging marketing strategy.

- Connect with and educate contractors and tradespeople about level 2 EV charger installation and compile a list of references for retailers. Providing a list of contractors who can provide EV charger installation services, as program staff noted is their intention, will be beneficial to promoting the EV charger measure. However, also engaging with local electricians and contractors to advise them on installation best practices, including both wiring and programming Wi-Fi-enabled scheduled charging, may serve to both expand the list of available tradespeople as well as further encourage participation in the program.

3.5 Home Rebates

This chapter presents findings from the impact and process evaluation of the 2021 program year for the Home Rebates Program.

3.5.1 Program Overview

The Home Rebates Program offered by the Public Services Company of Oklahoma (PSO) seeks to generate energy and demand savings for residential customers through the promotion of comprehensive efficiency upgrades to building envelope measures and HVAC equipment for both new construction homes and retrofits to existing homes. Offering PSO customers direct inducements for higher efficiency measures offsets the first cost obstacle, encouraging customers to choose the upgraded products. This evaluation will report on the program in its three components: New Homes, Multiple Upgrades, and Single Upgrade.

The New Homes component of the program provided prescriptive incentives to builders of single-family homes. Builders received $800 for construction that met the following standards:

- 95% CFL Lighting
- Insulation (15 R-value blown insulation walls; 38 R-value blown insulation attic) or (13 R-value foam insulation walls; 21 R-value foam insulation attic)
- HVAC – SEER 15 Air Conditioner
- Home infiltration (6 air changes per hour at 50 pascals)
- Duct infiltration (6 cfm25 /100 sq. ft. of conditioned floor area)
- 100% ENERGY STAR® certified windows

Additionally, bonus rebates were offered for:

- $200 for 95% LED lighting
- $400 for contiguous exterior grid installation
- $200 for installing SEER 16 Air Conditioner
- $300 for installing SEER 17 Air Conditioner
- $400 for installing SEER 18+ Air Conditioner
- $600 for installing SEER 20+ Air Conditioner
- $200/ton Heat Pump (max $1,000 per home)
- $1,000/ton Ground Source Heat Pump (max $5,000 per home)
- $100 for duct infiltration less than 4 cfm25 /100 sq. ft. of conditioned floor area

- $400 for ducts in conditioned space
- $400 for meeting ENERGY STAR® V 3.1 revision 08 certification requirements

The program provided design assistance for up to three house plans per builder, a value of $3,000, to help design program compliant homes. HERs raters received a $50 rebate per rated home or $150 rebate per ENERGY STAR® rated home. The program was promoted to builders of single-family dwellings and to customers buying new homes. Key program activities included:

- Develop energy savings impacts using Ekotrope as the home energy modeling software.
- PSO staff and the implementation team had regularly scheduled conference calls every two weeks. Topics usually included budgets, safety issues, current projects in the pipeline, and program performance. Program staff noted they are comfortable with the current communication between all parties and are in frequent communication outside of the bi-weekly calls. There were no immediate concerns raised by staff, therefore the current level of communication was sufficient for supporting the administrative needs of the New Homes program.
- Program staff develop relationships with builders and raters to ensure success of the implementation strategy.

The Multiple Upgrades component of the program focused on energy efficiency upgrades to existing residential homes. To qualify for the program in 2021, customers needed to install two or more eligible equipment upgrades. Eligible measures included:

Table 3-104: Multiple Upgrades Rebates Offered

Upgrades	Multiple Upgrades Rebates
Attic/Ceiling Insulation (R-22 or less existing)	$600
Knee Wall Insulation	$525
Wall Insulation (R-0 existing)	$450
Floor/Crawlspace Insulation (R-0 existing)	$450
Exterior Wall Insulation	$450
Air Infiltration	10% of air sealing cost covered up to $1,000
Duct Replacement	30% of duct replacement cost covered up to $3,000
Duct Sealing	30% of duct sealing cost covered up to $1,500
Air Conditioner/Heat Pump Replacement*	-
ENERGY STAR® SEER 16-16.99	$300
ENERGY STAR® SEER 17-17.99	$900
ENERGY STAR® SEER 18-19.99	$1,200
ENERGY STAR® SEER 20+	$1,500
Ductless Minisplit, 20 SEER Minimum*	$1,500
Geothermal/Ground Source Heat Pump	$1,200 + $525 per ton

** HVAC replacement in the Multiple Upgrades Program was combined with Duct Replacement or Duct Sealing.*

The Multiple Upgrades Program included a walk-through assessment from a PSO approved contractor to help identify energy-efficiency measures that could improve customers' comfort level while reducing energy costs. After the initial audit was complete, a PSO/ICF contracted employee, also referred to as PSO Third Party Verifier (TPV), performed a diagnostic test on the home after the upgrades were installed. This process measured and documented the efficiency gains from infiltration reduction and duct sealing measures along with HVAC equipment.

In 2021, PSO introduced a level requirement for Multiple Upgrades projects. Level 1 projects have a rebate cap of $5,000 per home, while Level 2 projects cap the rebate at $10,000 per home. However, all Level 2 projects require pre-approval and is limited to the first 50 Level 2 per year. Level 1 projects require a mandatory Home Performance Test-out of the home to verify the correct level of energy efficiency has been achieved, while Level 2 projects require a mandatory Home Performance Test-in and Test-out of the home.

The Single Upgrade component of the program focused on energy-efficiency upgrades to existing residential homes. To qualify for this component of the program, customers needed to install one or two eligible equipment upgrades. Eligible measures included:

Table 3-105: Single Upgrade Rebates Offered[73]

Upgrades	Single Upgrade Rebates
Attic/Ceiling Insulation (R-22 or less existing)	$400
Air Conditioner/Heat Pump Replacement	-
ENERGY STAR® SEER 16-16.99	$200
ENERGY STAR® SEER 17-17.99	$200
ENERGY STAR® SEER 18-19.99	$600
ENERGY STAR® SEER 20	$800
Ductless Minisplit, 20 SEER Minimum	$1,000
Geothermal/Ground Source Heat Pump	$800 + $350 per ton
HVAC Tune-Up (based on existing HVAC unit)	$150 + $25 per pound of refrigerant*
ENERGY STAR® Swimming Pool Pump	$400

**Up to 2 pounds of refrigerant per project*

Home Rebates 2021 performance metrics are summarized in Table 3-106.

[73] Drop-Off Energy Kits were included in the Single Upgrade Program in 2021 at no additional cost to program participants.

Table 3-106: Performance Metrics – Home Rebates Program

Metric	PY2021
Number of Participants	3,715
Budgeted Expenditures	$7,231,058
Actual Expenditures	$7,918,383
Energy Impacts (kWh)	
Projected Energy Savings	7,247,495
Reported Energy Savings	7,204,159
Gross Verified Energy Savings	7,099,975
Net Verified Energy Savings	6,961,029
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	2,749.10
Reported Peak Demand Savings	3,550.88
Gross Verified Peak Demand Savings	2,961.65
Net Verified Peak Demand Savings	2,639.91
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	1.78
Utility Cost Test Ratio	1.30

The EM&V methodologies and findings for the Home Rebates Program are presented in the next sections. The New Homes, Multiple Upgrades, and Single Upgrade components are reported in Section 3.5.2, Section 3.5.3, and Section 3.5.4, respectively.

3.5.2 New Homes

This section presents the methodologies used for evaluation of the 2021 New Homes portion of the Home Rebates Program.

3.5.2.1 EM&V Methodology

This section provides an overview of the gross and net impact evaluation and process evaluation of the New Homes component of the Home Rebates Program. Findings from the process evaluation for all program components are provided in Section 3.5.6.

Impact Evaluation Activities

ADM employed a site-specific evaluation approach to quantify electric impacts from the New Homes program. The impact evaluation for this program included the following steps:

- Program tracking data review for completeness, clerical errors, outliers, and accuracy.

- Establishing a sample design and selecting a random sample of homes for evaluation,
- Data collection activities (including HERS rater documentation, building drawings, and builder provided documentation)
- Gross Impact analysis. Engineering analysis of site-level and program level impacts
- Net Impact analysis. ADM used survey results from online builder surveys to determine the level of free ridership in the program. In addition, ADM determined spillover through program documentation.

Process Evaluation Activities

ADM performed a process evaluation assessing the 2021 Home Rebates Program operations and delivery. The program design, operations, and delivery were assessed for the New Homes Program through builder surveys, home buyer surveys, and a facilitated discussion with program staff at PSO and an implementation contractor. Table 3-107 summarizes the data collection activities.

Table 3-107: New Homes - Process Evaluation Data Collection Activities Summary

Data Collection Activity	Process Evaluation Research Objectives
Program Materials Review	Review reports and support materials for clarity and consistency with program objectives
Program Staff Facilitated Discussion	Assess program strengths, weaknesses, opportunities, and threats
Builder Survey	Assess program support, training, satisfaction, program influence on building practices, and suggestions for improvements
Home Buyer Survey	Investigate buyers' reasons for buying the home they did, importance of energy efficiency in their decision, as well as how well builders explained the energy-efficient characteristics of the homes

The process evaluation addressed the following research questions:

- Is the program marketing effective? What is working particularly well and what could be improved?
- Is the program reaching all segments of the target market? Is anyone under-represented or left out?
- How has the COVID-19 pandemic affected the program during 2021?

Sampling Plan

In developing the sample plan, ADM reviewed program tracking data to explore potential designs and ensure there were no duplicate entries or other inconsistencies. In this review ADM found that five HERS raters accounted for 98% of program savings. It was determined that the sample design would stratify the program population by each of these HERS raters, with the remaining HERS raters allocated to a sixth strata denoted as 'other' (as they collectively only accounted for 2% of program impacts). While this stratification proved an efficient sample design, it also enabled the evaluation to explore whether there were statistically significant differences between the HERS raters and provide program feedback.

The sample for the engineering review of building simulation models was designed to achieve ±10% relative precision or better at the 90% confidence interval. Sample design employed ex-ante (reported) annual energy savings estimates to determine sample sizes per stratum and precision. Sampled projects are selected randomly. Precision is then recalculated with verified annual energy savings to determine an ex-post (verified) precision. Sample design precision at the 90% confidence interval was ±9.25% for annual energy savings. Table 3-108 below summarizes the final sample framework and demonstrates that the evaluation exceeded the targeted 10% precision with a verified annual energy savings precision of ±9.22%.

Table 3-108: New Homes - Sample Design

Strata	Measure	Reported Energy Savings (kWh)	Population Size	CV*	Sample Size	Relative Precision
Stratum 1	Rater 1	1,182,427	466	0.30	9	16%
Stratum 2	Rater 2	686,299	374	0.30	8	17%
Stratum 3	Rater 3	419,832	213	0.30	8	17%
Stratum 4	Rater 4	298,136	114	0.30	6	20%
Stratum 5	Rater 5	64,302	22	0.30	1	49%
Stratum 6	Other	48,835	23	0.30	2	35%
Total	**-**	**2,699,832**	**1,212****	**-**	**34**	**9.22%**

** The CV of the ex-post energy savings (and realization rates) were set at a minimum value of 0.30 by strata for calculation of precision. This ensures that the number of sample points extrapolated by strata properly represents the strata compared to the population.*

***One home classified under Rater 4 and one home classified under Rater 5 had incentive dollars with no savings reported. Two homes with incentive dollars and no reported savings did not have raters attributed and were not counted in this total.*

Data Collection

Data collection activities supporting the evaluation included builder surveys, home buyer surveys, a facilitated discussion with program staff at PSO and an implementation contractor, and primary data collection through on-site and virtual verifications.

Builder Survey

For the New Homes Program, there were a total of 10 completed builder surveys. All New Homes builders were pulled from the tracking data and included in the survey sample list. The builder contact information was requested from PSO and any builder who participated in the program in 2021 was sent the online survey in January 2022. A total of 21 home builders were sent the online survey, which resulted in 10 survey completes.

Home Buyer Survey

For the New Homes Program, there were a total of 37 completed home buyer surveys. A sample of New Homes participants were pulled from the tracking data and included in the survey sample list. In August 2021, a letter containing a link to the survey was drafted and mailed to program participants using the program address. A total of 326 participants were sent the home buyer survey letter, which resulted in 37 survey completes.

Program Staff Facilitated Discussion

In November 2021, ADM evaluators had a facilitated discussion with PSO's program manager and program coordinator, as well as ICF's account manager. ADM conducted an analysis of the Home Rebates – New Homes Program strengths, weaknesses, opportunities, and threats (SWOT analysis) with program staff. The SWOT analysis involved a group discussion with key personnel responsible for discussing past program year recommendations and brainstorming possible implementation strategies. The discussion focused on 1) identifying current, internal strengths and weaknesses within the program, 2) providing specific examples of the strengths and weaknesses within the program, 3) identifying external opportunities and threats for/to the program, and 4) providing specific examples of opportunities and threats within the program.

On-Site and Virtual Verifications

ADM performed 5 in-person and 2 virtual on-site verifications in 2021. Field data collection forms were completed to verify attic insulation thickness and type, percentage of LEDs installed, and appliance model numbers. Additionally, photographs were taken to confirm the collected data. This information helped provide simulation model inputs during the implementation reviews.

Gross Impact Methodology

A sample of homes were randomly selected following the sample design previously discussed. Site-level gross impacts were then quantified using engineering reviews of the building simulation models used to generate the ex-ante savings estimates. Relevant project documentation, interviews with HERS raters, and implementation QA forms were used to verify building simulation model inputs were consistent with the physical residences.

The process by which ADM executed this engineering review can be formalized into the following steps:

- Review available program documentation related to the specifications of the residence and energy efficiency measures claimed.
- Obtain and initiate review of simulation models
- Establish appropriate baseline assumptions to measure level savings.
- Verify and adjust simulation model inputs as needed based on findings from project documentation and data collection.
- Execute updated building simulation to quantify savings impacts.

Obtain and Initiate Review of Simulation Models

- The simulation models for each rebated home were created in Ekotrope and initially submitted by participating builders/HERs raters to the implementation contractor. ADM then retrieved simulation models directly from Ekotrope. Some models were provided by the implementation team.
- ADM engineering staff reviewed these models within the Ekotrope software[74] and confirmed that Ekotrope conforms to RESNET standard algorithms when calculating internal loads (e.g., lighting and appliances). Ekotrope inputs were then compared to the program provided tracking data and each simulation model was verified to ensure reconciliation of the program claimed annual energy savings per home.

Baseline Assumptions Levied for Key Simulation Inputs

- New construction programs are unique in that they must measure energy impacts against a hypothetical baseline as there is no pre-existing structure or equipment to reference. This baseline is typically the prevailing building codes/standards for the state and/or region. In this case, the applicable building codes are Oklahoma residential building code which amends the 2015 International Residential Building (IRC) code to 2009 IRC energy code standards. This amended version of the IRC represents the baseline for all homes incentivized through this program.
- The key modeling assumptions impacted by the relevant building energy codes are outlined in Table 3-109. Values for the listed parameters were taken from either

74 ADM purchased a license from Ekotrope to facilitate this evaluation.

the Oklahoma residential building code or minimum efficiency values defined by the National Appliance Energy Conservation Act (NAECA). Note that the modeling software used in this evaluation employs the term 'reference home' to denote the baseline home and the term 'design home' to denote the as-built residence. ADM tries to employ similar terminology for consistency, though they can be used interchangeably.

Table 3-109: New Homes - Key Baseline Home Assumptions

Input	Verified Reference Home	Source
Attic Insulation	R-30	2009 IRC with amendments
Wall Insulation	R-13	2009 IRC with amendments
Window U	0.50	2009 IRC with amendments
Window SHGC	0.30	2009 IRC with amendments
Infiltration	0.00036 specific leakage area	2009 IRC with amendments
Slab Edge Insulation	0	2009 IRC with amendments
Cooling Efficiency (SEER)	14	NAECA minimum values.
Heating Efficiency (AFUE)	80	NAECA minimum values.
Heat Pump Heating Efficiency (HSPF)	8.2	NAECA minimum values, for both GSHP and ASHP.
Percent Efficient Lighting	75%	2009 IRC with amendments

The reference home assumptions were pre-programmed into the Ekotrope RATER modeling software. Reference home assumptions are to be based on the 2009 International Residential Code[75] and the Oklahoma Building Energy Codes Program[76].

Verification of Key Model Inputs

The measures implemented by this program are represented by above code improvements to key aspects of the participant residences. Typical aspects included envelope improvements (e.g., insulation, windows, and infiltration reduction), HVAC efficiencies, and interior lighting. Each of these aspects have corresponding inputs to define/simulate their physical characteristics within the simulation models. ADM used documentation collected from the HERS raters, virtual and on-site visits to collect data required to substantiate, and in some cases correct, these inputs.

The model inputs representing home improvements seen in this program include:

- Home layout, size, shape, location, and orientation
- Duct sealing test results

[75] https://codes.iccsafe.org/content/IRC2009/chapter-11-energy-efficiency
[76] https://www.energycodes.gov/status/states/oklahoma

- Infiltration test results
- Attic Insulation: R-values and area
- Interior, exterior, and garage lighting counts
- Heating and cooling temperature set points
- HVAC size and efficiencies (Capacity, SEER, EAE, AFUE, HSPF, COP)

Changes made to any of the above inputs represent differences between what was assumed to be present in the ex-ante simulations and what ADM found to be physically present through our evaluation and data collection. The effect of these differences across all sampled homes contributed to the differences in the ex-ante and verified ex-post energy savings estimates being reported.

Execute Building Simulation Analysis and Quantify Site Impacts

Upon completion of all data collection for each sampled home, ADM conducted its ex-post simulation by comparing existing key inputs of the provided simulation models, to what was found during the data collection efforts. The model inputs were then changed to reflect what was verified during the data collection process.

The verified energy and demand savings for each home were calculated by taking the difference in energy consumption between the simulated reference home and simulated design home. Realization rates for gross energy and demand savings were calculated for each sampling strata. Program results were derived by extrapolating the results from each sampling strata to the population of participating homes per the sample weights calculated in the sample design.

Net-to-Gross (NTG) Estimation

The evaluation team at ADM estimated the net impacts of the New Homes program using participating builder survey responses for free ridership and spillover. The surveyed builders responded to questions on the influence of the individual program components, the overall level of influence of the program on the construction practices incorporated into rebated homes, and the share of homes that would have been built to program standards if the program was not available. The scoring procedures described below were used to calculate a free ridership score for each builder.

Program Components Score:

- A Program Component's score was calculated based on how influential various program factors were in the builders' decisions to construct energy-efficient homes. Specifically, survey respondents rated the influence of the following factors on their decisions to build efficient homes using a scale where 1 meant "not at all influential" and 5 meant "extremely influential":
- Component 1: ENERGY STAR® design assistance

- Component 2: The rebates provided by the program
- Component 3: Program informational documents or marketing materials

A score was assigned to the ratings as follows:

  - 1 (Not at all influential) = 0
  - 2 = .25
  - 3 = .50
  - 4 = .75
  - 5 (Extremely influential) = 1

The Program Components score equaled the highest scored component.

Program Influence Score:

- The Program Influence Score was based on builders' ratings of the likelihood of having built homes to the same efficiency standards in the PSO service territory if the rebate program was not available. The Program Influence Score was developed from the rated likelihood as follows:
  - 1 (Not at all likely) = 0
  - 2 = .25
  - 3 = .50
  - 4 = .75
  - 5 (Very likely) = 1

No Program Score:

- The No Program Score was developed from the builder responses to the following questions:
- NPS1: Now, thinking about your history of working with the program, if the program had never been available, would you have built fewer or the same number of homes in [YEAR] to the PSO efficiency standards?
- NPS2: [IF FEWER] Why would you have built fewer homes?
- NPS3: What percent of those homes would you have built to those same standards if the program had never been available?

The intent of these questions was to capture the effect that builders' recent and previous experience with the program educational efforts had on their current construction practices. The No Program Score was equal to:

1 – Average (% Homes Built in Absence of the Program/100)

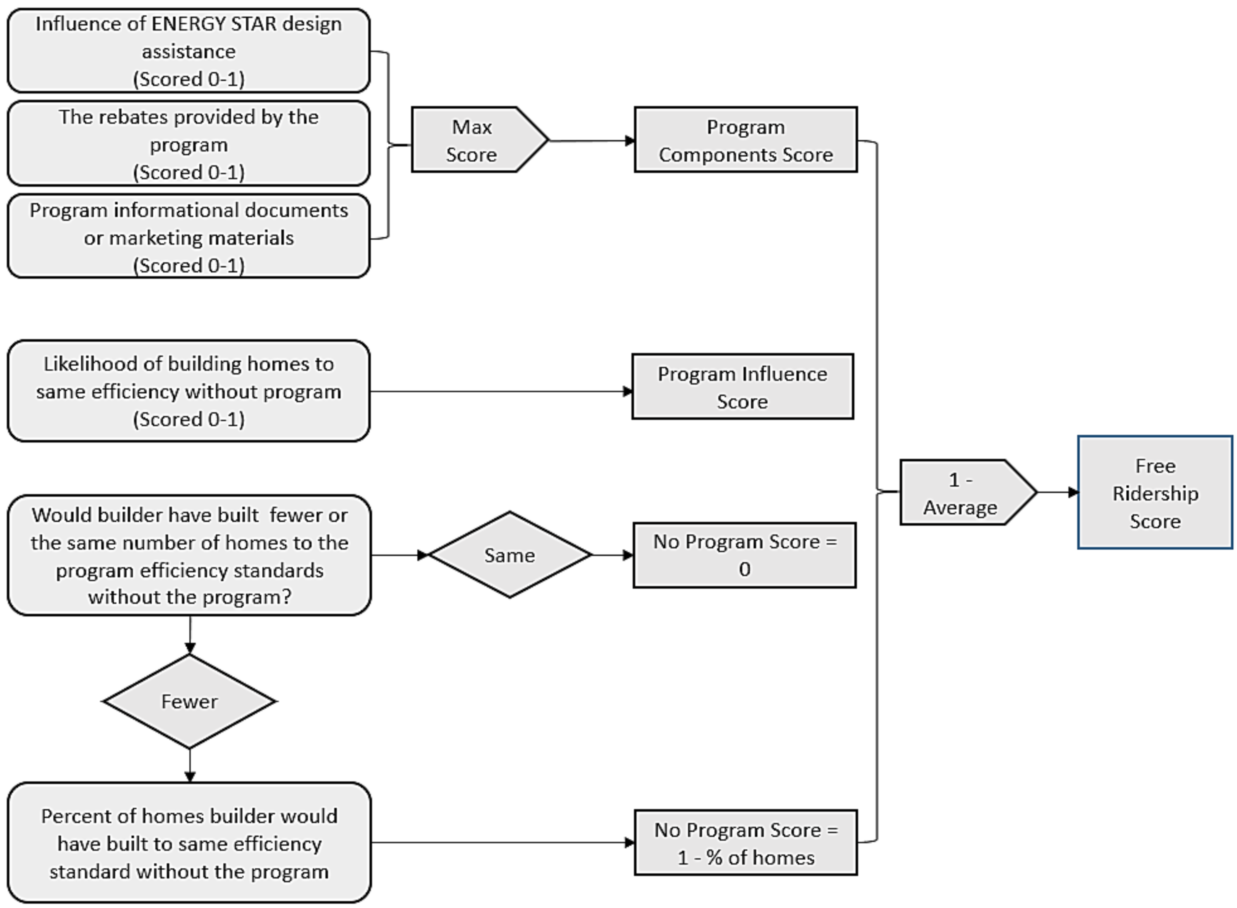
Free Ridership Score:

The evaluation team at ADM calculated the final free ridership score for each builder as equal to:

1 – Average (Program Components Score, Program Influence Score, No Program Score)

Figure 3-34 summarizes the free ridership scoring algorithm.

Figure 3-34: New Homes - Builder Free-Ridership Scoring



To estimate participant spillover, builders were asked if they completed any additional homes built to the program efficiency standards inside the PSO service territory without submitting them for a program rebate. In addition, program data was used to calculate spillover due to participation rates. In 2021, the New Homes portion of the program was over-subscribed. Builders submitted applications and followed the program guidelines for homes built that were not able to be incentivized.

3.5.2.2 Impact Evaluation Findings for New Homes

This section details the verified gross and net savings impacts for the New Homes portion of the Home Rebates program.

Program Activity

Participation and reported savings estimates per builder are shown in Table 3-110. The top five participating builders accounted for 75% of New Homes estimated annual energy savings.

Table 3-110: New Homes - Participation and Savings per Builder

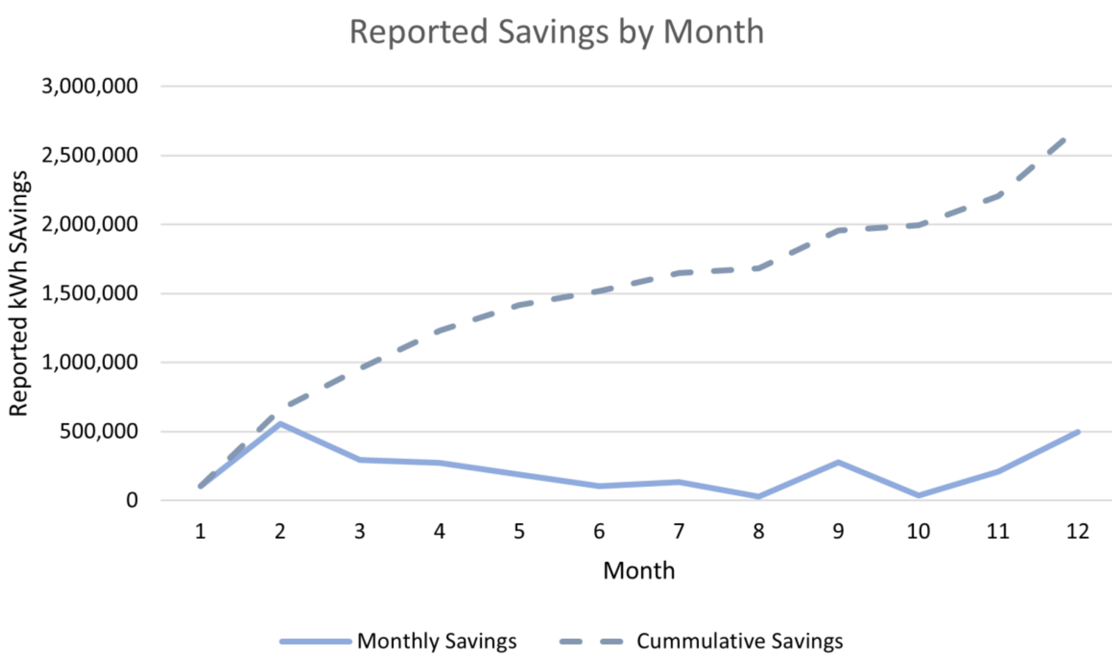
Builder	Number of Homes	Reported Energy (kWh)	Reported Demand (kW)	Percent of Program Energy Savings
Builder 1	289	760,295	309.73	28.2%
Builder 2	175	370,086	145.93	13.7%
Builder 3	167	328,542	130.02	12.2%
Builder 4	113	298,136	48.74	11.0%
Builder 5	186	267,711	101.49	9.9%
Builder 6	90	168,037	66.27	6.2%
Builder 7	40	79,734	32.16	3.0%
Builder 8	20	43,447	17.36	1.6%
Builder 9	19	40,061	16.55	1.5%
Builder 10	20	37,347	15.09	1.4%
Builder 11	17	35,584	13.75	1.3%
Builder 12	2	33,402	3.96	1.2%
Builder 13	11	30,212	12.20	1.1%
Builder 14	8	28,318	11.50	1.0%
Builder 15	7	21,942	8.65	0.8%
Builder 16	4	19,555	2.26	0.7%
Builder 17	7	15,902	6.17	0.6%
Builder 18	1	15,832	1.41	0.6%
Builder 19	4	14,546	4.85	0.5%
Builder 20	1	14,173	1.99	0.5%
Builder 21	6	10,996	4.07	0.4%
Builder 22	4	9,566	3.66	0.4%
Builder 23	4	7,954	3.18	0.3%
Builder 24	3	7,242	2.86	0.3%
Builders 25-34**	15	41,211	13.71	1.5%

Builder	Number of Homes	Reported Energy (kWh)	Reported Demand (kW)	Percent of Program Energy Savings
Total	**1,213***	**2,699,832**	**977.57**	**100%**

**One home classified under Builder 5, one home classified under Builder 19, and one home classified under Builder 31 with incentive dollars attributed did not report savings. One home with incentive dollars and no reported savings did not have a builder attributed and was not counted in this total. **The builder listed as Builder 28 was the homeowner, not the builder of the home.*

Participation in the New Homes program throughout the program year is shown in Figure 3-35. There was consistent participation from March to October, with an uptick in participation in November and December.

Figure 3-35: New Homes - Cumulative Reported kWh During the Program Year



Verified Gross Savings

For each sampled home, ADM was provided project documentation and energy models from the implementation contractor. The provided project documentation included the following types of documents: HERs rating certificates, HVAC Manual J calculations, floor plans, photos and Air-Conditioning, Heating & Refrigeration Institute (AHRI) certificates.

The implementation team performs quality checks on a sample of homes each year. Two of the randomly selected evaluation sample sites included quality control inspection documentation. An inspection report was provided from a non-sampled home for review. The report indicates a high level of detail in review of energy efficiency measures. The inspection form requires information and photographs entered related to the home’s general information (size, orientation, etc.), HVAC system, building envelope measures, water heating, ventilation/infiltration (blower door testing), and a review of appliances and lighting.

ADM was able to perform on-site and virtual data collection for a subset of the sample. Homes were recruited for primary data collection through the homeowner survey. Findings from these data collection activities were used to update simulation models as appropriate. Various updates to model inputs such as furnace EAE and AFUE %, air conditioner SEER, value, HVAC heating and cooling output capacities, water heater energy factor, and window u-value and SHGC were determine through analyzing provided photographs and documentation.

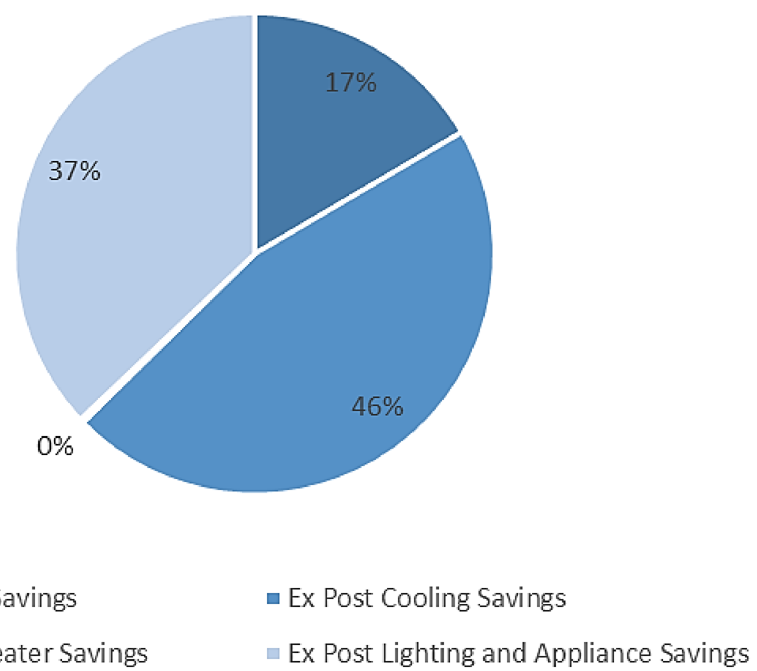
Differences Between Ex-Ante and Ex-Post Simulation Inputs

Using Ekotrope, the baseline conditions are pre-determined for all models based on Oklahoma energy code. The current Oklahoma energy code follows 2009 International Residential Code. The impact analysis found reported simulation models generally reflected the building characteristics verified during engineering desk reviews, though there were some areas, predominantly regarding HVAC equipment, where ADM found consistent differences:

- **Cooling Equipment Efficiency –** ADM found a different Annual Fuel Utilization Efficiency (AFUE) for three sampled homes. Variation for this measure lead to a slight decrease in savings.
- **Furnace Auxiliary Energy Consumption Rating –** 10 sampled projects were found to have furnace Auxiliary Energy Consumption (EAE) Ratings less than assumed in the ex-ante models. This factor led to a slight decrease in site energy savings and an overall decrease in program level savings.
- **Cooling Equipment Efficiency –** During documentation review, ADM found two homes for which the assumed SEER ratings were different compared to what was assumed in the ex-ante models. Differences existed in both directions (e.g., some higher and some lower). The net effect had a small net increase in savings.
- **HVAC Equipment Capacity –** ADM found HVAC heating capacity ratings differed from ex-ante assumptions on eight of the sampled projects and HVAC cooling capacities differed for 10 homes. Adjustments were made in both direction and the ultimate impact of this change was negligible.

Figure 1-3 is a pie chart of annual energy savings by end-use from the evaluation sample. As shown, the highest energy savings are realized with energy efficiency upgrades to heating systems, followed by upgrades to lighting and appliances.

Figure 3-36: New Homes - Energy Savings of Aggregated Sample by End Use



Ex-post adjustments to the models resulted in minor impacts to the program savings. Due to only minor changes in the ex-post models, the program achieved a 98% realization rate for program year 2021.Reported and verified energy impacts are presented in Table 3-111.

Table 3-111: New Homes - Gross Impact Results by Strata

Strata	Reported Annual Energy Savings (kWh)	Reported Peak Demand Reduction (kW)	Verified Annual Energy Savings (kWh)	Verified Peak Demand Reduction (kW)	Lifetime Energy Savings (kWh)	kWh Realization Rate	kW Realization Rate
Rater 1	1,182,427	464.63	1,142,893	452.45	22,857,859	97%	97%
Rater 2	686,299	268.41	679,302	266.83	13,586,037	99%	99%
Rater 3	419,832	163.06	416,215	162.08	8,324,300	99%	99%
Rater 4	298,136	48.74	298,219	49.06	5,964,377	100%	101%
Rater 5	64,302	20.58	61,213	19.16	1,224,261	95%	93%
Other	48,835	12.14	43,891	6.96	877,817	90%	57%

The difference in the reported and gross annual energy savings results were generated by differences between ex-ante model assumptions and physical homes verified by ADM (e.g., differences in key model inputs). Program level reported and gross annual energy savings are summarized in Table 3-112.. An estimated useful life (EUL) of 20 was applied to program lifetime savings. A 20-year EUL is based on typical measures installed in new home construction.

Table 3-112: New Homes - Reported and Gross Impacts

Reported Annual Energy Savings (kWh)	Reported Peak Demand Reduction (kW)	Verified Annual Energy Savings (kWh)	Verified Peak Demand Reduction (kW)	Lifetime Energy Savings (kWh)	kWh Realization Rate	kW Realization Rate
2,699,832	977.57	2,641,733	956.54	52,834,650	98%	98%

NTG Estimation Results

Twelve builders that contributed 75% of program kWh savings participated in online surveys for 2021. Builder surveys were used to estimate free ridership ratios for the New Homes Program. Free ridership ratios (ranging from zero to one, zero for complete free ridership and one for no free ridership) were determined for each surveyed home builder. Average free ridership ratios were weighted by the builder's verified savings contributions.

The New Homes portion of the Home Rebates Program was over-subscribed in 2021. This did not stop builders from filling out applications and continuing to build homes to program requirements. The implementation staff worked with builders to alleviate concerns and ensure homes were built with the energy efficiency expectations of the homeowners without incentive. ADM accounted for the energy savings of the homes tracked by the implementation team that went through the application process but were not able to receive an incentive. The energy savings for these homes is considered spillover for the program. The magnitude of energy impacts due to free ridership and spillover are presented in Table 3-113.

Table 3-113: New Homes - Free Ridership and Spillover Impacts

Free Ridership (kWh)	Free Ridership kWh Ratio	Free Ridership (kW)	Free Ridership kW Ratio	Spillover (kWh)	Spillover (kW)
205,093	10%	75.72	9%	785,040	64.35

Based on impact evaluation results, the total verified net energy and demand savings are presented in Table 3-114 below.

Table 3-114: New Homes - Gross and Net Savings Impacts

Verified Annual Energy Savings (kWh)	Verified Peak Demand Reduction (kW)	NTG Ratio kWh	NTG Ratio kW	Net Annual Energy Savings (kWh)	Net Peak Demand Reduction (kW)	Net Lifetime Energy Savings (kWh)
2,641,733	956.54	120%	97%	3,161,015	931	52,834,650

3.5.3 Multiple Upgrades

This section presents the methodologies used for evaluation of the 2021 Multiple Upgrades portion of the Home Rebates Program.

3.5.3.1 EM&V Methodology

This section provides an overview of the gross and net impact evaluation and process evaluation of the Multiple Upgrades component of the Home Rebates Program. Findings from the process evaluation for all program components are provided in Section 3.5.6.

Impact Evaluation Activities

Data collection included online participant and trade ally surveys and a facilitated discussion with program staff[77]. Additional sources of data to inform the impact evaluation were a census of program tracking data from the program implementor's tracking and reporting system (Sightline), along with project documentation obtained from VisionDSM. Program tracking data included customer contact information and descriptions of the measures installed with file storage for submitted applications, test-out photos and data, and contractor invoices for the work performed. The impact evaluation for this program included the following activities:

- Determination of the number of customers participating in the program by types of measures installed
- Determination of the gross energy savings and peak demand reduction per project
- Estimation of the net-to-gross ratios to determine the percentage of gross savings directly attributable to the program
- Documentation of incremental costs for benefit-cost analysis

Process Evaluation Activities

ADM performed a process evaluation assessing the 2021 Home Rebates Program operations and delivery. The program design, operations, and delivery were assessed for the Multiple Upgrades Program through participant surveys, trade ally surveys, and a facilitated discussion with program staff at PSO and an implementation contractor. Table 3-115 summarizes the data collection activities.

[77] ADM conducted an analysis of the Home Rebates – Multiple Program strengths, weaknesses, opportunities, and threats (SWOT analysis) with program staff.

Table 3-115: Multiple Upgrades - Process Evaluation Data Collection Activities Summary

Data Collection Activity	Process Evaluation Research Objectives
Program Materials Review	Review reports and support materials for clarity and consistency with program objectives.
Program Staff Facilitated Discussion	Assess program strengths, weaknesses, opportunities, and threats
Participant Survey	Assess participant experiences, including satisfaction.
Trade Ally Survey	Assess program support, training, satisfaction, program influence on trade ally practices, and suggestions for improvements.

The process evaluation addressed the following research questions:

- Is the program marketing effective? What is working particularly well and what could be improved?
- Is the program reaching all segments of the target market? Is anyone under-represented or left out?
- How has the COVID-19 pandemic affected the program during 2021?

Sampling Plan

Table 3-116 summarizes the sample size for each primary data collection activity. The random sample for verification was designed to achieve ±10% relative precision or better at the 90% confidence interval.

Table 3-116: Multiple Upgrades - Sample Sizes for Data Collection Efforts

Data Collection Activity	Achieved Sample Size
Participant Surveys Completed	101
Trade Ally Surveys Completed	23
Facilitated Discussion with Program Staff	2

Online Participant Surveys

For the calculation of sample size for survey completes for the online participant survey, a coefficient of variation of 0.5 was assumed.[78] With this assumption, a minimum sample

78 The coefficient of variation, cv(y), is a measure of variation for the variable to be estimated. Its value depends on the mean and standard deviation of the distribution of values for the variable (i.e., cv(y) = sd(y)/mean(y)).

size of 68 participants was needed, as shown in the following formula. This minimum sample size of 68 was exceeded with 101 surveys completed.

Equation 3-3: Minimum Sample Size Formula for 90 Percent Confidence Level

$$n_0 = \left(\frac{Z * CV}{RP}\right)^2 = \left(\frac{1.645 * 0.5}{0.10}\right)^2 = 68$$

Where:

n_0	= minimum sample size
Z	= Z-statistic value (1.645 for the 90% confidence level)
CV	= Coefficient of Variation (assumed to be 0.5)
RP	= Relative Precision (0.10)

Data Collection

Data collection activities supporting the evaluation included participant surveys, trade ally surveys, a facilitated discussion with program staff at PSO and an implementation contractor, and collection of all program documentation to complete a census engineering analysis.

Participant Survey

For the Multiple Upgrades Program, there were a total of 101 completed participant surveys. All Multiple Upgrades participants (as of November 2021) were pulled from the tracking data and included in the survey sample list. Any participant with a valid email address was sent the online participation survey. The survey was launched in two separate “waves”, with the first wave in September 2021 and the second wave in November 2021. A total of 660 participants were sent the online survey, which resulted in 101 survey completes.

Trade Ally Survey

For the Multiple Upgrades Program, there were a total of 23 completed trade ally surveys. All Multiple Upgrades trade allies with contact information were pulled from the tracking data and included in the survey sample list. Any trade ally with a valid email address was sent the online trade ally survey in November 2021. A total of 95 trade allies were sent the online survey, which resulted in 23 survey completes.

Program Staff Facilitated Discussion

In November 2021, ADM evaluators had a facilitated discussion with PSO’s program manager and program coordinator, as well as ICF’s account manager. ADM conducted an analysis of the Home Rebates - Multiple Upgrades Program strengths, weaknesses, opportunities, and threats (SWOT analysis) with program staff. The SWOT analysis involved a group discussion with key personnel responsible for discussing past program year recommendations and brainstorming possible implementation strategies. The discussion focused on 1) identifying current, internal strengths and weaknesses within the program, 2) providing specific examples of the strengths and weaknesses within the program, 3) identifying external opportunities and threats for/to the program, and 4) providing specific examples of opportunities and threats within the program.

Gross Impact Methodologies

The method used to calculate energy savings (kWh) and demand savings (kW) consisted of:

- Program tracking data census. The tracking data was reviewed for a census of homes and measures. The data was verified for duplicate participation within the program and between programs.
- Measure installation verification. In-service rates (ISR) were calculated by measure for a sample of program participants using data collected from the online participant survey.
- Reported savings review. Reported savings calculations were reviewed for all measures to determine the cause of savings discrepancies.
- Standard for verification of savings. The data collected from program tracking data were used as inputs to the savings algorithms as listed in the Arkansas Technical Reference Manual, Version 7.0 (AR TRM 7.0) and the Oklahoma Deemed Savings Document (OKDSD).

A brief description of each measure calculation method is described in the sections below. Appendix G lists the measure-level algorithms and deemed savings values utilized for the energy and peak demand savings algorithms.

Air Sealing Package: The AR TRM 7.0 was utilized to calculate energy and demand impacts of air sealing measures. Savings were calculated by multiplying the air infiltration reduction (CFM), with the energy savings factor corresponding to the climate zone and HVAC type. The air infiltration reduction estimate in cubic feet per minute (CFM at 50 Pascal) was obtained through blower door testing performed by the program contractor for each home serviced. A pre-installation blower door test measured by the contractor was required for all air sealing projects. Only homes with electric cooling systems were eligible for the measure (central AC or room AC).

Duct Sealing/Duct Replacement: All savings for duct replacement projects were captured in the corresponding duct sealing project for 2021. This measure involves replacing/sealing leaks in ducts of the distribution system of homes with either a central AC or a ducted heating system. The post-installation duct leakage is measured by the contractor. Savings were estimated by updating the inputs to the savings algorithm listed in the AR TRM 7.0 for duct sealing, with full load hours and the coincidence factor (CF) value from the OKDSD. Deemed savings factors were based on the location of the ducts (attic or crawlspace). Savings were calculated by multiplying the duct leakage reduction results with the outdoor/indoor seasonal specific enthalpy (OKDSD) corresponding to the climate zone and HVAC type and are divided by the HVAC unit efficiency.

Attic Insulation: Savings were estimated by updating the savings algorithm inputs listed in the AR TRM 7.0 for attic insulation and are based on the R-value of the baseline insulation. The savings factor was climate zone specific, determined by the pre-insulation thickness R-value compared to the post-installation thickness R-value. The savings algorithms require new insulation to meet a minimum R-value of R-38. Savings were scaled for installed thickness between the table values of R-38 and R-49. As the AR TRM 7.0 energy and demand savings factors are based on multiple starting insulation R-values, and just two final insulation R-values, an interpolation was completed for those values between R-38 and R-49. Savings were calculated by multiplying the applicable savings value (based on the pre- and post-insulation thickness R-value) by the square footage insulated.

Floor Insulation: Savings were estimated by updating the savings algorithm inputs listed in the OKDSD for floor insulation, along with project-specific data, installed square feet, and insulation R-value. The OKDSD prototype home model considered cell foam insulation for the measure, which is the product used for the insulation rebate. The cell foam insulation provides both sensible and latent cooling season savings. The same algorithm as knee wall insulation was used, with the savings factor from the OKDSD. The savings factor was climate zone specific, and HVAC equipment specific, then factored by the installed area. The AR TRM 7.0 for wall insulation was used to calculate incremental cost for all floor insulation projects. There were only two projects completed for floor insulation in the program in 2021.

Wall Insulation: Savings were estimated by updating the savings algorithm inputs listed in the AR TRM 7.0 for wall insulation. The savings algorithm requires new insulation to meet a minimum R-value of R-13. Deemed savings provided in the AR TRM 7.0 are based on the heating and cooling system type of the home and the R-value of the insulation installed. Savings were calculated by multiplying the corresponding savings value by the insulated square footage. There was only one project completed for exterior wall insulation.

Knee Wall Insulation: Savings were estimated by updating the savings algorithm inputs listed in the AR TRM 7.0 for knee wall insulation. The savings factor was dependent upon climate zone and HVAC equipment type. Additionally, deemed savings are driven by the heating and cooling system type of the home and the post-installation R-value. The TRM table was modeled for a home starting at zero insulation going to a R-19 or R-30 value. The savings estimated considered the initial insulation R-value and adjusted the savings value. The program tracking data indicated an open cell or closed cell foam applied to attic vertical walls. The final R-value was interpolated for the R-values between R-19 and R-30 and all the projects reached a minimum R-value of R-19. Savings were calculated by multiplying the applicable savings value (based on the pre- and post-insulation thickness R-value) by the square footage insulated.

Central Air Conditioners, Air Source Heat Pumps, Ductless Mini-Split Heat Pumps, and Ground Source Heat Pumps: Savings were estimated by updating the savings algorithm inputs in the OKDSD blended with the Federal Minimum Efficiency Requirements.[79]. OKDSD baseline SEER is 12.44 and baseline HSPF is 7.7, which were updated in the reported savings based on the 2016 federal minimum to 14 SEER and 8.2 HSPF, respectively. Savings calculations considered right-sizing savings up to a 1-ton difference and are based on the size/efficiency of each unit. For any ductless mini-split heat pump replacement in the Multiple Upgrades Program, it must have been combined with a duct replacement/duct sealing project.

Lifetime kWh Savings

Lifetime kWh savings were calculated by multiplying the gross annual kWh savings by the Estimated Useful Life (EUL) for each measure type. EUL values for each measure were based on the assumptions in the AR TRM and OKDSD. Table 3-117 shows the EUL and source for each measure type.

Table 3-117: Multiple Upgrades – Per Measure Estimated Useful Life (EUL)

Measure Type	EUL (years)
Air Sealing	11
Duct Replacement	20
Duct Sealing	18
Central AC	19
Heat Pump	16
Ductless Mini-Split Heat Pump	13
Ground Source Heat Pump	25
Attic Insulation	20
Floor Insulation	20
Knee Wall Insulation	20
Wall Insulation	20

79 Federal minimum regulations equipment for Southeast region, https://www.energy.gov/sites/prod/files/2015/11/f27/CAC%20Brochure.pdf

Net-to-Gross (NTG) Estimation

This section provides a summary of the method to score the responses from the online survey of participants for the measure-level free ridership score, project-level free ridership score, and spillover score. The survey results were weighted and extrapolated to the population of participants. Details of the questions used for free ridership and spillover estimation are listed in Section 3.5.8.

Measure-Level Free Ridership Score

For customers who completed projects that did not include HVAC measures, the free ridership score was based entirely on responses to questions in the participant survey. Program education and outreach efforts for HVAC measures may have influenced service providers' selling of efficient equipment in ways that are not apparent to customers. The assessment of free ridership for HVAC equipment also included a service provider influence component. The following paragraphs summarize the approach to assessing both the participant free ridership score and the service provider component.

Participant Free Ridership Score

The participant free ridership questions addressed several criteria to determine the likelihood that a customer is a free rider. If the respondent reported they had no financial ability to install the measure without the program, then the final participant free ridership score was equal to 0. In that case, no other consideration affected the score.

If the respondent reported they had the financial ability to install the measure without the program, then the final participant free ridership score was a function of three other factors: the respondent's prior plans to implement the project before learning of the program rebate, the reported likelihood of implementing the measure in the absence of the program, and the impact of the program on the timing of the project.

The first questions produced a Plans Score, with a value of 1 or 0, representing the existence of prior plans relating to the energy saving measures installed. Respondents who reported prior plans to implement measures that provided at least as much energy savings as those done through the program received a Plans Score of 1, while all others received a Plans Score of 0.

A separate set questions produced a Likelihood Score, ranging from 0 to 1, which represented the likelihood that the respondent would have installed the measures without the program. The average of the Plans Scores and the Likelihood Score produced the preliminary participant free ridership score, with a value ranging from 0 to 1.

Finally, the respondent's report of how the program affected the timing of the project produced a Timing Score, with a value ranging from 0 (the program moved the project forward by at least one year) to 1 (the program did not move the project forward). For each respondent, the final participant free ridership score was the product of the preliminary participant free ridership score and the Timing Score.

Service Provider Free Ridership Score

The service provider free ridership score related to the service providers influence of their marketing and sales of energy efficient equipment on the participant, ranging in value from 0 (highest influence) to 1 (lowest influence). A second question assessed whether the program influenced the service provider’s equipment recommendations.

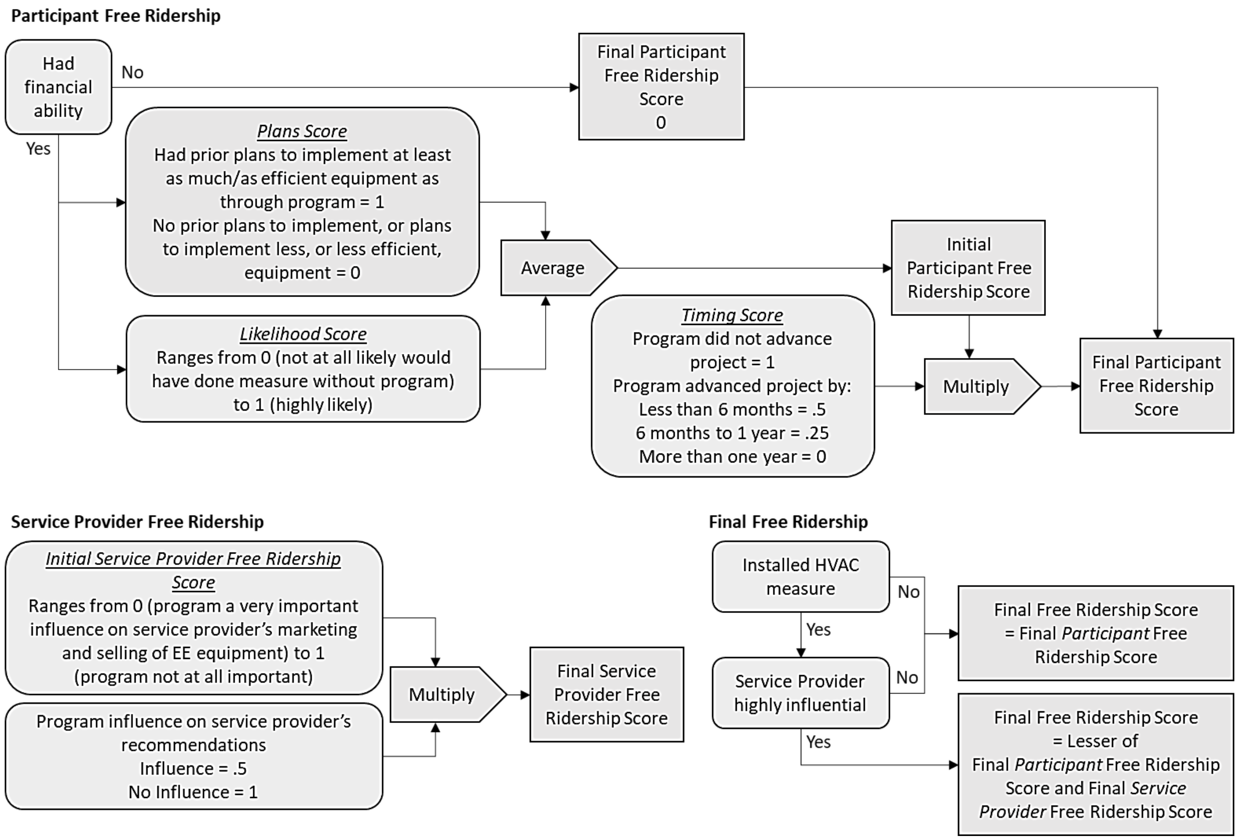
Final Free Ridership Score

The final participant free ridership score represented the final free ridership score in either of two cases: 1) The participant did not have HVAC equipment installed; or 2) the participant had HVAC equipment installed but did not receive any equipment information or recommendation from the service provider who installed it that the participant considered “very influential.”

If, however, a participant installed HVAC equipment and reported that the service provider who installed the equipment gave information or a recommendation that was “very influential,” then the final free ridership score was the lesser of two scores: 1) That participant’s Final Participant Free Ridership Score; and 2) the service provider free ridership score. For any given participant, if that participant’s service provider completed the service provider survey and provided a service provider free ridership score, then the evaluation team at ADM used that service provider’s score as the service provider free ridership score for the participant; otherwise, the mean service provider free ridership score was calculated across all surveyed service providers.

Figure 3-37 illustrates the above process for generating the final participant free ridership score.

Figure 3-37: Single & Multiple Upgrades - Free Ridership Flow Diagram



Project Level Free Ridership

For each respondent, a project level free-ridership score was determined by weighting the measure-level free-rider scores, over the project energy savings.

Survey responses about other energy-efficient measures installed recently were vetted against their participation in other projects, or programs, and the program influence on their purchase or installation of these measures. Spillover identified by the survey is vetted for influence by the program, then extrapolated to the population.

3.5.3.2 Impact Evaluation Findings

This section details findings from Multiple Upgrades program activity for 2021, the reported and verified gross savings that resulted from that activity, and the NTG estimates applied to the gross savings to produce the net savings reported in Section 3.5.5.

Program Activity

The Multiple Upgrades part of Home Rebates in 2021 had 941 total projects installed as part of the program. Final energy savings were based on a total of 2,314 energy-saving measures. See Table 3-118 below for a breakdown of total quantities for each energy-saving measure in the program.

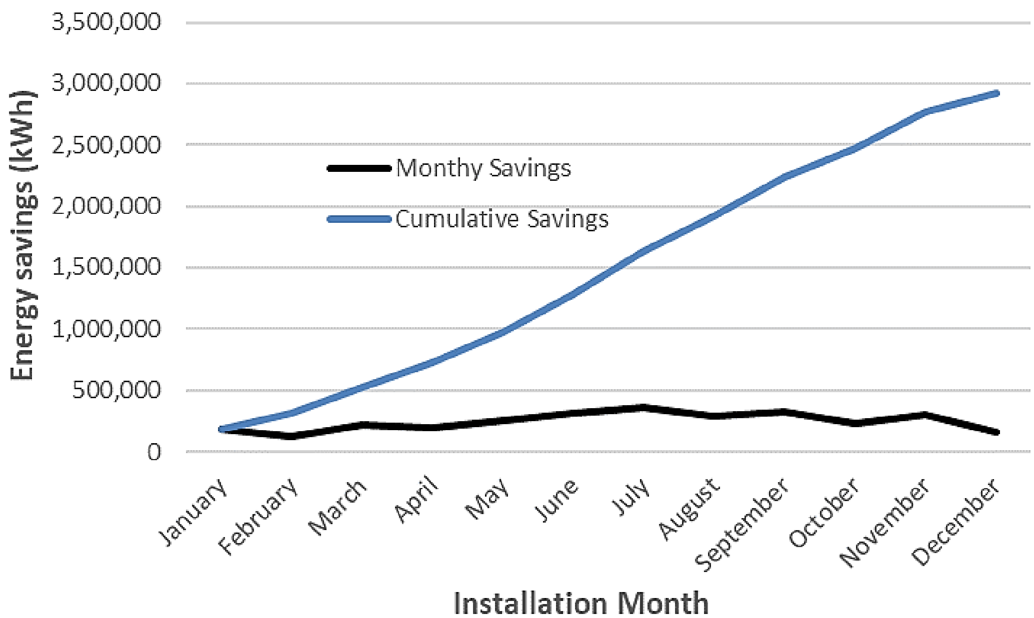
Table 3-118: Multiple Upgrades - Per Measure Equipment Quantities

Measure	Quantity in Program
Air Sealing Package	5
Duct Replacement	226
Duct Sealing	989
Central AC	864
Heat Pump[80]	36
Ground Source Heat Pump	3
Attic Insulation	160
Floor Insulation	2
Knee Wall Insulation	28
Wall Insulation	1
Total	**2,314**

The monthly energy savings, along with the cumulative annual savings for the 2021 Multiple Upgrades Program are detailed in Figure 3-38 below.

[80] Measure includes air source heat pumps and ductless mini-split heat pumps.

Figure 3-38: Multiple Upgrades - Cumulative Reported kWh Savings During the 2021 Program Year



Reported and Verified Gross Savings

The Multiple Rebates program's gross verified savings estimates resulted in an energy savings realization rate of 96% and demand reduction realization rate of 80%. The following presents the gross verified savings by measure, lifetime energy savings (kWh), and realization rates.

Table 3-119: Multiple Upgrades - Reported and Verified Gross Energy & Demand Savings

Measure	Reported Energy (kWh)	Gross Verified Energy (kWh)	Reported Demand (kW)	Gross Verified Demand (kW)	Lifetime Energy Savings (kWh)	RR_{kWh}	RR_{kW}
Air Sealing	1,286	1,286	1.00	0.94	14,146	100%	94%
Duct Sealing & Duct Replacement[81]	1,764,646	1,802,868	1,115.67	1,049.11	32,451,616	102%	94%
Central AC	853,455	755,277	504.61	249.21	14,350,255	88%	49%
Heat Pump[82]	119,725	74,049	56.29	11.70	1,184,776	62%	21%
Ground Source Heat Pump	18,630	17,735	5.79	5.07	443,387	95%	88%
Attic Insulation	161,221	161,050	108.94	114.38	3,221,007	100%	105%
Floor Insulation	1,507	1,507	0.39	0.39	30,131	100%	100%
Knee Wall Insulation	6,913	7,621	4.99	5.39	152,413	110%	108%
Wall Insulation	480	480	0.22	0.22	9,600	100%	100%
Total	**2,927,861**	**2,821,872**	**1,797.90**	**1,436.40**	**51,857,331**	**96%**	**80%**

The gross impact analysis consisted of verifying measure installation using self-reported data from the participant survey results and checking the program tracking data to ensure that deemed savings algorithms were appropriately applied. ISRs for each measure type were developed based on the findings from the online participant survey data and extrapolated to the population. Findings from the online participant survey determined a 100% ISR for all sampled measures in Multiple Upgrades for 2021. A description of verified gross findings for each measure type is included below.

Air Sealing (Infiltration Reduction): There were five air sealing projects in the Multiple Upgrades Program in 2021. The realization rate for air sealing was 100% for energy savings and 94% for the demand savings. ADM continued to utilize AR TRM 7.0 deemed values for all infiltration reduction projects. The difference in the demand savings is due to one project in the data using a DSF kW factor of 0.00014 (Climate Zone 8b) instead of 0.000098 (Climate Zone 9).

Duct Sealing/Duct Replacement: All savings for duct replacement projects were captured in the corresponding duct sealing project for 2021.[83] These two measures were

[81] All gross verified energy and demand savings for duct replacement projects were captured in the corresponding duct sealing project.
[82] Measure includes air source heat pumps and ductless mini-split heat pumps.
[83] There is one duct replacement project in the program tracking data with reported kWh and kW savings. The ADM evaluation team believes the savings for this project are being double counted in the corresponding duct sealing project. The verified savings calculations do not include duct replacement savings for this project; only duct sealing savings for this project are reported in the gross verified energy and demand savings.

the largest energy savings measures of the program with 1,802,868 kWh of verified energy savings and 1,049.11 kW of demand savings. The estimated savings for the combined duct replacement and duct system sealing measures had an overall realization rate of 102% and 94% for energy and demand savings, respectively. Although the realization rates were close to 100%, the difference between the reported and verified savings may be due to the reported savings calculations using a blower subtraction method to account for the pre- and post-leakage for the whole house, while the verified energy savings are calculated by multiplying the deemed savings value for the corresponding area and weather zone by the square footage of the conditioned area of the home.

Central Air Conditioners: The realization rate for central air conditioners was 97% for energy savings and 54% for demand savings. The right sizing of the unit, reducing the capacity of new unit to less than the baseline unit, was considered when the capacities were similar (i.e., a 1-ton mini split replacing a 1.5-ton unit, but not a 1-ton unit replacing a 4-ton unit). The difference in energy savings is a result of 38 projects in the data having a baseline capacity higher than the efficient capacity. For those projects, the verified energy saving calculations used the baseline condition; ADM assumed that the contractor right sized the unit in the baseline condition as any additional oversized baseline would have a different EFLH. The difference in demand savings is a result of the verified savings calculations using the 2016 federal minimum EER of 11.8 for all units in the program, while the reported savings calculations are using the old federal minimum baseline EER value of 10.8.

Heat Pumps:[84] The realization rate for heat pumps was 62% for energy savings and 21% for demand savings. The gross verified savings also included the “right sizing” for units that were similar in size (for example, a 1-ton heat pump replacing a 1.5-ton air conditioner). In those cases, the same capacity was used for the baseline and efficient capacity when upsizing. Projects for mini-split heat pump installation often replaced a room or window air conditioner but had the baseline capacity of a larger unit in the home listed. In those cases, the baseline capacity was set equal to the new mini-split heat pump, to only consider the mini-split heat pump energy savings. These differences in baseline and efficient capacities resulted in the realization rate for energy savings to be less than 100%. The difference in demand savings is a result of the verified savings calculations using the 2016 federal minimum EER of 11.8 for all units in the program, while the reported savings calculations are using the old federal minimum baseline EER values of 10.8 for all but 14 projects. Fourteen projects in the program as using a baseline EER value of 9.7 for the verified savings calculations.

Ground Source Heat Pumps: There was three ground source heat pump projects in the Multiple Upgrades Program in 2021. The realization rate for ground source heat pumps

[84] Measure includes air source heat pumps and ductless mini-split heat pumps.

was 95% for energy savings and 88% for demand savings. The difference in energy savings is a result of the verified savings calculations using the 2016 federal minimum SEER of 14 for all units in the program, while the reported savings calculations are using the old federal minimum baseline SEER value of 13. The difference in demand savings is a result of the verified savings calculations using the 2016 federal minimum EER of 11.8 for all units in the program, while the reported savings calculations are using a baseline EER values of 11.2.

Attic Insulation: The realization rate for attic insulation was 100% for energy savings and 105% for demand savings. The verified savings calculations used deemed values from the AR TRM 7.0 based on whether the insulation was attic or roof deck. The reported savings calculations used deemed values for attic for all projects.

Floor Insulation: There were two floor insulation projects in the Multiple Upgrades Program in 2021. The realization rate for floor insulation was 100% for energy savings and 100% for demand savings.

Knee Wall Insulation: The realization rate for knee wall insulation was 110% for energy savings and 108% for demand savings. The verified saving calculations are based on zero existing insulation due to the assumptions in the AR TRM 7.0 of the baseline being an uninsulated knee wall. However, multiple projects in the reported savings calculations had a baseline insulation depth reported.

Exterior Wall Insulation: There was one wall insulation project in the Multiple Upgrades Program in 2021. The realization rate for wall insulation was 100% for energy savings and 100% for demand savings.

Net-to-Gross (NTG) Estimation Results

Survey data from a total of 101 Multiple Upgrades participants were used to determine the NTG ratio for this program. Survey respondents were asked a series of questions aimed at determining the program influence on the purchase and installation decisions for each installed measure. Each respondent was assigned a free ridership score (ranging from 0 for no free ridership to 1 for complete free ridership) based on their responses for each measure they installed. The measure-level free ridership of each survey participant was then weighted by the measure energy savings and averaged to determine the project-level free ridership score. This score was applied to the other measures where a survey response was not obtained.

The survey also included questions related to their retail purchase or contractor installation of similar products offered by the program. Although 40 survey participants provided specific details of additional equipment/products they purchased in 2021, the savings were not considered spillover as their program influence score was not high enough to claim added savings in the NTG estimation. Therefore, there was 0% spillover for the program in 2021.

The average free ridership score was 16%. The measure score was weighted and rolled up into the project level score and applied to the verified gross savings for the projects without a survey response. The sum of the verified net project savings over the total verified gross savings resulted in a NTG ratio of 84% for energy and demand savings. Based on the impact evaluation results, the total verified net energy savings for the Multiple Upgrades program are 2,377,509 kWh, and the total verified net peak demand savings are 1,212.25 kW. A summary of Multiple Upgrades net impact findings is shown in Table 3-120.

Table 3-120: Multiple Upgrades - Gross/Net Verified Energy & Demand Savings

Program	Gross Verified Energy (kWh)	Gross Verified Demand (kW)	Net Verified Energy (kWh)	Net Verified Demand (kW)	NTG Ratio
Multiple Upgrades	2,821,872	1,436.40	2,377,509	1,212.25	84%

3.5.4 Single Upgrade

This section presents the methodologies used for evaluation of the 2021 Single Upgrade portion of the Home Rebates Program.

3.5.4.1 EM&V Methodology

This section provides an overview of the gross and net impact evaluation and process evaluation of the Single Upgrade component of the Home Rebates Program. Findings from the process evaluation for all program components are provided in Section 3.5.6.

Impact Evaluation Activities

The primary data collection activities for Single Upgrade consisted of online participant and trade ally surveys and a facilitated discussion with program staff[85]. Additional sources of data to inform the impact evaluation were a census of program tracking data from the program implementor's tracking and reporting system (Sightline), along with project documentation obtained from VisionDSM. Program tracking data included customer contact information and descriptions of the measures installed with file storage for submitted applications, and contractor invoices for the work performed. The impact evaluation for this program included the following activities:

- Determination of the number of customers participating in the program by types of measures installed
- Determination of the gross energy savings and peak demand reduction per project

[85] ADM conducted an analysis of the Home Rebates – Single Upgrade Program strengths, weaknesses, opportunities, and threats (SWOT analysis) with program staff.

- Estimation of the net-to-gross ratios to determine the percentage of gross savings directly attributable to the program
- Documentation of incremental costs for benefit-cost analysis

Process Evaluation Activities

ADM performed a process evaluation assessing the 2021 Home Rebates Program operations and delivery. The program design, operations, and delivery were assessed for the Single Upgrade Program through participant surveys, trade ally surveys, and a facilitated discussion with program staff at PSO and an implementation contractor. Table 3-121 summarizes the data collection activities.

Table 3-121: Single Upgrade - Process Evaluation Data Collection Activities Summary

Data Collection Activity	Process Evaluation Research Objectives
Program Materials Review	Review reports and support materials for clarity and consistency with program objectives.
Program Staff Facilitated Discussion	Assess program strengths, weaknesses, opportunities, and threats
Participant Survey	Assess participant experiences, including satisfaction.
Trade Ally Survey	Assess program support, training, satisfaction, program influence on trade ally practices, and suggestions for improvements.

The process evaluation addressed the following research questions:

- Is the program marketing effective? What is working particularly well and what could be improved?
- Is the program reaching all segments of the target market? Is anyone under-represented or left out?
- How has the COVID-19 pandemic affected the program during 2021?

Sampling Plan

Table 3-122 summarizes the sample size for each primary data collection activity. The random sample for verification was designed to achieve ±10% relative precision or better at the 90% confidence interval.

Table 3-122: Single Upgrade - Sample Sizes for Data Collection Efforts

Data Collection Activity	Achieved Sample Size
Participant Survey	126
Trade Ally Surveys Completed	23
Facilitated Discussion with Program Staff	2

Participant Survey

The sample size for the participant survey was determined by the minimum sample size algorithm with 90% precision and 10% relative precision. With this assumption, a minimum sample size of 68 participants was needed, as shown in Equation 3-3. This minimum sample size of 68 was exceeded with 126 surveys completed.

Data Collection

Data collection activities supporting the evaluation included participant surveys, trade ally surveys, a facilitated discussion with program staff at PSO and an implementation contractor, and collection of all program documentation to complete a census engineering analysis.

Participant Survey

For the Single Upgrade Program, there were a total of 126 completed participant surveys. All Single Upgrade participants (as of November 2021) were pulled from the tracking data and included in the survey sample list. Any participant with a valid email address was sent the online participation survey. The survey was launched in two separate "waves", with the first wave in September 2021 and the second wave in November 2021. A total of 950 participants were sent the online survey, which resulted in 126 survey completes.

Trade Ally Survey

For the Single Upgrade Program, there were a total of 23 completed trade ally surveys. All Single Upgrade trade allies with contact information were pulled from the tracking data and included in the survey sample list. Any trade ally with a valid email address was sent the online trade ally survey in November 2021. A total of 95 trade allies were sent the online survey, which resulted in 23 survey completes.

Program Staff Facilitated Discussion

In November 2021, ADM evaluators had a facilitated discussion with PSO's program manager and program coordinator, as well as ICF's account manager. ADM conducted an analysis of the Home Rebates - Single Upgrade Program strengths, weaknesses, opportunities, and threats (SWOT analysis) with program staff. The SWOT analysis involved a group discussion with key personnel responsible for discussing past program year recommendations and brainstorming possible implementation strategies. The discussion focused on 1) identifying current, internal strengths and weaknesses within the program, 2) providing specific examples of the strengths and weaknesses within the program, 3) identifying external opportunities and threats for/to the program, and 4) providing specific examples of opportunities and threats within the program.

Gross Impact Methodologies

The method used to calculate energy savings (kWh) and demand savings (kW) consisted of:

- **Program tracking data census.** The tracking data was reviewed for a census of homes and measures. The data was verified for duplicate participation within the program and between programs.
- **Measure installation verification.** In-service rates (ISR) were calculated by measure for a sample of program participants using data from the online participant survey.
- **Reported savings review.** Reported savings calculations were reviewed for all measures to determine the cause of savings discrepancies.
- **Standard for verification of savings.** The data collected from the program tracking data were used as inputs to the savings algorithms as listed in the Arkansas Technical Reference Manual, Version 7.0 (AR TRM 7.0) and the Oklahoma Deemed Savings Document (OKDSD).

A brief description of each measure calculation methodology has been described in the Multiple Upgrades section above (see Section 3.5.3.1), except variable speed drive pool pumps, HVAC tune-ups, and Drop-Off Energy Kits. Appendix G includes the measure-level algorithms and deemed savings values utilized for the verified gross annual energy savings (kWh) and peak demand reduction (kW) calculations.

Variable Speed Drive Pool Pumps: Savings were estimated using the deemed savings method in the OKDSD. The savings algorithm inputs are dependent upon the horsepower of the motor, and the seasonal usage (summer or year-around). ADM applied the deemed savings table values from the OKDSD, including the summer-only and year-round operating hours.

HVAC Tune-Ups: This measure involves tuning up existing central AC or heat pump units. The implementation team ensures that the required action items listed in the AR TRM 7.0 are followed by service providers. Service providers report the results of all action items through a digital tool developed specifically for the application of HVAC tune-ups. Savings were calculated using Method 2 from the AR TRM 7.0 algorithm and is a change in efficiency based on pre- and post- measurement of the system. Deemed savings factors are based on the pre and post EER of the HVAC unit. The max savings for all verified and reported calculations is 6,000 kwh.

Drop-Off Energy Kits:

Drop-Off energy kits were included in the program to support outreach and non-wires solutions efforts in underserved areas. Each Drop-Off Energy Kit that program participants received contained the following measures:

Table 3-20: Single Upgrade – Drop-Off Energy Kit Measures

Item Description	Item #	Quantity
Premium 9W LED Bulb	L09A1927KENCL	8
Filter Tone Furnace Filter Alarm	150589	1
LED Nightlight	LD-47	1

Savings for the premium 9W LED bulb were estimated using algorithms found in the ARM TRM 7.0. A modification to the hours of use per year (960.61 HOU per year) was utilized by ADM. Modification of the hours of use was sourced from a lighting benchmarking study performed in 2016 by ADM and found daily hours of use of 2.63 blended hours for indoor/outdoor applications, or 960.61 hours per year.[86] The algorithm used to determine savings for FilterTone® Alarms is based on the Pennsylvania Technical Reference Manual (PA TRM). The source for the equivalent full load hours (EFLH) for the FilterTone® alarms calculation was the PY2019 – PY2021 Demand Portfolio Model. The algorithm used to determine savings for LED nightlights was from the PA TRM.

Lifetime kWh Savings

Lifetime energy savings (kWh) were calculated by multiplying the gross annual kWh savings by the Estimated Useful Life (EUL) for each measure type. EUL values for each measure were based on the assumptions in the AR TRM and OKDSD. Table 3-123 shows the EUL and source for each measure type.

86 ADM HOU Memo, 2016.

Table 3-123: Single Upgrade – Per Measure Estimated Useful Life (EUL)

Measure Type	EUL (Years)
Central AC	19
Heat Pump	16
Ductless Mini-Split Heat Pump	13
Ground Source Heat Pump	25
Attic Insulation	20
Pool Pump	10
HVAC Tune-Up	10[87]
Drop Off Energy Kits	17[88]

Net-to-Gross (NTG) Estimation

This section provides a summary of the method used to score survey responses for free ridership and spillover. The online survey sample of program participants were asked a series of questions aimed at estimating program attribution and identifying spillover measures. The attribution scoring system had three components: measure-level free ridership score, project-level free ridership score, and the spillover score. Each part is described in Section 3.5.8, as well as the details of the questions used for free ridership and spillover estimation.

This NTG estimation method for the Single Upgrade component of the Home Rebates program is the same as that for the Multiple Upgrades component (Section 3.5.3.1), except in the Single Upgrade Program, each participant was limited to two equipment upgrades so the free ridership assessment was similarly limited.

3.5.4.2 Impact Evaluation Findings for Single Upgrade

This section details the level of the Single Upgrade program activity for 2021, the reported and verified gross savings that resulted from that activity, and the NTG estimates that were applied to the gross savings to produce the net savings reported in Section 3.5.5.

Program Activity

In 2021, the Single Upgrade portion of Home Rebates had 1,560 total projects installed as part of the program. Final energy savings were based on a total of 1,625 energy-savings measures. See Table 3-124 below for a breakdown of total quantities for each energy-saving measure in the program.

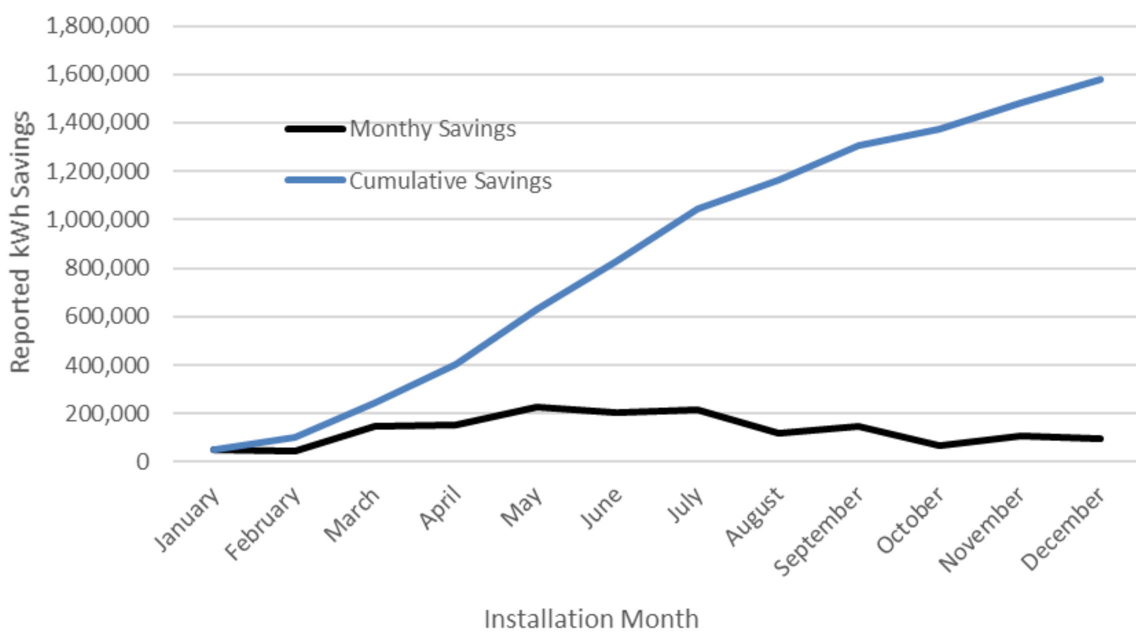
[87] Used default EUL of 10 years (refrigerant added) from AR TRM 7.0.
[88] Used the average EUL of all three measures in the Drop-Off Energy Kit.

Table 3-124: Single Upgrade – Per Measure Equipment Quantities

Measure	Quantity in Program
Central AC	643
Heat Pump	121
Ground Source Heat Pump	11
Attic Insulation	196
Pool Pump	270
HVAC Tune-Up	237
Drop Off Energy Kits	147
Total	**1,625**

The monthly energy savings, along with the cumulative annual savings for the 2021 Single Upgrade Program are detailed in Figure 3-39 below.

Figure 3-39: Single Upgrade - Cumulative Reported kWh Savings During the Program Year



Single Upgrade Reported and Verified Gross Savings

The verified gross and reported savings by measure are shown in the following table. The savings estimates result in a gross annual energy realization rate of 104% and a peak demand reduction realization rate of 73%. Table 3-125 presents the gross verified savings by measure, lifetime energy savings (kWh), and realization rates.

Table 3-125: Single Upgrade - Reported and Verified Gross Energy and Peak Demand Savings

Measure	Reported Energy (kWh)	Gross Verified Energy (kWh)	Reported Demand (kW)	Gross Verified Demand (kW)	Lifetime Energy Savings (kWh)	RR_{kWh}	RR_{kW}
Central AC	492,257	494,129	356.48	179.57	9,352,888	100%	50%
Heat Pump[89]	206,448	215,815	58.59	29.62	3,345,599	105%	51%
Ground Source Heat Pump	28,111	58,083	14.71	13.19	1,452,069	207%	90%
Attic Insulation	147,631	149,530	82.05	82.74	2,990,592	101%	101%
Pool Pump	418,623	418,643	96.44	96.44	4,186,425	100%	100%
HVAC Tune-Up	254,529	271,304	159.40	159.40	2,713,044	107%	100%
Drop Off Energy Kits	28,866	28,867	7.75	7.75	490,739	100%	100%
Total	**1,576,465**	**1,636,370**	**775.41**	**568.71**	**24,531,356**	**104%**	**73%**

The gross impact analysis consisted of verifying measure installation using self-reported data from the participant survey results and reviewing the program tracking data to ensure the deemed savings algorithms were appropriately applied. ISRs for each measure type were developed based on the findings from the online participant survey data and extrapolated to the population. Findings from online participant survey determined a 100% ISR for all sampled measures in Single Upgrade for 2021. A description of verified findings for each measure type is included below:

Central Air Conditioner: The realization rate for central air conditioners was 100% for energy savings and 50% for demand savings. The right sizing of the unit, reducing the capacity of new unit to less than the baseline unit, was considered when the capacities were similar (i.e., a 1-ton mini split replacing a 1.5-ton unit, but not a 1-ton unit replacing a 4-ton unit). The difference in demand savings is a result of the verified savings calculations using the 2016 federal minimum EER of 11.8 for all units in the program, while the reported savings calculations are using the old federal minimum baseline EER value of 10.8.

Heat Pumps:[90] The realization rate for central air conditioners was 105% for energy savings and 51% for demand savings. Projects for mini-split heat pump installation often

[89] Measure includes air source heat pumps and ductless mini-split heat pumps.
[90] Measure includes air source heat pumps and ductless mini-split heat pumps.

replaced a traditional window air conditioner but had the baseline capacity of a larger unit in the home listed. In those cases, the baseline capacity was set equal to the new mini-split heat pump, to only consider the mini-split heat pump energy savings. However, the gross verified savings did include the “right sizing” for units that were similar in size (for example, a 1-ton heat pump replacing a 1.5-ton air conditioner).

The slight difference in energy savings between the reported savings calculations and verified savings calculations are a result of two projects in the reported savings having 0 kWh savings. The verified savings include kWh savings for both projects. The difference in demand savings between the reported savings calculations and verified savings calculations are a result of the verified savings calculations using the 2016 federal minimum EER of 11.8 for all units in the program, while the reported savings calculations are using the old federal minimum baseline EER of 10.8 for all units in the program.

Ground Source Heat Pump: The realization rate for ground source heat pumps was 207% for energy savings and 90% for demand savings. The difference in energy savings is a result of the reported savings calculations not claiming heating savings for some of the units, while the reported savings calculations considered all as normal replacement units with heating savings. The difference in demand savings is a result of the verified savings calculations using the 2016 federal minimum EER of 11.8 for all units in the program, while the reported savings calculations are using a baseline EER values of 11.2.

Attic Insulation: The energy savings for attic insulation has a realization rate of 101% and the demand savings has a realization rate of 102%. The AR TRM savings table is based on two final insulation values with many different baseline R-values. The realization rate is slightly over 100% because the insulation R-value between the R-38 and R-49 table values are linearly interpolated. The actual relationship between heat transfer and the R-value is non-linear, with heat savings diminishing faster than the R-value.

Variable Speed Drive Pool Pumps: ADM calculated savings for each home with a variable speed drive pool pump (summer only and year-round) and determined the realization rate for energy savings to be 100% and the realization rate for demand savings to be 100%.

HVAC Tune-Ups: HVAC tune-ups were performed on central AC or heat pump units in the program. The energy savings for HVAC tune-ups had a 107% realization rate and the demand savings 100%. Deemed savings factors were based on the pre- and post-EER of the HVAC unit. The verified savings calculations utilized Method 2 from the AR TRM 7.0 algorithm and was based on a change in efficiency based on pre- and post-measurement of the system. The additional energy savings are due to the verified calculations including a heat pump savings credit for all heat pump tune-up projects, which lowered the baseline HSPF.

Drop-Off Energy Kits: The energy savings for drop-off energy kits had a 100% realization rate and the demand savings had a realization rate of 100%. Although, this measure was not offered through the website, it was distributed to a total of 147 program participants. The kits included three measures: (8) 9W LED lightbulbs, (1) filter tone furnace filter alert, and (1) LED nightlight. A deemed ISR of 100% was used for these two measures based on the implementation strategy of personal delivery to the customer.

Single Upgrade NTG Estimation Results

Survey data from a total of 126 Single Upgrade participants were used to determine the NTG ratio for this program. Survey respondents were asked a series of questions aimed at determining the program influence on the purchase and installation decisions for each installed measure. Each respondent was assigned a free ridership score (ranging from 0 for no free ridership to 1 for complete free ridership) based on their responses for each measure they installed. The measure-level free ridership of each survey participant was then weighted by measure energy savings and averaged to determine the project-level free ridership scores. This score was applied to the other measures where a survey response was not obtained.

Survey respondents were also asked a series of questions to determine if they had installed any additional, non-rebated, energy efficiency measures because of their participation in the program (spillover). Fifty-seven respondents said they had installed additional measures in 2021. Out of those 57 respondents, 14 had a high enough program influence score to indicate that the program was influential in their decision to install those additional measures. The result was 4,578 kWh spillover savings from the sampled responses for a total 3.33% spillover attributed to the program.

The average free ridership score was 13%. The measure score was weighted and rolled up into the project level score and applied to the verified gross savings for the projects without a survey response. The sum of the verified net project savings over the total verified gross savings resulted in a NTG ratio of 87% for energy savings and demand savings. Based on the impact evaluation results, the total verified net energy savings for the Single Upgrade Program are 1,422,505 kWh, and the total verified net peak demand savings are 496.49 kW. A summary of Single Upgrade impact findings is shown in Table 3-126.

Table 3-126: Single Upgrade - Gross, Net Energy & Demand Savings

Program	Gross Verified Energy (kWh)	Gross Verified Demand(kW)	Net Verified Energy (kWh)	Net Verified Demand (kW)	NTG Ratio
Single Upgrade	1,636,370	568.71	1,422,505	496.49	87%

3.5.5 Home Rebates Impact Evaluation Findings

The component programs of the Home Rebates are listed below with the verified gross energy and demand savings in Table 3-127.

Table 3-127: Program Level Gross Energy and Demand Savings

Program	Reported Energy (kWh)	Reported Demand (kW)	Gross Verified Energy (kWh)	Gross Verified Demand (kW)	Lifetime Energy Savings (kWh)
New Homes	2,699,832	977.57	2,641,733	956.54	52,834,650
Multiple Upgrades	2,927,861	1,797.90	2,821,872	1,436.40	51,857,331
Single Upgrade	1,576,465	775.41	1,636,370	568.71	24,531,356
Total	**7,204,159**	**3,550.88**	**7,099,975**	**2,961.65**	**129,223,337**

Table 3-128 and Table 3-129 summarize the verified net impacts of the complete Home Rebates Program.

Table 3-128: Verified Gross and Net Energy Savings

Program	Free Ridership	Participant Spillover	NTG Ratio	Gross Verified Energy (kWh)	Net Verified Energy (kWh)
New Homes	10%	30%	120%	2,641,733	3,161,015
Multiple Upgrades	16%	0%	84%	2,821,872	2,377,509
Single Upgrade	13%	3%	87%	1,636,370	1,422,505
Total				**7,099,975**	**6,961,029**

Table 3-129: Verified Gross and Net Peak Demand Reduction

Program	Free Ridership	Participant Spillover	NTG Ratio	Gross Verified Demand (kW)	Net Verified Demand (kW)
New Homes	9%	7%	97%	956.54	931.17
Multiple Upgrades	16%	0%	84%	1,436.40	1,212.25
Single Upgrade	13%	3%	87%	568.71	496.49
Total				**2,961.65**	**2,639.91**

3.5.6 Process Evaluation Findings

The evaluation team at ADM performed a process evaluation that assessed program documentation and primary data collected from program stakeholders. The evaluation included participant surveys, completed facilitated discussion with program staff, reviewed program documentation, and analyzed the program tracking data. A portfolio level process evaluation memo was provided to PSO after the completion of the program year.

3.5.6.1 New Homes

The following summarizes the key findings of the process evaluation of the New Homes component:

- Strong working relationships with different stakeholders has been key to the success of the Home Rebates program. According to staff, the HERS raters work with program staff and each other to provide the best service possible. HERS rater's relationships with code officials helps them stay informed on the latest state and local building codes and encourage the use of ENERGY STAR® products. Staff also stated they train their HERS raters, builders, and sales representatives on energy efficiency knowledge so they can then educate home buyers and their clients. According to staff, this training has been an effective marketing tool.
- Improving and expanding New Homes is a priority for staff. Program staff indicated they are exploring ways to enhance New Homes. For example, one of the ways staff would like to strengthen the relationship with builders is by helping them understand that PSO and ICF are a resource to them. Program staff would like to further collaborate with SPEER, a regional organization that aims to accelerate the adoption of more energy efficient building constructions and products in Texas and Oklahoma. Finally, staff indicated they would like to explore how to better incorporate non-energy benefits (e.g., carbon efficiency, environmental benefits, comfort) and promote them to builders and buyers.
- Limitations to New Homes included housing demand, budget limitations, and material shortages. According to program staff, the current demand for program rebates is currently outpacing the incentive budget. The current market for supplies is limited and prices are high (i.e., supply chain bottlenecks, increased cost of raw materials, etc.), which potentially could create a higher demand for rebates from builders. Furthermore, the program's budget has gradually been decreasing over the years. Program staff are concerned about their ability to provide rebates to builders for all the homes they built in 2021.
- External threats to New Homes included codes changes, restrictions to incented measures, and competition with gas rebates. According to program staff, future building code changes will increase difficulty of meeting energy efficiency needs, and current regulations restrict what and how measures can be incentivized. Competition with gas rebates from energy competitors challenges the expansion of all-electric homes. Finally, myths about new homes already built to high energy efficiency standards continue to dissuade some participants and even home buyers from participating or buying homes with a PSO standard for high energy efficiency.

3.5.6.2 Single and Multiple Upgrades

The following summarizes the key findings of the process evaluation of the Multiple Upgrades component:

- Reduced incentives for lower SEER HVAC equipment that qualified for the program, and new incentivized measures were added to the program. The 16 – 16.99 SEER air conditioning and heat pump incentives were reduced from $750 to $300. The 17 – 17.99 SEER air conditioning and heat pump incentives were reduced from $825 to $300. Although some HVAC incentives were reduced, exterior wall insulation rebates were added to the Multiple Upgrades Program to accommodate current market need.
- Program staff adopted new recruitment and communication strategies to adapt to the new circumstances. Program staff indicated that the HVAC contractor recruitment and training was done virtually in early 2021. In-person HVAC contractor recruitment and training was done the rest of the year, but only for new contractors in the program.
- Overall, the program participants and trade allies are satisfied with the PSO Home Rebate – Multiple Upgrades Program. Program participants were generally satisfied with their contractors and with PSO program staff. The trade allies, too, had positive feedback for the program staff and indicated that their communication with program staff was helpful. None of the trade allies had any issues with the Third-Party Verifiers (TPV). They indicated that it would be beneficial to make it easier to contact customer service when they have any questions about the program. Some trade allies also expressed interest in having additional trainings for the program.

The following summarizes the key findings of the process evaluation of the Single Upgrade component:

- PSO holds regular meetings to discuss and ensure that customer needs are being met through the program. Through these meetings and market research, it was determined that there was a market need for HVAC tune-ups. HVAC tune-up incentives were added to the Single Upgrade Program in 2021 to meet this need. PSO also conducts focus groups to gather information on desired energy efficiency measures based on current market conditions. Through a focus group, it was determined that there is a need to expand the types of thermostats available for program rebates other than Honeywell brand thermostats (previously in the Power Hours Program).
- There is less service provider participation for the Single Upgrade Program than desired. It has been identified that additional marketing material is needed for the

rural areas outside of Tulsa to expand the awareness of the program to potential service providers.

- Incentives were reduced for the lower SEER HVAC equipment that qualified for the program, and new incentivized measures were added to the program. The 16 – 16.99 SEER air conditioning and heat pump incentives were reduced from $500 to $200. The 17 – 17.99 SEER air conditioning and heat pump incentives were reduced from $550 to $200. Although some HVAC incentives were reduced in 2021, HVAC tune-up rebates were added to the Single Upgrade Program to accommodate current market need.
- Overall, the program participants and trade allies are satisfied with the PSO Home Rebate - Single Upgrade Program. Program participants were generally satisfied with their contractors and with PSO program staff. The trade allies, too, had positive feedback for the program staff and indicated that their communication with program staff was helpful. They indicated that it would be beneficial to make it easier to contact customer service when they have any questions about the program. Some trade allies also expressed interest in having additional trainings for the program.

3.5.7 Conclusions and Recommendations

The following recommendations are offered for continued improvement of the New Homes component:

- Continue improving the relationship with stakeholders. As the state continues to adapt to the new socio-economic changes resulting from the past couple of years, program staff could benefit from strengthening their relationships with all their stakeholders. Program staff could consider creating additional meetings with interest groups to discuss innovative strategies on how to better meet the needs of the territory.
- Expand campaigns to educate the public on PSO's standards of high energy efficiency homes. With help from the marketing team and other energy-efficiency programs, consider ways to inform the public on why homes built with a PSO standard of energy efficiency is better. The marketing team could develop social media material, printed flyers, vlogs/blogs, showing the benefits of homes constructed with energy efficiency as a top priority. Program staff could also work with other programs (e.g., Power Hours, Energy Saver Kits, etc.) to further explain how energy efficient homes can help save more money when the ratepayer participates in these programs.

- Revisit Ekotrope baseline models to ensure the energy code is properly followed. Some aspects of the energy models are still unclear and may need fine-tuned. For example, percentage of CFL lighting in the baseline condition is not clearly defined.

The following recommendations are offered for continued improvement of the Multiple Upgrades component:

- Recommend increasing target marketing materials in rural areas. Regional diversity is a goal for the program. Increased communication to rural areas outside of the Tulsa area where there is less program activity may help increase the regional diversity for both customers and service providers who may not know about the program. Increasing customer awareness about the program and desire to receive program incentives can help increase the number of service providers who participate in the program as well.
- Recommend developing a ticket system to increase communication regarding test-out assessments. It has been indicated by both PSO program staff and implementation staff that there is a lack of communication with the third-party verifiers which can delay the test-out assessments. This delay can create customer hesitancy to have the test-out assessment performed as part of the program. If a test-out assessment is not performed, the participant no longer qualifies for the program. To increase contractor/sales communication, a service provider could create a ticket when a test-out assessment is ready to be scheduled. ICF would then follow-up with the third-party verifier until the test-out is complete. This would create an automated communication process to help finish a project and receive rebates.
- Verification of reported energy and demand savings for duct replacement projects should be in place. There was one duct replacement project in the Multiple Upgrades Program tracking data for 2021. This one project had reported savings in both corresponding projects for duct replacement and duct sealing. Additional verification processes may be needed to ensure that all energy and demand savings for duct replacement projects are captured in the corresponding duct sealing project.
- Ensure the inputs in the program tracking data align with the 2016 Federal Minimum Efficiency Requirements. The EER baseline values being used from the program tracking data in some of the reported savings calculations for central air conditioners, air source heat pumps, and ground source heat pumps do not align with current Federal Minimum Efficiency Requirements (southeast region). This is causing a difference between the reported savings and verified savings since the verified savings calculations use the Federal Minimum Efficiency Requirements for all baseline values.

The following recommendations are offered for continued improvement of the Single Upgrade component:

- Validate refrigerant added data collection for the HVAC tune-ups without burdening the contractors. The ADM evaluation team is unable to verify if and how much refrigerant is added during the tune-up process even after reviewing the project documentation in VisionDSM. The evaluation team should work with the implementation team on a system to verify a refrigerant charge as to not add additional burdens to the tune-up contractors.
- Verify process for how the post-HVAC tune-up EER is calculated. For HVAC tune-ups, the average improvement in EER_pre to EER_post is 400%. This also includes projects that did not have any refrigerant charge reported in the program tracking data. The evaluation team should work with the implementation team on a system to verify if best practices are in place.
- Recommend program staff communicate with current customers. Many customers expressed a lack of understanding about the rebate process. Communication with program staff was rated highly by customers, so having program staff reach out to a select number of customers periodically may increase customers' knowledge and understanding of the program process. It will also reassure customers that their needs are being met. Additional hand-out material for service providers to provide to customers may also be beneficial.
- Recommendation to continue focusing on marketing. Most customers learn of the program through their service providers as opposed to knowing about the program before they make an appointment to upgrade their equipment. Additional marketing can persuade customers to consciously make appointments to upgrade their equipment. Marketing material can also be used by the service providers to better explain the benefits of the qualifying higher-efficiency measures that they may be recommending to customers.
- Ensure the inputs in the program tracking data align with the 2016 Federal Minimum Efficiency Requirements. The EER baseline values being used from the program tracking data in some of the reported savings calculations for central air conditioners, air source heat pumps, and ground source heat pumps do not align with current Federal Minimum Efficiency Requirements (southeast region). This is causing a difference between the reported savings and verified savings since the verified savings calculations use the Federal Minimum Efficiency Requirements for all baseline values.

3.5.8 Single and Multiple Upgrades Net-To-Gross Questions

Questions relating to the assessment of net-to-gross (NTG) address both free ridership and spillover. Both the participant survey and service provider survey include questions relating to program participation and free ridership. For customers who completed projects that did not include HVAC measures, the free ridership score is based entirely on responses to questions in the participant survey. For customers who completed projects that included HVAC measures and who reported that equipment information or a recommendation from their service provider was highly influential in their decision to implement the HVAC measures, the assessment of free ridership includes information from the service provider survey. This is because program education and outreach efforts for HVAC measures may influence service providers' selling of efficient equipment in ways that are not apparent to customers.

The following subsections describe the questions from the participant and service provider surveys that the evaluation team at ADM used to assess free ridership and spillover, as described in Section 3.5.3.1 for Multiple Upgrades and Section 3.5.4.1 for Single Upgrade of this report.

3.5.8.1 Participant Free Ridership Questions

The participant free ridership (PFR) questions addressed the following criteria to determine the likelihood that a customer is a free rider:

- Financial ability to install the energy efficiency measures without program support
- Prior plans regarding installation of the energy efficiency measures
- Likelihood of implementing the measures in the absence of the program
- The program's impact on the timing of measure implementation

Financial Ability

Financial ability was assessed with the following question:

- PFR1: Because energy-efficient upgrades are higher in cost, would you have still purchased the [MEASURE] without the PSO rebate/discount?

Respondents who indicated that they were not able to afford the efficiency measure without the financial support provided by the program were deemed to not be free riders. For all others, a free ridership score was assigned based on a combination of their reported prior plans to implement the measure, the reported likelihood they would have installed one without the program, and the reported effect of the program on the likely timing of the installation (as described in following subsections).

Prior Plans

The presence of plans prior to involvement with the program was assessed through the following questions:

- PFR2: Before learning about the PSO rebate program, did you have plans to purchase or install the [MEASURE]?
- PFR3: Did you purchase and install [a more efficient/more] [MEASURE] because of the PSO rebate/discount?
- PFR4: [For duct sealing and knee wall insulation measures] Before participating in the program, did you know that your [duct system was leaking / knee walls needed more insulation]?
- PFR5: [For duct sealing and knee wall insulation measures] Were you aware that you could save energy by [sealing your ducts/insulating your knee walls] before you participated in the program?

For measures other than duct sealing and knee wall insulation, respondents who answered “Yes” to PFR2 and “No” to PFR3 were assigned a “plans” score of 1. All other respondents were assigned a “plans” score of 0. For duct sealing and knee wall insulation measures, respondents who said “Yes” to PFR4 and PFR5 were assigned a “plans” score of 1 and all other respondents were assigned a “plans” score of 0.

Likelihood of Implementing the Measure in the Absence of the Program

The respondents’ stated likelihood of implementing the measure in the absence of the program was assessed through the following two questions:

- PFR6: How likely is it that you would have purchased and installed the [MEASURE] without the PSO rebate/discount?
- PFR7: How likely would you have been to purchase and install the [MEASURE] if you had not learned about PSO’s Home Rebates Program from [SOURCE]?

Based on the responses to the likelihood question, the following point values were assigned to each of the responses:

- 1 (Not at all likely) = 0
- 2 = 0.25
- 3 = 0.5
- 4 = 0.75
- 5 (Very likely) = 1

The likelihood score was based on the lowest rating provided on questions PFR6 and PFR7.

Program Impact on Timing

The program effect on the timing was assessed with the following two questions:

- PFR8: Did you purchase and install the [MEASURE] sooner than you would have because of the PSO rebate/discount?
- PFR9: If you had not received a PSO rebate/discount, when would you have purchased and installed the [MEASURE]?

The information provided in the response to these questions is used in the following manner:

- If the respondent stated that they would have installed the measure in more than one year, the preliminary free ridership score is multiplied by 0, resulting in a final free ridership score of 0. This is consistent with the AR TRM definition of a free rider as someone who would have implemented a program measure within one year of when it was installed through a program.
- If the respondent stated that they would have installed the measure in 6 months to one year, the preliminary free ridership score is multiplied by 0.25.
- If the respondent stated that they would have installed the measure within 6 months of when it was installed, the preliminary free ridership score is multiplied by 0.5.

3.5.9 Participant Questions to Assess Service Provider Influence on HVAC Installation

The participant survey asked participants:

- PFR10: Were any of the following energy-efficient equipment/upgrades recommended by your contractor during the initial visit?
- PFR11: How likely is it that you would have purchased the following energy-efficient equipment/upgrades if your contractor had not recommended it?

A “Yes” response to PFR10 and rating of 5 for PFR11 indicates service provider influence.

3.5.10 Service Provider Free Ridership Questions

The service provider survey included two service providers free ridership (SPFR) questions:

- SPFR1: How important was the PSO Home Rebates Program, including the rebates and information provided through the program, in influencing your level of marketing and selling of energy efficient measures to PSO customers during [YEAR]?

- SPFR2: Would you have recommended different equipment types, quantities, or efficiency levels to customers if the program were not available?

The responses to SPFR1 were scored as following (where higher values indicated higher free ridership):

- 0 (Not at all important) = 1
- 1 = 0.9
- 2 = 0.8
- 3 = 0.7
- 4 = 0.6
- 5 = 0.5
- 6 = 0.4
- 7 = 0.3
- 8 = 0.2
- 9 = 0.1
- 10 (Very important) = 0

If the service provider answered “Yes” to question SPFR2, the score from SPFR1 is reduced by 50%.

3.5.11 Spillover Questions

Spillover (SO) is defined as energy efficiency measures that respondents report installing in their home without receiving additional incentives but that were installed based on program influence. Potential spillover respondents were identified using the question below:

- SO1: Since participating in the program, have you purchased and installed any additional energy-saving equipment or home improvements in 2021, with or without receiving a program rebate or discount?

Participants indicating that they have purchased and installed one or more energy efficiency projects since participating in the PSO Home Rebates Program were then asked two questions to determine whether the energy savings resulting from those measures may be attributed to the program:

- SO3: How important was your experience with PSO’s Home Rebates Program in your decision to purchase and install the additional equipment/upgrades?
- SO4: How likely would you have been to purchase and install the additional equipment/upgrades if you had not participated in PSO’s Home Rebates Program?

The responses to SO2 were scored as following (on a scale of 0 to 10, where higher values indicated higher spillover):

- 0 (Not at all important) = 1
- 1 = 0.9
- 2 = 0.8
- 3 = 0.7
- 4 = 0.6
- 5 = 0.5
- 6 = 0.4
- 7 = 0.3
- 8 = 0.2
- 9 = 0.1
- 10 (Very important) = 0

The responses to SO3 were scored as following (on a scale of 1 to 15, where higher values indicated higher spillover):

- 1 (Not at all likely) = 0
- 2 = 0.25
- 3 = 0.5
- 4 = 0.75
- 5 (Very likely) = 1

Participants responding to question SO3 with a rating of 7 or higher and responding to question SO4 with a rating of 3 or lower, were considered to have been motivated by the program to make these additional purchases, and the energy savings from these items were attributed to the program. Savings for spillover measures like those offered through the program were calculated and then extrapolated to the population of respondents.

3.6 Education Program

This chapter presents findings from the impact and process evaluation of the 2021 PSO Education program.

3.6.1 Program Overview

The PSO Education Program, known by teachers, students, and parents as the PSO Energy Saver Kits Program, provides educational materials and energy-efficient products to 5th grade students in the PSO service territory. The program provides students with the opportunity to learn about energy efficiency through hands-on classroom activities and gives each student a kit with energy efficient products to reduce their home energy use. The PSO Education Program has operated continuously since 2010 and has claimed savings since 2016.

Table 3-130 summarizes the overall performance of the program in Program Year 2021.

Table 3-130: Performance Metrics – Education Program

Metric	PY2021
Number of Customers	15,782
Budgeted Expenditures	$1,120,000
Actual Expenditures	$872,061
Energy Impacts (kWh)	
Projected Energy Savings	4,394,641
Reported Energy Savings	3,546,752
Gross Verified Energy-savings	3,185,305
Net Verified Energy-savings	3,185,305
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	516.84
Reported Peak Demand Savings	726.97
Gross Verified Peak Demand Savings	636.80
Net Verified Peak Demand Savings	636.80
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	2.41
Utility Cost Test Ratio	2.20

The Education program consists of three components. (1) Education materials provided to teachers, (2) kits with energy saving measures for students to install at home, and (3) the PSO Education Program webpage.[91]

Educational materials were developed by the implementer to form a five-day curriculum designed to support the Oklahoma Academic State Standards for 5th graders. The curriculum was designed to be easily integrated into the teacher's curriculum at no cost to the school district, teachers, or students. The ready-made curriculum includes documentation explicitly outlining the Oklahoma Academic Standards supported through the program in language arts, mathematics, and science.

Students are engaged through compelling stories and illustrated characters such as C.A.D.E. (the Champion And Defender of Energy). C.A.D.E. goes on energy-saving adventures and teaches students about energy-saving habits and ways to be more energy-efficient at home.

Each student is then provided with an Energy Saver Kit containing 4 LED lightbulbs, an LED nightlight, a smart power strip, a furnace whistle, and a digital thermometer. Students are given instructions on how to install the measures in the kit and instructed to install them in their homes. The measures provide energy savings to participating families and reinforce concepts taught through the curriculum.

The final component of the program, the PSO Education program website, provides additional resources for teachers, students, and parents. Teachers can access additional resources and educational materials to enrich the students' experience in the program. Students can access additional information about kit contents and links to educational activities through sites such as the Department of Energy Kids, the Energy Information Administration (EIA) Kids, NASA Climate Kids, GetWise and Smithsonian Kids. Parents can access installation instruction for kit contents and other energy-saving tips.

Some of the available program literature for parents was developed in English and Spanish to add to the program's penetration and efficacy. A "parent pack" was included in the kit that includes a bilingual "Quick Start Guide" to help parents with product installation and other energy-savings tips.

3.6.2 EM&V Methodologies

This section provides an overview of the data collection activities, gross impact calculation methodologies, net-to-gross estimation, and process evaluation activities that ADM employed in evaluating the PSO Education Program.

[91] https://www.pso-education.com/

3.6.2.1 Data Collection

ADM collaborated with the program implementers to develop two quizzes and two surveys to be conducted through the program. The quizzes assess the student's knowledge about electricity and energy use before and after participation in the program. The surveys collect information about the home, such as heating fuel and air conditioning system type, and information about program-related activities, including measure installation and behavioral changes. Impact calculations use survey responses to inform the savings analysis. Teachers are eligible for a $50 gift card when 80% of student surveys are completed and returned.

Program surveys do not collect student contact information. Collecting any student contact information beyond the student's first name would be in violation of the Personal Information Protection Act (PIPA) and Family Educational Rights and Privacy Act (FERPA).

ADM conducted a survey of teachers to collect information on teacher's perceptions of the program, past participation, how teachers used the curriculum, and their perception of PSO and the Education program.

Finally, ADM conducted an in-depth interview with four program staff to gain insight into the program execution. ADM completed interviews in October 2021 with key personnel responsible for the program and discussed past program year recommendations and brainstormed possible implementation strategies for future changes. Table 3-131 summarizes the data collection activities and purpose.

Table 3-131: Data Collection and Sample Size Effort by Survey

Data Collection Activity	Data Use	Achieved Sample Size
Program Tracking Data	Impact/Process	15,782
PSO Student Survey	Impact/Process	4,061
ADM Teacher Survey	Process	113
Implementation Staff Interviews	Process	4

3.6.2.2 Reported Savings Calculations Review

ADM reviewed reported savings sources and calculations for all measures to explain any savings discrepancies. Measure level In-Service Rates (ISR) were calculated from student surveys. The student surveys are provided with the kits and collected by the implementation team.

3.6.2.3 Gross Impact Methodologies

To calculate annual energy-savings (kWh) and peak demand impacts (kW), ADM conducted the following evaluation activities:

- Reviewed a census of program tracking data: ADM reviewed the tracking data for a census of kits. The review looked for data completeness, data entry errors, duplicates, and outlier savings values. Review of program tracking data was conducted periodically during the program year.
- Reviewed program invoices: ADM conducted a review of program invoices to verify shipment of kits reported in program tracking data and reconcile program costs.
- Calculated gross verified savings: ADM verified gross savings using engineering algorithms from industry standard references. The sources for deemed savings algorithms are the 2016 Pennsylvania Technical Reference Manual (PA TRM) and Arkansas Technical Reference Manual v7.0 (AR TRM).
- Determined measure installation for gross savings adjustments: ADM calculated the ISR for ENERGY STAR® LEDs, FilterTone® alarms, LED night lights, and the advanced power strip using data collected from a sample of program participants in the student surveys.

ENERGY STAR® LEDs

The algorithm used to determine annual energy-savings and peak demand reduction for ENERGY STAR® LEDs is described in Appendix G, Section G.1.5.1 based on the Arkansas Technical Reference Manual (AR TRM).

The AR TRM stipulated value for hours of use (HOU) for omnidirectional lamps is 792.6 hours per lamp. However, ADM conducted a lighting benchmarking study in PY2016 and found daily hours of use of 2.63 blended hours for indoor/outdoor applications, or 960.61 hours per year.[92] This value was used for the 2021 analysis. In-service rates, interactive effects, and coincident factors were determined from the reported number of installed bulbs and the number of bulbs installed indoors and outdoors, as reported in the Student Survey.

Advanced Power Strips

The algorithm used to determine annual energy-savings and peak demand reduction for advanced power strips in residential applications is based on the AR TRM and detailed in Appendix G, Section G.1.5.2. In-service rates were determined from the student surveys. Due to the complexity of correctly installing advanced power strips, ADM calculated in-service rates based on the number of students who reported installing the power strip with parental help or supervision.

FilterTone® Alarm

The algorithm used to determine annual energy-savings and peak demand reduction for FilterTone® Alarms is based on the PA TRM and is detailed in Appendix G, Section

[92] ADM HOU Memo, 2016.

G.1.5.3. In-Service Rate was determined from student surveys. Due to the complexity of correctly installing FilterTone® alarms, ADM calculated in-service rates based on the number of students who reported installing the alarm with parental help or supervision. Due to differences in climate zone from methodology reference, the source for equivalent full load hours (EFLH) for the FilterTone® alarms calculation was the PY2019 – PY2021 Demand Portfolio Model.

LED Night Light

The algorithm used to determine energy-savings for LED Night Lights is from the PA TRM and detailed in Appendix G, Section G.1.5.4. Measure In-Service Rate was determined from student surveys.

Digital Thermometer

PSO did not claim energy-savings or demand reduction for the digital thermometers distributed in the Education Program kits.

The survey questions and the evaluation inputs for which they were used, are shown in Table 3-132.

Table 3-132: Student Survey Questions and Uses

Survey Question	Question Use
There were four 9-watt LED light bulbs included in your kit. How many of the LED Light Bulbs did your family install on the inside of your home? AND How many of the four LED Light Bulbs did your family install on the outside of your home?	LED Bulbs ISR, Interactive Effects, and Coincidence Factor
Did your family install the Advanced Power Strip in your home? AND If you answered "yes" to question 5, did you receive help from your parents to install the Advanced Power Strip?	Advanced Power Strip ISR
If you answered "yes" to question 5, where did you install your Advanced Power Strip?	Advanced Power Strip Savings
Did your family install the FilterTone Alarm? AND If you answered "yes" to question 1, did you receive help from your parents to install the FilterTone Alarm?	Furnace Whistle ISR
Did your family install the LED Night Light?	LED Night Light ISR

3.6.2.4 Net-to-Gross Estimation

The Education Program has a net-to-gross (NTG) ratio of 100%. The fifth-grade students and parents of the students do not have the option to opt-out of the program. The teachers decide whether to participate. It is therefore not reasonable to assume that a parent or student was a free rider when they received the kit.

3.6.2.5 Lifetime Savings

Lifetime annual energy savings were calculated by multiplying the gross annual energy savings by the Effective Useful Life (EUL) for each measure type. EUL values for each measure were based on the assumptions in the AR TRM and PA TRM. Table 3-133 shows the EUL and source for each measure type.

Table 3-133: Per-Measure Estimated Useful Life (EUL)

Kit Contents	EUL	Source
ENERGY STAR® 9W LED	19[93]	AR TRM
Advanced Power Strip	10	AR TRM
FilterTone® Alarm	14	PA TRM
LED Night Light	8	PA TRM

3.6.2.6 Process Evaluation

ADM's process evaluation activities included a review of program materials and databases, a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis with PSO and implementer staff, School Kits survey data collected from students, and a survey of participating teachers.

Table 3-134 below summarizes the data collection activities and corresponding process evaluation research objectives.

Table 3-134: Process Evaluation Data Collection Activities Summary

Data Type	Process Evaluation Research Objectives
Review of Program Materials and Databases	Provide information on program design, implementation, and delivery. Provide school and teacher participation data to help interpret data from student surveys.
PSO and Implementation Staff SWOT Analysis	Confirm program design, implementation, and delivery; identify any changes. Get perspective on successes, challenges, developments, progress toward goals, and barriers.
Assessment of Student Survey Data	Assesses the survey responses from 5th grade students receiving education kits to understand how the energy efficiency measures provided in the kit are being used and evaluate the knowledge acquired through the program.
Teacher Survey	Assess teacher perceptions of the program, materials, and kits; use of materials in curriculum development; and level of teacher involvement in kit distribution.

The process evaluation addressed the following research questions to better understand the program's effectiveness and efficiency:

[93] ADM followed the AR TRM algorithms for LED bulbs, and used EISA Tier 1 baselines for the first two years of the measure life (2021-2022), and EISA Tier 2 baselines thereafter.

- Do program utility and implementation contractor staff effectively coordinate to deliver the program?
- Were there any notable successes, challenges, or other program developments?
- Did the program meet its kit distribution goals? If not, what are the barriers to meeting the distribution goals?
- Does the program serve all areas of the PSO service territory and all segments of PSO's residential customer population?
- What do teachers think about the program, the educational materials, and the kits? To what degree do the teachers incorporate the educational materials into their curriculum, and what would they teach if they did not receive those materials?
- Are there ways to improve the design or implementation process?
- How has the COVID-19 pandemic affected the program?

3.6.3 Impact Evaluation Findings

Using the methodology described in this chapter, the impact evaluation determines verified annual energy savings, lifetime energy savings, and peak demand reductions.

3.6.3.1 Program Tracking Data

ADM reviewed the program tracking data periodically throughout the year and worked with the implementation team to address any issues. The final program tracking data was verified to not contain any issues such as duplicate entries or missing data.

3.6.3.2 Energy Impact Adjustments

ADM verified gross energy impacts using the engineering algorithms described in the methodology section of this chapter. Gross energy impacts were adjusted for ISR to determine verified energy impacts. In-Service Rates, as calculated based on the methodology section, are the result of student surveys. In total, 3,863 student surveys were completed. Table 3-135 displays the in-service rates by measure.

Table 3-135: School Kit In-Service Rates

Measure	Number of Measures	ISR
7-Plug Advanced Power Strip	15,782	43%
LED Night Light	15,782	71%
FilterTone® Furnace Filter Alarm	15,782	39%
9-watt LED	63,128	45%[94]

3.6.3.3 Advanced Power Strip

ADM confirmed the savings methodology was consistent between reported results and verified results. ADM used the student survey to determine the proportion of distributed power strips that were installed, and the proportion of installed advanced power strips controlling home offices, home entertainment systems, or other devices. These values were used to create weighted average savings and demand reduction for advanced power strips. Based on the student survey responses, ADM found a lower overall ISR of 43% for advanced power strips, compared to the assumed ISR of 47%. Installation locations were found to be roughly similar to the installation locations reported in 2020.

The verified average energy savings and demand reductions were found to be 83 kWh and 0.01 kW per power strip, resulting in a realization rate for advanced power strips of 92% for both energy and demand due to differences in installation from ex-ante (reported) assumptions and a verified in-service rate that was lower than assumed.

3.6.3.4 LED Night Light

ADM confirmed the savings methodology was consistent between reported results and verified results. The program level realization rate for energy savings was found to be 91%. Verified energy savings differ from reported due to the differences between the assumed in-service rate (77%) and verified in-service rate (71%). There is no demand reduction from LED night lights.

3.6.3.5 FilterTone® Alarm

ADM confirmed the savings methodology was consistent between reported results and verified results. The program level kWh and kW realization rates for FilterTone® Alarms were 87%. Verified energy savings differ from reported due to the differences between the assumed in-service rate of 45%, and the verified in-service rate of 39% calculated from the student survey.

[94] Average in-service rate across all 4 bulbs. Per bulb in-service rates varied from 61% for the first bulb to 28% for the fourth bulb. The 2021 in-service rates decreased from the 2020 in-service rates, which varied from 67% to 35%.

3.6.3.6 ENERGY STAR® LED

ADM confirmed the savings methodology was consistent between reported results and verified results. The program level realization rates for kWh and kW were 89% and 84%, respectively. ADM used student surveys to determine LED in-service rates, interactive effects, and coincidence factors. The differences in savings and demand reductions between ADM and the implementer were due to differences between the verified and assumed values for these inputs, as shown in Table 3-136.

Table 3-136: Differences Between Assumed and Verified Inputs for LED Light Bulb Calculations

Calculation Input	Assumed Value	Verified Value
In-Service Rate	50%	45%
Interactive Effect (Energy)	0.93	0.94
Interactive Effect (Demand)	1.24	1.23
Coincidence Factor (CF)	0.078	0.075

Verified annual energy savings and peak demand reduction are based on unit-level gross energy impacts adjusted for ISR for each energy efficiency measure. Table 3-137 details the education kit contents and savings impacts per measure.

Table 3-137: Summary of Kit Contents and Verified Energy Savings and Demand Reduction by Measure

Kit Contents	Quantity	Verified kWh Savings Per Measure	Verified kW Reduction Per Measure	Verified kWh Savings Per Kit	Verified kW Reduction Per Kit
7-Plug Advanced Power Strip	1	82.50	0.0095	82.50	0.0095
LED Night Light	1	18.53	0.0000	18.53	0.0000
FilterTone® Alarm	1	46.38	0.0252	46.38	0.0252
9-Watt LED Light Bulb	4	13.61	0.0014	54.42	0.0056
Digital Thermometer	1	0.00	0.0000	0.00	0.0000
Total				**201.83**	**0.0404**

Table 3-138 and Table 3-139 show a comparison of the verified gross annual energy-savings (kWh) and peak demand reduction (kW) of the 2021 Education Program, by measure to the reported savings estimates.

Table 3-138: Gross Energy-Savings (kWh) Summary by Measure for PY2021

Measure	Reported Energy (kWh) Savings	Verified Energy (kWh) Savings	Realization Rate (kWh)	Verified Lifetime Energy Savings (kWh)
7-Plug Advanced Power Strip	1,415,661	1,302,066	92.0%	13,020,660
LED Night Light	320,122	292,410	91.3%	2,339,277
FilterTone® Furnace Filter Alarm	842,901	731,925	86.8%	10,246,949
9-watt LED	968,068	858,905	88.7%	6,441,786
Total	**3,546,752**	**3,185,305**	**89.8%**	**32,048,673**

Table 3-139: Gross Demand Reductions (kW) Summary by Measure for PY2021

Measure	Reported Demand (kW) Reduction	Verified Demand (kW) Reduction	Realization Rate (kW)
7-Plug Advanced Power Strip	163.68	150.43	91.9%
LED Night Light	0.00	0.00	-
FilterTone® Furnace Filter Alarm	458.33	397.98	86.8%
9-watt LED	104.97	88.39	84.2%
Total	**726.97**	**636.80**	**87.6%**

Evaluation findings represent a kit level realization rate for energy-savings and demand reduction of 90% and 88%, respectively. Reported savings are based on the verified program savings from PY2020, meaning differences between the reported and verified program savings is due to differences in installation locations from 2020 results (used for ex-ante estimates), and a verified in-service rate that was lower than assumed.

3.6.4 Process Evaluation Findings

ADM's process evaluation activities included student and teacher surveys as well as a structured conversation with key personnel responsible for the program. ADM provided a detailed process evaluation memo to PSO after the completion of the 2021 program year.

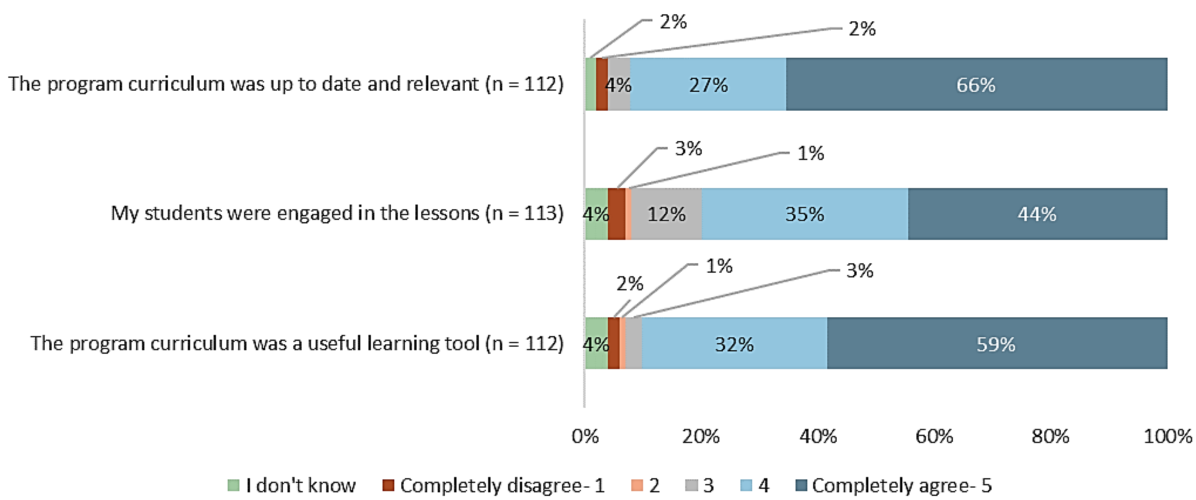
Table 3-140 provides an overview of the kit distribution among the top ten cities out of 129 cities that received kits. The largest proportion of distributed kits occurred in the cities of Tulsa (23%), Broken Arrow (13%) and Lawton (7%).

Table 3-140: Kit Distribution Among Top Ten Cities

City	Number of Schools[95]	Number of Kits	Percentage of Kits
Tulsa	67	3,640	23%
Broken Arrow	24	2,051	13%
Lawton	19	1,053	7%
Bartlesville	9	542	3%
Owasso	7	498	3%
Coweta	2	366	2%
Collinsville	2	340	2%
Bixby	2	272	2%
Sand Springs	5	265	2%
Weatherford	1	222	1%

Most teachers agreed that the program curriculum was up to date and relevant, was appropriate for the learning level of their students, and was a useful learning tool (see Figure 3-40).

Figure 3-40 Teacher Perceptions of the Program Curriculum

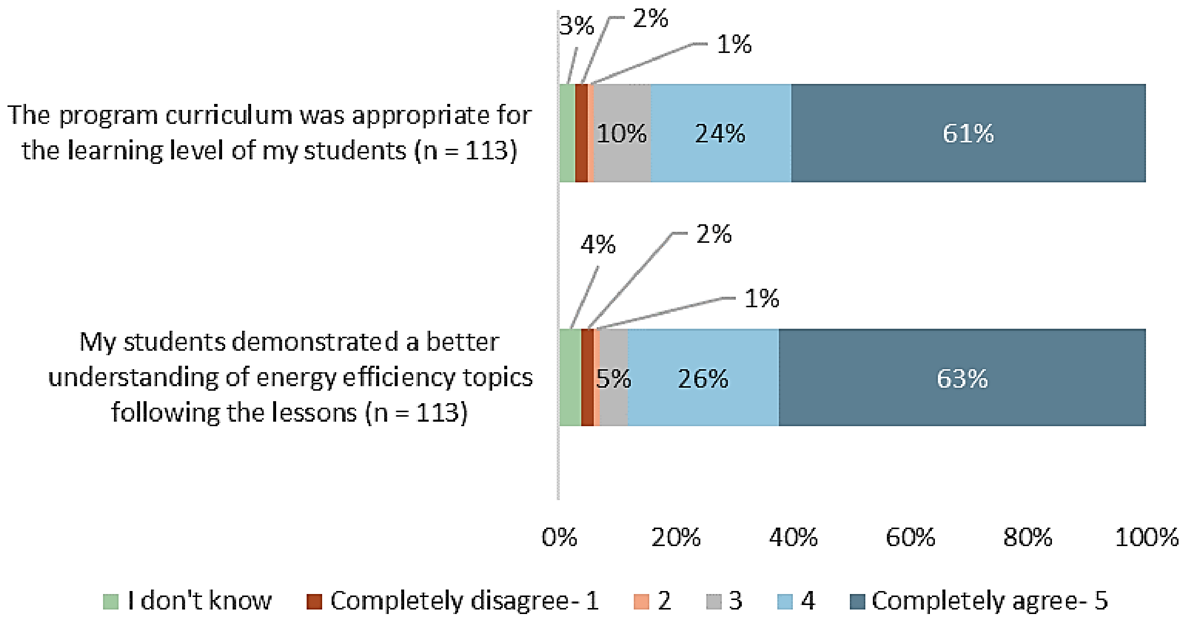


Of the 113 teachers who responded to the survey, most (63%) reported teaching concepts that they normally teach in their regular curriculum. Many teachers indicated their lessons and curriculum would not have been as interactive, and they would not have taught energy efficiency as thoroughly as the program provides.

95 Many schools had multiple teachers participating.

Most teachers (85%) agreed that the material was appropriate for their students' learning level and 89% agreed their students demonstrated a better comprehension of energy efficiency from the lessons (see Figure 3-41).

Figure 3-41 Perception of Student Experience



Almost all teachers (91%) stated they would participate in the program again if given the opportunity.

3.6.5 Conclusions and Recommendations

The following are the key conclusions from the evaluation of the Education program.

- Measures in the kits remained the same from PY2020 to PY2021. Implementers continued to provide digital materials and activities for student and teachers to assist in virtual learning objectives as many schools shift to hybrid learning modes.
- Verified annual energy savings were slightly reduced from the previous year. Gross energy savings are primarily adjusted by the percentage of energy efficiency measures installed, as determined through survey efforts. In 2021, ADM found lower installation rates compared to the previous year, resulting in a 10% reduction in annual energy savings.
- Program was successful in reaching customers and achieved 98.6% of the kit distribution goal of 16,000 kits. Over 70% of teachers surveyed indicated they are repeating program participants, of which 63% stated they have participated for the past four years or more. A total of 15,782 kits were sent to 465 different fifth grade teachers within the PSO territory for PY2021. According to the data, the

implementer sent 554 kits during the spring semester and 15,228 in the fall. The largest proportion of distributed kits occurred in the cities of Tulsa (23%), Broken Arrow (13%), and Lawton (7%).

- Teachers indicated that the COVID-19 pandemic affected different aspects of their instructional time. More than half of teachers indicated that the COVID-19 pandemic impacted their instructional time. Fifty percent reported it impacted their lesson plans, 64% stated it impacted their classroom activities, and 25% said the pandemic impacted the distribution of the kits to students.
- Teachers were satisfied with the program, wanted to participate again, and overall did not feel that the program significantly added to their workload. Almost all teachers (91%) stated they would participate in the program again if given the opportunity. Many survey respondents had positive comments and feedback about the program. Forty-nine percent of teachers indicated that their participation in the program did not add to their overall workload, and none reported a significant increase in their workload because of the program. Many teachers indicated their lessons and curriculum would not have been as interactive, and they would not have taught energy efficiency as thoroughly as the program provides.
- Students were happy with the program and broadened their knowledge of energy efficiency and energy use. Quizzes completed by students before and after completing the curriculum showed an increase in knowledge after participation. Overall, 58% of students stated their family changed energy usage and 61% indicated they worked with their family. Eighty-nine percent rated the PSO Energy Saver Kit as either good or excellent.
- The program continues to reach rural and underserved communities. A total of 820 kits were delivered to schools in cities and towns with fewer than 500 inhabitants. An additional 1,012 kits were delivered to cities and towns with more than 500 and fewer than 1,000 inhabitants (based on 2020 Census data).

The following recommendations are offered for continued improvement of the Education Program.

- Program impacts may be increased by further encouraging teachers to instruct their students on where and how to install the measures in the kits. Providing more instruction to teachers and students on how to install measures such as the advanced power strip and FilterTone® alarm could improve installation rates and result in higher savings.
- Continue to provide online resources and online surveys options to give further flexibility for teachers, students, and parents. Instead of having physical surveys given to the students, continue to promote the digital surveys, especially if these are mobile-friendly. Explore ways of making the survey more interactive as the

students complete their at-home activities (e.g., link how-to videos, create filters that students can use to create social media posts with parent consent, etc.). By providing different channels for resources this could also reduce workload for teachers.

- Consider updating the language in the student survey to provide clearer and more consistent responses. Some of the current language on the student surveys, such as language that includes “If you answered yes to the previous question…” appears to be mis-interpreted or disregarded by students. Consider updating this language to reduce respondent confusion.
- Continue exploring ways to expand the program to other grade levels that builds upon the information taught to fifth graders. For example, creating a different curriculum and kit for seventh graders could be a way of boosting installation rates for more complex measures like furnace whistles and advanced power strips and including additional measures such as home weatherization measures, water saving measures, and smart home devices. The curriculum could focus more on career opportunities and STEAM fields important to the energy sector.
- Continue to focus on recruiting new teachers for the program. Based on program data, ADM estimates that roughly half of the teachers participating are new each year. Continuing to promote the program to new teachers, either through referral incentives, direct outreach to schools, or marketing materials, could improve the reach of the program and help achieve energy saving targets.
- Consider conducting a focus group with willing teachers to learn from them the best ways to improve the program. Twenty-five teachers who participated in the program in 2021 indicated that they would be willing to participate in a focus group to improve the program. Reaching out directly to these teachers could provide new insights as to how the program could continue to serve teachers and students.
- Consider reevaluating the number of measures included in the program. The decrease in ISRs in 2021 may have altered the cost effectiveness of measures in the program, in particular, the four LED bulbs. It may be valuable to review the appropriate number of bulbs for the program based on the cost-effectiveness of the “final” bulb.

3.7 Behavioral Modification

This chapter presents findings from the impact and process evaluation of the 2021 Behavioral Modification program.

3.7.1 Program Overview

The Behavioral Modification Program provides customers with individualized energy reports to generate greater awareness of energy use and educate customers on ways they can reduce energy consumption. The energy report recommends energy saving behaviors and provides customers with a comparison of energy use at similar homes in their area, and across multiple years. It is expected the regular tips and reminders will encourage customers to adopt energy saving behaviors that will lead to more efficient energy use in their homes. In addition, participants are also encouraged to go to an online portal where they can input information about their home to receive specific tips addressing their home energy use.

In developing the program, a pool of potential participants was identified that had emails associated with their accounts. Participants who used more than 5,000 kWh or less than 100 kWh during any month in the review period were excluded from the pool of eligible participants. The implementers used a third-party data set to focus on single-family homes within that pool of potential participants. Participants were randomized into treatment and control groups and the equivalency of their pre-program-year data was verified.

PY2019 was the first year that the current implementor executed the program. In PY2017 and PY2018 the program was implemented by a different team. As of 2021, 4 separate cohorts of PSO customers have received reports through the program. The first group of participants (Wave 1) began receiving reports on October 25, 2017. A second wave (Wave 2) commenced on May 22, 2018. Both Wave 1 and Wave 2 participants initially only received emailed reports and mailed paper reports were also delivered to a subset of customers starting in 2019.

Wave 3 of the program was added on March 20, 2019, via paper reports, and email reports when email contact information is available. Finally, a fourth wave (Wave 4) was added for 2020, and this group began receiving paper and emailed reports on March 1, 2020. No new waves were added in 2021.

Paper energy reports were mailed to treatment participants between February and November 2021. Additionally, emailed energy reports were sent to participants in each wave where email addresses were available.

Table 3-141 shows the performance metrics achieved by the program.

Table 3-141: Performance Metrics – Behavioral Modification Program

Metric	PY2021
Number of Customers	174,380
Budgeted Expenditures	$1,273,750
Actual Expenditures	$1,095,354
Energy Impacts (kWh)	
Projected Energy Savings	22,680,000
Reported Energy Savings	20,200,193
Gross Verified Energy Savings	18,143,843
Net Verified Energy Savings	18,143,843
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	4,123.64
Reported Peak Demand Savings	3,740.42
Gross Verified Peak Demand Savings	3,535.55
Net Verified Peak Demand Savings	3,535.55
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	1.28
Utility Cost Test Ratio	1.22

PSO's Behavioral program serviced 174,380 households during the 2021 program year. Table 3-142 shows the annual energy savings (kWh) per wave for PY2021.

Table 3-142: Verified Energy Savings per Wave

Wave	Number of Treatment Customers	Daily kWh Savings per Customer	Average Annual kWh Savings per Customer	Verified Gross kWh Savings	Verified Net kWh Savings
1	68,439	0.31	111.6	7,637,792	7,637,792
2	29,476	0.42	152.9	4,506,880	4,506,880
3	38,914	0.20	73.3	2,852,396	2,852,396
4	37,551	0.23	83.8	3,146,774	3,146,774
Total	**174,380**	**0.29***	**104.0***	**18,143,843**	**18,143,843**

Reflects an average value weighted by the count of treatment group participants.

3.7.2 EM&V Methodologies

This section provides a brief overview of the data collection activities, gross and net impact calculation methodologies, and process evaluation activities that ADM employed in the evaluation of the Behavioral Modification program.

To determine annual energy savings (kWh) and peak demand reduction (kW), ADM performed an analysis of the billing data for participants in the program using panel regression modeling. The data cleaning steps and methodology for the panel regression approach are presented in the following section.

3.7.2.1 Data Collection

ADM incorporated several types of data into the preparation of the dataset that was used in the regression analysis outlined in this section:

- Pre-program and program year raw monthly billing data for all treatment and control group participants
- Regional temperature obtained from the National Oceanic and Atmospheric Administration (NOAA) for Tulsa International Airport in Tulsa, OK.
- Participant information, including the associated account number and whether the participant was still a part of the program.
- Date each treatment participant received their first energy report.
- A dataset compiled by ADM of participants in PSO's other residential programs used to control for cross-program participation.
- Treatment and control surveys to determine differences in LED purchasing patterns, potential impacts of the coronavirus pandemic, and customer satisfaction.
- In-depth interviews with program staff to support the process evaluation.

3.7.2.2 Survey Sampling Plan

To ensure proper extrapolation of survey results to program participants, ADM surveys a statistically representative sample of both participants and non-participants. For the calculation of sample size for survey completes, a coefficient of variation of 0.5 was assumed.[96] With this assumption, a minimum sample size of 68 participants was required, as shown in Equation 3-4.

[96] The coefficient of variation, cv(y), is a measure of variation for the variable to be estimated. Its value depends on the mean and standard deviation of the distribution of values for the variable (i.e., cv(y) = sd(y)/mean(y)). Where y is the average savings per participants. Without data to use as a basis for a higher value, it is typical to apply a CV of 0.5 in residential program evaluations.

Equation 3-4: Minimum Sample Size Formula for 90 Percent Confidence Level

$$n_0 = \left(\frac{Z*CV}{RP}\right)^2 = (\frac{1.645*0.5}{0.10})^2 = 68$$

Where:

n_0	= minimum sample size
Z	= Z-statistic value (1.645 for the 90% confidence level)
CV	= Coefficient of Variation (assumed to be 0.5)
RP	= Relative Precision (0.10)

3.7.2.3 Survey Objective

The objective of the program survey was to assess participants' overall satisfaction with the program, perceptions of the reports, actions taken to reduce energy consumption, and to compare treatment and control group behaviors, household characteristics, changes due to the COVID-19 pandemic, and LED lighting purchases.

The survey was administered online using an emailed link to a randomly selected group of participants and controls. Reminder emails were sent as needed to increase the number of responses. ADM achieved the targeted number of responses for all groups except Wave 4 Treatment group. The number of customers contacted, and number of surveys completed, by wave, is shown in Table 3-143.

Table 3-143: Summary of Customers Contacted and Response Rates

Wave	Control Group		Treatment Group	
	Number of Customers Contacted	Number of Completed Surveys	Number of Customers Contacted	Number of Completed Surveys
1	1,003	76	1,004	77
2	999	76	998	91
3	999	78	998	72
4	997	70	999	52
Total	**3,998**	**300**	**3,999**	**292**

3.7.2.4 Preparation of Data

ADM performed the following steps to prepare the dataset that was utilized to determine the verified energy savings for the Behavioral Modification Program.

- Verified that participants were sent energy reports during 2021.
- Calendarized the billing data provided by PSO.

- Cleaned the data by removing duplicate bills and string characters in the monthly consumption column.
- Removed billing months with negative consumption on their monthly bill.
- Removed billing readings with consumption less than 10 kWh or greater than 10,000 kWh.
- Removed billing months with reported length of fewer than 9 days or more than 60 days. It is assumed that these values are in error.
- Removed customers without sufficient pre-program and post-program billing data. Pre-Program data was defined as January 1, 2016 – December 31, 2016, for Wave 1, and the 400 days preceding the start date for Waves 2-4.

3.7.2.5 Cross Participation and Uplift

Cross participation occurs when a participant in the Behavioral program also participates in any of PSO's other residential energy-efficiency programs during the program year. These programs included the down-stream measures for Energy Saving Products, Home Rebates, Home Weatherization, and Power Hours, as well as upstream measures from the Energy Saving Products lighting program. Although one of goals of the Behavioral program is to educate participants on other PSO programs, these programs are all evaluated independently and must be considered to avoid double counting of savings.

A two-sample t-test was used to determine if there was a statistically significant difference between the rate of cross-participation among those who received reports (participants), and those who did not (controls). For programs and waves where there was a statistically significant difference in the rate of cross participation (p-value < 0.1), ADM removed all cross participants from both the treatment and control groups to avoid double-counting savings from other programs.

Because the participants in the upstream lighting program are unknown, ADM asked participants and controls about the number of bulbs that they purchased during the year. ADM evaluated if there was a statistically significant difference between the number of bulbs purchased by participants and controls in each wave using a two-sample t test.

3.7.2.6 Methodology for Regression Approach

ADM utilized the mixed effects panel regression model specified in Equation 3-5 to determine daily average electricity savings for treatment group members.

Equation 3-5: Mixed Effects Panel Regression Model

$$AEC_{i,t} = \alpha_i \mathrm{Customer_i} + \beta_1 CDD_{i,t} + \beta_2 HDD_{i,t} + \beta_3 Post_{i,t} + \beta_4 Post_{i,t} * Treat_{i,t} + \beta_5 Post_{i,t} * CDD_{i,t} + \beta_6 Post_{i,t} * HDD_{i,t} + E_{i,t}$$

Where the subscript i denotes individual customers and t = 1. $T_{(i)}$ serves as a time index, where $T_{(i)}$ is the number of bills available for customer i. The model is defined as "mixed effects" because the model decomposes its parameters into fixed-effects (i.e., Heating Degree Days (HDD), Cooling degree days (CDD), Post-Installation period (Post), treatment (Treat), and various interactions) and random effects (i.e., the individual customer's baseline period usage). A fixed effect is assumed to be constant and independent of the sample, while random effects are assumed to be sources of variation (other than natural measurement error) that are uncorrelated with the fixed effects.

The program implementer provided ADM with a dataset that included the participation start date for each treatment group member and their corresponding control group. The first billing period after the beginning of treatment is considered the "deadband period". Observations that occur in the deadband period are not included in the mixed effects panel regression as they contain a mix of pre-treatment and post-treatment data. For the treatment and control group members, the post period begins in the first billing period following the deadband period. The post variable is defined as a 0 in the billing periods prior to the beginning of treatment and a 1 for billing periods following the deadband period.

Heating degree day (HDD) and cooling degree day (CDD) were used in the model to control for energy demand based on outside temperature. HDD is defined as the monthly average difference between 65 degrees (the outside temperature above which it is assumed that a building needs no heating) and the actual outside air temperature. CDD is defined as the monthly average difference between the actual outside air temperature and 65 degrees (the outside temperature under which it is assumed that a building needs no cooling). A minimum value of 0 is used for both HDD and CDD. A description of the variables used in the regression model is shown in Table 3-144.

Table 3-144: Description of Variables Used in the Regression Model

Variable	Variable Description
Average Electricity Consumption ($AEC_{i,t}$)	Average daily use of electricity (kWh) for period t for a customer (determined by dividing total usage in a period by number of days in that period)
Customer	A panel of dummy variables that is a 1 for customer i or a 0 if not
Cooling Degree Days (CDD)	The mean cooling degree days per day during the billing period
Heating Degree Days (HDD)	The mean heating degree days per day during the billing period
Post	Post is a dummy variable that is 1 if the monthly period is after the customer received their first energy report and 0 for the periods before
Treatment	Treatment is a dummy variable that is 1 if the customer is a member of the treatment group and a 0 if the customer is a member of the control group
E_t	E_t is the error term

Table 3-145 describes the coefficients that were determined by using the mixed effects panel model shown in Equation 3-5.

Table 3-145: Description of the Coefficients Estimated by the Regression Model

Coefficient	Coefficient Description
α_i	α_i is a coefficient that represents the grand mean of the customer specific intercepts used to control for any customer specific differences
β_1	β_1 is a coefficient that adjusts for the main effect of cooling
β_2	β_2 is a coefficient that adjusts for the main effect of heating
β_3	β_3 is a coefficient for the main effect of time, i.e., whether an observation falls in the pre-period or post-period
β_4	β_4 is a coefficient that represents the interactive effect of whether an observation falls in the post-period and the treatment effect. This coefficient represents savings attributable to the program.
β_5	β_5 is a coefficient that adjusts for the interactive effect between the post-period and cooling
β_6	β_6 is a coefficient that adjusts for the interactive effect between the post-period and heating

3.7.2.7 Calculation of Annual Energy Savings

The average daily annual energy savings for the post period treatment group is defined as coefficient β_4 in the regression model. To determine per participant annualized savings, the average daily energy savings value is multiplied by 365. The verified annual energy savings for the program is determined by multiplying the annualized energy savings by the number of participants in the treatment group who had existing accounts in 2021 and had not opted out of the program.

3.7.2.8 Calculation of Coincident Peak Demand Reduction

The peak demand reduction was determined by applying the program annual energy savings to a normalized hourly load shape that represents typical residential energy consumption, resulting in an 8,760 hourly annual savings curve. The selected load shape was the same used to determine estimates for the Behavioral Modification Program during portfolio planning. An average value across the peak demand window was drawn from the energy savings curve. The peak demand window is defined as consumption non-holiday weekdays between 2 PM and 6 PM in the months of June through September.

3.7.2.9 Net-to-Gross Estimation

The Behavioral Modification Program was administered using a Randomized Control Trial (RCT) design, allocating participants to either the treatment or control group randomly. As a result, free riders are equally likely to be distributed in both the treatment and control group. The NTG ratio is assumed to be 1, because the RCT design minimizes selection bias and the only assumed difference between the treatment and control groups is the receipt of energy reports.

3.7.2.10 Lifetime Savings

The Behavioral program is considered to have an effective useful life (EUL) of 1 year. This is consistent with behavioral practices and the recommended value from the energy efficiency portfolio plan, as all participants are evaluated each year. Therefore, the lifetime savings total is equivalent to the annual verified energy savings.

3.7.2.11 Process Evaluation

ADM evaluators completed a process evaluation of the PSO Behavioral Program. The Behavioral program provides energy usage reports to residential customers, known as Home Energy Reports (HERs). The program was designed to generate greater awareness of energy use and suggests ways to reduce energy use through behavioral changes. The evaluators conducted participant and non-participant surveys to assess program design, operations, and delivery.

The evaluation addressed the following research questions to better understand the program's effectiveness and efficiency:

- What information is presented in the HERs? Is the information presented clearly or are there opportunities for improvement?
- Did customers notice and read the reports? How many and how thoroughly? Why do some report recipients not read, believe, or act based on the reports?
- Were the program participants satisfied with the content of the reports and the frequency of delivery? What would participants change about how, or how often, the reports are delivered?
- What did the customers think of the information provided? How easy was it to understand? What, if anything, was not easy to understand or did not make sense?
- Do recipients find the reports to be clear and useful? Do report recipients believe what the reports say?
- Was information on their home's energy use accurate and up to date? If they think it wasn't, what did they disagree with and why?
- What actions did participants take to save energy? What kept them from taking other recommended actions? What might have induced them to take additional recommended actions?
- How much does the program affect energy-saving actions and purchases?
- Did customers purchase LED lighting?

- How has the coronavirus pandemic affected the program during 2021? How has it affected customer behaviors and energy usage?
- What were the customer demographics and home characteristics?

Table 3-146 below summarizes the data collection activities and corresponding process evaluation research objectives used to complete the process evaluation.

Table 3-146: Process Evaluation Data Collection Activities Summary

Data Collection Activity	Process Evaluation Research Objectives
Program Materials Review	Review reports and support materials for clarity and consistency with program objectives.
Participant Online Survey	Assess experience with and perceptions of the reports and other information on home energy use, actions taken to reduce energy use, satisfaction, and efficient equipment purchases (including LEDs).
Non-participant Online Survey	Assess actions taken to reduce energy and efficient equipment purchases (including LEDs).

3.7.3 Impact Evaluation Findings

The following section reports the findings for PY2021 annual energy savings and coincident peak demand reduction.

3.7.3.1 Data Review

ADM calculated the average daily pre-treatment consumption for both the treatment and control group participants with current billing data. This step was performed to ensure that the average daily pre-treatment consumption was similar for both the treatment and control groups. The results are reported in Table 3-147.

Table 3-147: Pre-Treatment Average Daily Consumption

Wave	Control Group		Treatment Group		t test p value
	Number of Customers in Regression Model	Average Daily Pre-Treatment kWh	Number of Customers in Regression Model	Average Daily Pre-Treatment kWh	
1	15,638	42.13	68,214	42.16	0.75
2	12,466	47.84	29,371	47.97	0.24
3	19,355	35.00	38,661	35.00	0.97
4	10,853	39.53	37,405	39.55	0.83

3.7.3.2 Cross Participation

ADM assessed whether members of the treatment and control groups participated in PSO's other residential energy-efficiency programs at the same rate by comparing participation in treatment and control groups using a two-sample t-test. ADM determined that there was a statistically significant difference in the rate at which Wave 3 treatment and control group customers participated in the Home Rebates - Single Upgrade program. Members of the Wave 3 treatment and control group who participated in the program were eliminated from the model to avoid double counting savings from the program. No other statistically significant differences were found between participation rates among treatment and control groups for any wave.

Table 3-148 shows the results of the t-tests for each program and wave. The p-value showing evidence of a statistically significant difference is bolded.

Table 3-148: Cross Participation with other PSO Residential Programs

ESP program					
Behavioral Program Wave	Control Group		Treatment Group		t-test
	n	%	n	%	p-value
1	89	0.57%	394	0.58%	0.967
2	59	0.47%	126	0.43%	0.621
3	73	0.38%	149	0.38%	0.943
4	32	0.29%	121	0.32%	0.728
Home Weatherization					
Behavioral Program Wave	Control Group		Treatment Group		t-test
	n	%	n	%	p-value
1	69	0.44%	355	0.52%	0.241
2	49	0.39%	128	0.43%	0.563
3	102	0.52%	181	0.47%	0.365
4	54	0.50%	232	0.62%	0.172
Home Rebates, Multiple Upgrades					
Behavioral Program Wave	Control Group		Treatment Group		t-test
	n	%	n	%	p-value
1	67	0.43%	240	0.35%	0.168
2	28	0.22%	69	0.23%	0.901
3	47	0.24%	81	0.21%	0.472
4	29	0.27%	77	0.21%	0.269

Home Rebates, Single Upgrade					
Behavioral Program Wave	Control Group		Treatment Group		t-test
	n	%	n	%	p-value
1	83	0.53%	316	0.46%	0.287
2	57	0.46%	144	0.49%	0.676
3	44	0.23%	138	0.35%	**0.011**
4	32	0.29%	121	0.32%	0.728
Power Hours					
Behavioral Program Wave	**Control Group**		**Treatment Group**		**t-test**
	n	**%**	**n**	**%**	**p-value**
1	1564	9.97%	6912	10.10%	0.721
2	1009	8.07%	2344	7.95%	0.875
3	828	4.25%	1572	4.04%	0.226
4	577	5.30%	1904	5.07%	0.315

Since the participants of the Energy Saving Products' (ESP) upstream lighting program are unknown, ADM surveyed Behavioral Program treatment and control participants to understand their lighting purchases. To determine if there was program uplift on upstream LED purchases due to the Behavioral Modification program, ADM performed a two-sample t-test on the treatment and control survey data results regarding lighting purchases. The results are provided in Table 3-149. The t-test shows that there was no significant program uplift in LED purchases due to the Behavioral Modification program. Each wave was also tested individually and no statistically significant difference in LED purchases between Treatment and Control participants by wave were identified.

Table 3-149: Cross Participation with ESP's Upstream Lighting Program

Control Group		Treatment Group		t-test p-value
Mean Number of LEDs Purchased	n	Mean Number of LEDs Purchased	n	
11.9	184	12.5	190	0.60

Data Cleaning

Table 3-150 shows the number of accounts left after each step of data cleaning to determine the participants to be used in the model. The steps and rationale for removing participants were based on whether they were cross-participants in other residential PSO programs, if there was no active billing data in the program year, the participant had opted out of the program, billing records were abnormal or outliers, or participants had insufficient data to include in the panel regression analysis. A description of the data cleaning steps is provided in Section 3.7.2.4.

Table 3-150: Number of Accounts After Each Data Cleaning Step

Cleaning Step	Wave 1		Wave 2		Wave 3		Wave 4	
	Control Group	Treatment Group	Control Group	Treatment Group	Control Group	Treatment Group	Control Group	Treatment Group
Original participant list	23,999	104,999	17,830	41,689	25,000	50,000	13,000	45,000
Removed participants not active PSO customers in the program year	15,682	68,455	12,509	29,494	19,461	38,948	10,893	37,557
Removed participants who opted out of email and mailed reports	15,682	68,439	12,509	29,476	19,461	38,914	10,893	37,551
Filter to participants with valid billing readings	15,667	68,347	12,500	29,432	19,443	38,878	10,881	37,519
Removed cross participants	15,667	68,347	12,500	29,432	19,399	38,741	10,881	37,519
Removed outliers	15,638	68,214	12,466	29,371	19,355	38,661	10,853	37,405
Removed accounts with insufficient data	15,638	68,214	12,466	29,371	19,355	38,661	10,853	37,405
Number of accounts in final model	**15,638**	**68,214**	**12,466**	**29,371**	**19,355**	**38,661**	**10,853**	**37,405**

3.7.3.3 Calculated Energy Savings (kWh)

Table 3-151 provides the results of the mixed-effects panel regression model. A negative coefficient indicates daily savings attributable to the program.

Table 3-151: Results of Mixed Effect Panel Regression Modeling

Wave	Post × Treat Coefficient	Standard Error	T-Statistic	P-Value	R-Squared
1	-0.31	0.05	-5.67	<0.001	0.69
2	-0.42	0.08	-4.96	<0.001	0.73
3	-0.20	0.04	-4.75	<0.001	0.59
4	-0.23	0.07	-3.27	0.001	0.68

3.7.3.4 Total Annual Energy Savings (kWh)

Annual energy savings per customer were determined by multiplying the daily kWh savings value by 365 days. Then, the verified annual energy savings total for the program was determined by multiplying the annualized annual energy savings by the number of participants that were in the treatment group. The annual energy savings by wave are reported in Table 3-152.

Table 3-152 Annual Energy Savings, by Wave

Wave	Number of Treatment Customers	Daily kWh Savings per Customer	Average Annual kWh Savings per Customer	Verified Gross kWh Savings	Verified Net kWh Savings
1	68,439	0.31	111.6	7,637,792	7,637,792
2	29,476	0.42	152.9	4,506,880	4,506,880
3	38,914	0.20	73.3	2,852,396	2,852,396
4	37,551	0.23	83.8	3,146,774	3,146,774
Total	**174,380**	**0.29***	**104.0***	**18,143,843**	**18,143,843**

**Reflects an average value weighted by the count of treatment group participants.*

The average daily savings in 2021 remain roughly comparable to the average savings from 2020. The average daily savings for each wave from 2019 through 2021 are shown in Table 3-153.

Table 3-153 Average Daily Savings, by Wave, from 2019-2021

Wave	Daily kWh Savings per Customer, PY2019	Daily kWh Savings per Customer, PY2020	Daily kWh Savings per Customer, PY2021	2020 to 2021 Change
1	0.10	0.29	0.31	+0.02
2	0.20	0.47	0.42	-0.05
3	0.16	0.24	0.20	-0.04
4	-	0.24	0.23	-0.01
Weighted Average	**0.14**	**0.30**	**0.29**	**-0.01**

3.7.3.5 Coincident Peak Demand Reduction (kW)

The peak demand reduction results by wave are reported in Table 3-154.

Table 3-154: Coincident Peak Demand Reduction, by Wave

Wave	Number of Treatment Customers	Verified Net kW Peak Reduction
1	68,439	1,488.32
2	29,476	878.22
3	38,914	555.82
4	37,551	613.19
Total	**174,380**	**3,535.55**

3.7.3.6 Verified Gross Impacts

Verified and reported annual energy savings (kWh) as well as peak demand reduction (kW) are shown in Table 3-155.

Table 3-155: Reported and Verified Annual Energy Savings and Peak Demand Reduction

Reported Energy Savings (kWh)	Reported Peak Demand Savings (kW)	Verified Gross Energy Savings (kWh)	Verified Gross Peak Demand Savings (kW)	kWh Realization Rate	kW Realization Rate
20,200,193	3,740.42	18,143,843	3,535.55	90%	95%

3.7.3.7 Net and Lifetime Evaluation Impacts

As described in the methodology section, net impacts are equivalent to gross impacts for the Behavioral Modification Program. The effective useful life of the Behavioral Modification Program is 1 year, making the lifetime energy savings equivalent to the annual energy savings.

3.7.4 Process Evaluation Findings

ADM’s process evaluation activities included 592 survey responses, an interview with the PSO Program manager, and an interview with the implementer. ADM provided a process evaluation memo to PSO in November of 2021 with detailed findings. The following summarizes the key findings from the process evaluation of the Behavioral Modification Program. The PSO Behavioral Program remained consistent with previous years, with no significant program changes or new waves launched in 2021.

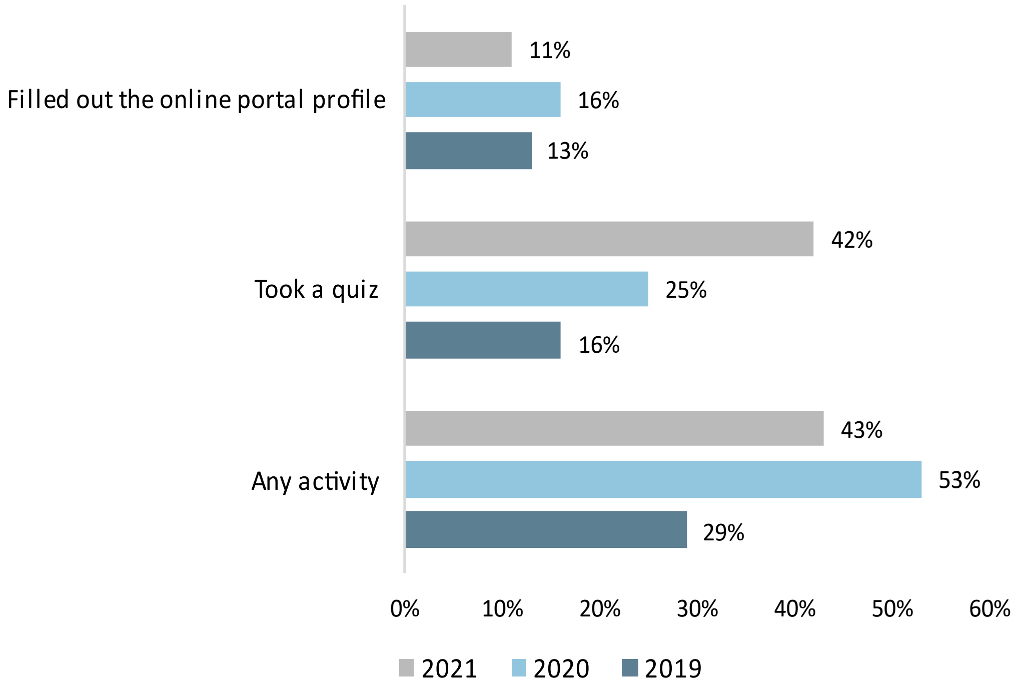
Participant satisfaction was reported for several program characteristics and has remained consistently high from 2019 to 2021. Ratings on the information provided in the energy reports as well as the frequency and method of receiving the reports were high with over 70% of respondents reporting being satisfied or very satisfied. Results are shown in Table 3-156.

Table 3-156: Program Year Comparison of Satisfaction with HERs Aspects

Customer Satisfaction	2019	2020	2021
Information Provided on Home's Energy Use			
1 – Very dissatisfied	2%	1%	3%
2	3%	1%	3%
3	11%	14%	13%
4	31%	22%	28%
5 – Very satisfied	51%	60%	52%
Number of Emails Received on Home's Energy Use			
1 – Very dissatisfied	1%	1%	1%
2	3%	4%	3%
3	14%	19%	17%
4	30%	23%	26%
5 – Very satisfied	45%	48%	47%
Frequency of Receiving HER			
1 – Very dissatisfied	1%	1%	1%
2	2%	3%	5%
3	13%	9%	14%
4	28%	26%	22%
5 – Very satisfied	50%	56%	56%
Method of Receiving HER			
1 – Very dissatisfied	1%	1%	2%
2	1%	2%	2%
3	9%	8%	11%
4	23%	26%	24%
5 – Very satisfied	64%	63%	59%

The amount of participant interactions with available online tools can be used as an indicator of interest in performing energy efficiency actions. Program year 2021 saw a slight decrease in Smart Energy Rewards activity among participants based on survey results. Results are shown in Figure 3-42.

Figure 3-42: Program Year Comparison of Participation in Online Portal



3.7.5 Discussion of Differences Between PY2019, PY2020, and PY2021.

The Behavioral Program energy savings during 2021 remain comparable with energy savings found in 2020 and higher than savings found in 2019. The increase in savings in 2020 and 2021 is likely due to the persistent impacts of the COVID-19 pandemic on residential customers as customers continue to spend more time at home and adjust their behaviors in response to the pandemic. The values reported in this evaluation are consistent across the industry.[97]

To determine the potential impact of the coronavirus pandemic on program savings in 2021, ADM included survey questions in both the control and treatment participant surveys. The questions inquired about behavioral and usage changes related to economic impacts and safety ordinances due to the COVID-19 Pandemic. ADM performed a two-sample t-test on the treatment and control survey data results regarding these behavioral changes. The results are provided in Table 3-157. The results of the t-tests show no statistically significant differences between the control and treatment

[97] Measured savings over 400 kWh/year have been verified in some instances. For an example of a compilation of Behavioral program annual savings results, see Kane, R. and Srinivas, N. “Unlocking the Potential of Behavioral Energy Efficiency: Methodology for Calculating Technical, Economic, and Achievable Savings Potential,” ACEEE Summer Study on Energy Efficiency in Buildings. 2014. Accessible via: https://www.aceee.org/files/proceedings/2014/data/papers/5-284.pdf

groups regarding ways participants' energy usage may have been affected by the pandemic.

Table 3-157: Coronavirus Pandemic Responses

Question	Percent Impacted		T Test P Value
	Control Group	Treatment Group	
How has the coronavirus pandemic changed the amount of time you spend at home?	76%	74%	0.72
Has the coronavirus pandemic affected your ability to participate in PSO's energy-efficiency programs?	55%	61%	0.18
Have you noticed any change in your electricity bill since the coronavirus pandemic?	41%	48%	0.15

3.7.6 Conclusions and Recommendations

This section presents conclusions and recommendations based on evaluation of the program for the 2021 program year.

3.7.6.1 Conclusions

The following conclusions were developed from the evaluation findings.

- The PSO Behavioral program fell slightly short of the projected energy savings for PY2021. Final verified net annual energy savings totaled 18,143,843 kWh and verified net peak demand reduction totaled 3,535.55 kW, for a program-level realization rate of 90% for kWh and 95% for kW.
- Most survey respondents have consistently rated the energy saving tips and recommendations included in the HERs as valuable since 2019. On average, 70% of survey respondents indicate the energy saving tips and recommendations are valuable to them.
- Participants who reported behavioral changes engaged with more program components. 80% of respondents said that the information provided in the HERs was important in their decision to take energy-saving actions. Many of the people who underwent behavioral changes reported logging on more frequently to the My Energy Advisor web portal. Of those who said they logged on, 76% reported making some changes, compared to only 61% of those who did not say they logged on to the portal.
- Most respondents reported buying LED bulbs in 2021, and just over 20% of respondents reported purchasing or installing energy efficient equipment or appliances other than lighting in 2021. The most common items were ENERGY STAR® certified appliances.

- Approximately three-quarters of survey respondents reported spending more time at home in 2021 and 48% noticed a change in their electricity bill since the start of the pandemic, with most indicating an increase.

3.7.6.2 Recommendations

The following recommendations are offered for improvement of the Behavioral Program.

- Explore ways of increasing the accessibility of mailed and emailed Home Energy Reports. Some respondents suggested increasing the font size on reports. Increasing font size and creating 508 compliant (e.g., color-blind-friendly) graphs could increase the utility of the reports for those with poor eyesight, such as elderly participants.
- Consider providing customer education about the home comparison component. Nearly all comments about inaccuracies in the Home Energy Report related to concerns around the home comparison. It may be helpful to provide additional details regarding the analysis of home comparisons to increase trust in this component.
- Some participants appear to exhibit unusually high energy consumption compared to other homes in their cohort. These customers appear to be especially dissatisfied with the home energy reports as they do not believe the results shown in the report. It may be possible to identify participants with especially high consumption and reach out directly to them to explore ways of reducing their energy consumption. This would provide additional savings for the program and could improve perceptions of the company and the Behavioral program.

3.8 Conservation Voltage Reduction (CVR) Program

This chapter presents findings from the impact and process evaluation of the 2021 Conservation Voltage Reduction (CVR) program.

3.8.1 Program Overview

PSO's Conservation Voltage Reduction (CVR) program uses a system of devices, controls, software, and communications equipment to manage reactive power flow and lower voltage level for implemented distribution circuits. Under ANSI Standard C84.1 Electric Power Systems and Equipment, a utility system is to deliver electricity to end-users at a voltage within the range of 120 ± 5% volts (i.e., 114 – 126). With the usual system design, customers close to a substation receive voltages closer to 126 volts and customers farther from the substation receive lower voltages. Because most electric devices are designed to operate most efficiently at 115 volts, any "excess" voltage is typically wasted, usually in the form of heat.[98] PSO's CVR program uses a software program called "Yukon", a control system from Eaton that monitors the voltage and power factor along the distribution circuit and lowers the voltage profile within an acceptable bandwidth. The tighter voltage regulation provided by CVR technology allows end-use devices to potentially operate more efficiently without any action on the part of consumers. Consumers receive a lower but still acceptable voltage and use less energy to accomplish the same tasks.

PSO approached the implementation of CVR in a holistic, system-wide manner, to fully optimize the energy efficiency potential. PSO considered the following three system configurations and decided on full implementation of these configurations.

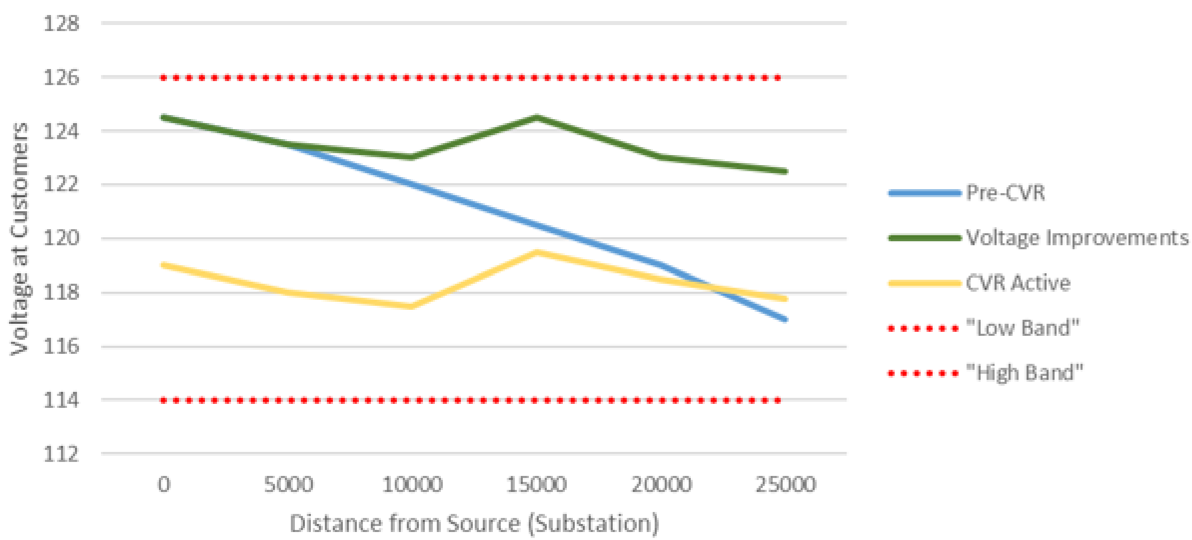
- Typical distribution configuration: This configuration utilizes existing equipment in its current state to assist with distribution operation. It does not include any update to equipment or settings.
- Distribution equipment location optimization: This configuration includes new optimized locations with new equipment and settings for capacitor banks and regulators, which allow the system to operate more efficiently.
- Networked distribution equipment settings optimized: The final stage includes optimized locations for the equipment, along with end of line sensors that monitor the voltage. All the equipment is now communicating with a backend system (Yukon) and a fully implemented CVR system.

The inclusion of systematic upgrades results in a more consistent delivery of voltage to customers. As shown in Figure 3-43, blue represents voltage of a typical distribution system configuration, green represents a typical distribution system with equipment

[98] https://www.tdworld.com/grid-opt-smart-grid/cvr-here-stay

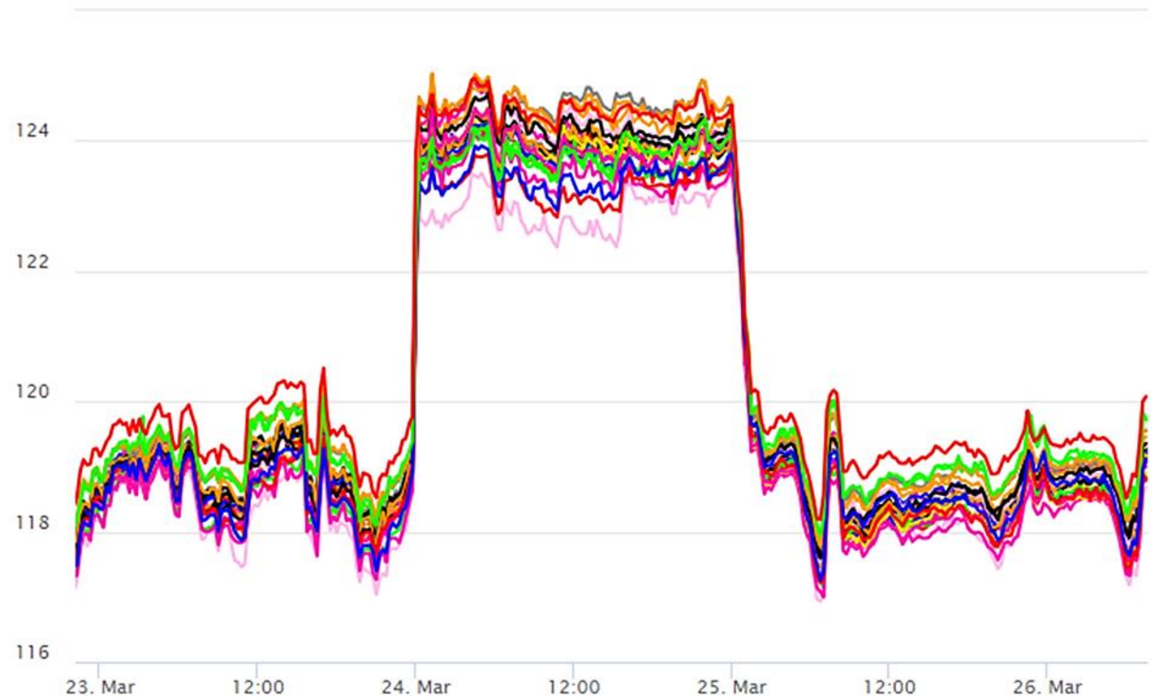
locations and settings optimized, and yellow represents the lowered voltage with typical CVR enabled (hardware and software). Keeping the system below 120V provides an efficient voltage for customers and reduced load demand from the utility and reduced usage from the customer.

Figure 3-43: Various Voltage Profiles with Modifications



A tighter distribution of voltages is evident in PSO's implementation of optimizing networked distribution equipment. As shown in Figure 3-44, CVR is enabled on March 23rd, disabled on March 24th, and enabled on March 25th. Each colored line represents a piece of equipment along the feeder providing a unique voltage reading. The tighter the distribution, the tighter bandwidth that PSO is operating at along the entire circuit. A larger distribution of voltages would likely indicate the system could not reduce voltage drop further through the utilization of system upgrades such as a capacitor bank, thus resulting in additional energy losses. When CVR is enabled, there is a significantly lower voltage with a tighter spread between the voltage points, compared to when CVR is disabled.

Figure 3-44: Example PSO Circuit with CVR and Upgrades during Evaluation Testing



To support CVR at this configuration, PSO had electrical engineers design, model, and coordinate the installation of equipment. Once the equipment was installed, the engineers worked with numerous departments to implement a communication network and install Eaton's Yukon software to get CVR active and online. PSO followed a bid process to select Eaton's Yukon software based on price, features, and operational standards.

The PY2021 CVR program M&V evaluation consisted of 4 substations and 24 circuits (See Table 3-158). PSO's CVR deployment included upgrades inside the substation, as well as on the distribution system. Inside the substation included installing a new RTU, as well as new relaying or metering equipment to provide all the necessary information for the CVR system to function properly. The distribution system required the installment of voltage regulators, capacitor banks, end of line monitors, and repeaters. Once the construction was complete, all devices underwent a commissioning period of field testing. After field testing was completed and Yukon was programmed, CVR was put into service.

Table 3-158: CVR Deployment Timeline

Substation	Construction Start Date	Construction Complete Date	In Service Date
Bartlesville Southeast	6/1/2020	9/10/2020	11/17/2020
Broken Arrow & 101st	5/18/2020	6/23/2020	8/26/2020
Weatherford Junction	5/18/2020	6/9/2020	8/27/2020
Yale & Archer	5/8/2020	6/29/2020	11/19/2020

Circuits associated with the four substations serve a range of residential, commercial, industrial, municipal, and other/unknown customers. A breakdown of customer counts by sector (from historical data) is shown in Table 3-159.

Table 3-159: Circuit Customer Count

Substation	Customer Count	Residential	Commercial	Industrial	Other/Unknown	Municipal
Bartlesville Southeast	7,811	88%	6%	1%	5%	1%
Broken Arrow & 101st	11,122	90%	6%	0%	4%	0%
Weatherford Junction	2,669	67%	15%	2%	12%	5%
Yale & Archer	7,783	76%	7%	1%	15%	1%

Gross annual energy savings at the substation were projected to be 15,970,311 kWh for the circuits claimed in 2021. ADM's verified savings estimates for CVR at the substation are 16,771,745 kWh, resulting in an 105% realization rate for gross annual energy savings. Table 3-160 provides reported and verified program performance metrics.

Table 3-160: PY2021 CVR Program Overview

Metric	PY2021
Number of Customers	29,385
Budgeted Expenditures	$1,026,114
Actual Expenditures	$1,485,248
Energy Impacts (kWh)	
Projected Gross Energy Savings	15,619,842
Reported Energy Savings	15,970,311
Gross Verified Energy Savings	16,771,745
Net Verified Energy Savings	16,771,745
Peak Demand Impacts (kW)	
Projected Gross Peak Demand Savings	4,402.93
Gross Verified Peak Demand Savings	3,569.03
Net Verified Peak Demand Savings	3,569.03
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	1.45
Utility Cost Test Ratio	1.32

PSO implemented the program using Eaton's Yukon Integrated Volt/VAR Control (IVVC) automation software.[99] Voltage levels were controlled independently for each of the three phases for all evaluated circuits.

3.8.2 EM&V Methodologies

For the PY2021 CVR Program, ADM estimated typical year annual energy savings (kWh) resulting from the implementation and evaluation testing of CVR for the first year of each circuit. This section provides a description of the data collection, data cleaning, and regression analysis methodologies that ADM employed in the evaluation of the Conservation Voltage Reduction program.

ADM provided a schedule of events to either deactivate CVR or conduct a transition test on the evaluated circuits on certain days. These two evaluation methods are described in detail in this section. The schedule was balanced in terms of days where CVR was either on, off, or had transition tests conducted such that ADM would be able to maximize operational time but still have enough "off" and "transition test" period data to achieve a statistically significant counterfactual baseline for the evaluation methodologies employed in this analysis. In addition, timeseries voltage and power consumption data at minute intervals was provided to ADM by PSO every month for the evaluated circuits reflecting the substation operating schedule recommended by ADM. Upon delivery of this data ADM conducted a review to verify that the "off" events and transition tests were responding as expected such that it could be incorporated into the final analysis of savings. ADM alerted PSO to any abnormalities or departures from steady state operation that would interfere with the accurate evaluation of savings.

3.8.2.1 On / Off Regression Analysis Methodology

ADM performed an extensive review of data which involved both algorithmic and graphical detection of abnormalities. This involves any sudden voltage or consumption spikes, repeating values, or other unusual behaviors not characteristic of typical substation operation. Data identified as capable of biasing the regression analysis was necessarily removed as even small abnormalities can alter results when trying to identify a relatively small effect (less than a 5% change in consumption) due to operation of CVR mode. Various data processing steps are applied to the data before analyzed. These steps include:

[99] Eaton Integrated Volt/VAR Control
https://www.eaton.com/content/dam/eaton/products/utility-and-grid-solutions/grid-automation-systems/volt-var-management/volt-var-management-software/integrated-volt-var-control-br910005en.pdf
https://www.eaton.com/FTC/buildings/KnowledgeCenter/WhitePaper2/index.htm

Combining substation data from PSO with weather data from NOAA

Local temperature data was retrieved from the National Oceanic and Atmospheric Administration (NOAA). Temperature values were converted to cooling degree days (CDD) and heating degree days (HDD). This was done because CDD and HDD values can quantify how power consumption relates to the weather more effectively than temperature values. Equation 3-6 shows how temperature is converted to CDD.

Equation 3-6: Temperature to CDD Conversion and Temperature to HDD Conversion

$$CDD_t = \begin{cases} 0 & if\ temp_t < cddbase \\ (temp_t - cddbase)\ /\ 24 & if\ temp_t \geq cddbase \end{cases}$$

$$HDD_t = \begin{cases} 0 & if\ temp_t > hddbase \\ (hddbase - \ temp_t)\ /\ 24 & if\ temp_t \leq hddbase \end{cases}$$

Where:

$temp_t$ = temperature at time t

$cddbase$ = CDD base temperature

$hddbase$ = HDD base temperature

To calculate the most accurate CDD and HDD values, the optimal CDD and HDD base temperature for each circuit was interpreted. For a detailed description of how optimal CDD and HDD base temperatures are determined, see Appendix G.

Identifying CVR Mode for each hour of the year

To determine when CVR is operational (on) and when it is not (off). Specifically, ADM fits a k-means clustering model (with two centers) to a circuit's voltage data. Hours with voltages assigned to the higher value voltage center is classified as an "on" hour, and hours with voltages assigned to the lower value voltage center is classified as an "off" hour. Manual inspection of all circuits' CVR mode classifications are also performed, and any obvious misclassifications are corrected.

Extreme outlier removal

In some instances, usage values can be extremely high or low. There are many different reasons this could occur, such as loads being temporarily shifted between circuits due to substation maintenance, extreme and unusual conditions that impact substation usage, or simple data recording errors. While these extreme values are rare, they have potential to have a large negative impact on the quality of a linear regression model. Due to this, any value that is it is more than 1.5 * IQR above the third quartile or 1.5 * IQR less than the first quartile is considered an extreme outlier and removed from the analysis.

Creating a representative 50:50 sample of ON and OFF days

For the most accurate results, the data that is input into the regression consists of an approximately equal number of data points where CVR was on and off under like conditions. Since the schedule ADM provided to PSO consisted of approximately one day per week where CVR was off to maximize operational time, this meant filtering down to days adjacent to any days where CVR was off to maximize the likelihood of capturing like conditions. Specifically, each datapoint where CVR was operational is matched with a datapoint where CVR was not operational, within five days of the operational datapoint, and had similar weather. This creates a dataset with an equal number of datapoints where CVR was "on" and CVR was "off".

Regression Analysis

The on/off regression analysis for CVR is the accepted industry standard for evaluation of voltage control technologies.[100] The regression model configuration used for this analysis is described in Equation 3-7.

Equation 3-7: CVR Regression Model Configuration

$$kWh_t = \beta_o + \beta_1 * Mode_t + \beta_2 * CDD_t + \beta_3 * WeatherVar2_t + \beta_4 * DayType_t + \beta_\theta * Hour_t + e_t$$

Where:

t = the hourly interval the model is predicting usage for

$Mode_t$ = 1 if CVR is on during time t; 0 otherwise

CDD_t = cooling degree days at time t

$WeatherVar2_t$ = if modeling the heating season months then it is heating degree days at time t; otherwise, it is cooling degree days at time t-1

$DayType_t$ = the hourly interval the model is predicting usage for

$Hour_t$ = 1 if CVR is on during time t; 0 otherwise

The coefficient β_1 gives the estimated hourly savings the occur due to a substation circuit operating in CVR mode. All other coefficients are meant to control for other known variables that impact energy consumption, such as weather, time-of-day, and time-of-week. Separate regressions are run for the cooling season dataset (May through September) and the heating season dataset (October through April). In the event circuit level consumption is not dependent on weather (such as high industrial loads) the regression parameters are adjusted as needed.

[100] Conservation Voltage Reduction/Volt VAR Optimization EM&V Practices https://www.energystar.gov/sites/default/files/asset/document/Volt%20Var%20and%20CVR%20EMV%20Best%20Practice%2006-01-17clean%20-%20508%20PASSED.PDF

CVR Factor Calculation

The result of the regression analysis is an estimated hourly savings value that results from CVR being operational on the given circuit during a given season. This value is then extrapolated to a percent reduction value to calculate the "CVR factor". The CVR factor represents the ratio between the percentage change in energy and the associated percentage change in voltage. Equation 3-8 shows how this value is calculated.

Equation 3-8: CVR Factor Calculation

$$CVR\ Factor = \frac{\%\Delta\ Energy\ Consumption}{\%\Delta\ Voltage}$$

Where:

$\%\Delta\ Energy\ Consumption$ = the % reduction in energy consumption when CVR is operational vs. not operational, as estimated in the regression analysis

$\%\Delta\ Voltage$ = the average % reduction in voltage when CVR is operational vs. not operational

Voltage Profile Determination

The final estimate of savings for each circuit and phase in the evaluation pool was calculated by taking the CVR factor for each circuit and phase from the analysis and multiplying it by the percent change in voltage of the voltage profile that best reflects both the average baseline and average operational voltages for that circuit. For more information on the process used for determining the most accurate voltage profile for each circuit are as follows.

Where available, ADM uses voltages from circuit regulators. We will take a weighted mean across the line voltage regulators (where the weights are determined by the load for each regulator section) in both their off and on conditions. Regulator voltages represent operating conditions accurately in cases where the substation is operated on a load tap change (LTC) system. LTC's have limited functionality due to operating in a "gang" related manner: if one phase is raised, all three must be raised and vice versa. This creates a limit in the system's ability to lower voltage both due to load imbalances between phases and from geographic limitations. For imbalanced phases, the minimum achievable voltage on one phase limits the change in voltage on the other phases (i.e., Phase B with an operational midline around 120 volts will not be able to achieve lower voltages if Phase A is already at its' lower limit). Geographic limitations exist in systems that include a large variety of conductor sizing and load locations. This mainly applies to rural areas where there may be three feeders on one transformer, but each feeder has a very different distribution of load.

Regulator stations provide the ability to isolate voltages along the line for providing a more accurate representation of the system voltage profiles. If this data is not available, has significant missing data, or if the data is counterfactual (example: voltage is regularly listed as being lower at the circuit's feeder head than at the regulator stations), then this method is not used to determine the voltage profile

Where regulator voltage and kilowatt-hour data are not available, ADM uses the operational voltages from the feeder head, from the year before CVR was installed. In this method, the baseline condition is determined to be the pre-installation operational voltages from the feeder head. Applying the pre-installation voltages helps account for the efficiency improvements made by new equipment (capacitor banks, regulator stations, etc.) that otherwise would not be detected in the "off" condition after the new equipment installation. Note that in some cases pre-installation voltages are not available. In these cases, the baseline voltage profile used is simply the average voltage across all hours where CVR was not operational.

Final Savings Calculation

With CVR factors calculated and baseline voltage profiles determined, final savings can be calculated. Note that this is done separately for each circuit, phase, and season combination. Equation 3-9 shows how average daily percent usage reductions are calculated using the CVR factors estimated in previous steps.

Equation 3-9: Daily Percent Savings Calculation

$$DailySavingsPercent = CVRFactor * \%\Delta\, Voltage$$

Where:

$CVRFactor$ = The CVR factor

$\%\Delta\, Voltage$ = the average % reduction in voltage when CVR is operational vs. not operational

Daily kWh savings are then calculated by multiplying the average daily percent savings value with the average daily baseline energy consumption value. Final seasonal savings values are then calculated by multiplying the actual daily kWh savings by the number of days in the season. Equation 3-10 shows this calculation.

Equation 3-10: Season Savings Calculation

$$SeasonSavings = (DailySavingsPercent * DailyBaselineEnergyUsage) * sdays$$

Where:

$DailySavingsPercent$ = Average daily % reduction in energy consumption

$DailyBaselineEnergyUsage$ = Average daily usage when CVR is not operational

$sdays$ = Number of days in the evaluated season

Note that these are "typical year annual energy savings". This means that final savings values represent the amount of savings that would have occurred had CVR been operational during every hour of the year.

3.8.2.2 Methodology Changes Unique to Specific Circuits

Most circuits go through the same process for data cleaning, analysis, and results calculation. However, there were some special cases during PY2021 in which certain circuits needed to be evaluated differently than the others. Table 3-161 shows each circuit/season combination that had a unique step in its evaluation, as well as the reason why this unique step was needed.

Table 3-161: Unique On/Off Analysis Steps for PY2021

Circuits	Season	Description
J1, J2, J6	Cooling	CVR on these circuits had a significant amount of down time, resulting in there not being enough usable data in the cooling season to generate statistically significant savings results. Savings were instead extrapolated by taking an average CVR factor from circuits J3, J4, and J5. These circuits were chosen for the averaging due to them being on the same substation and having the most similar distribution of energy load between residential, commercial, and industrial sectors.
WJ19	Both	This circuit showed no correlation between weather variables and energy usage. Because of this the regression analysis for this circuit did not include the two weather variables that were used in all other models.
85736	Heating	Usage patterns in the months of January to April and usage patterns in the months of October to December varied. Due to these differences, it was not possible to fit a well performing linear regression model to the entire dataset. As a result, ADM fit this circuit's regression model using only data from the months of October to December.
ZJ5	Both	One of the three phases was missing 5% of data. Due to this, ADM used average values from the other two phases to represent the third phase for the missing periods.

3.8.2.3 Coincident Peak Demand Reduction (kW) Methodology

The gross verified peak demand reduction (kW) is calculated by multiplying the identified percent energy consumption reduction for each circuit and phase by the total consumption during the system-wide peak consumption hour. In PY2021, the system peak consumption time was 4 PM to 5PM on August 25th.

3.8.2.4 Transition Test Methodology

The transition test analysis involved determining the effect on consumption for each test and then averaging the effect across all tests for each circuit and phase to develop a reasonable estimate of savings. For each approximately 10-minute-long transition test, the consumption and voltage were averaged across the transition test portion and the time periods approximately 10 minutes prior and following the test. Equation 3-11 shows how savings are calculated for a single transition test.

Equation 3-11: Transition Test Event Savings

$$kWhSavings = mean_{t \in OFFTimes}(kWh_t) - mean_{t \in ONTimes}(kWh_t)$$

Where:

kWh_t = kWh that occurred during the one-minute time interval t

$OFFTimes$ = the set of all one-minute time intervals that occurred ten minutes before the start of the test and ten minutes after the end of the test

$ONTimes$ = The set of all one-minute time intervals that occurred after the start of the test and before the end of the test

The estimated daily savings for each date (which can consist of 2-4 individual transition tests) is then calculated using a weighted average where the weights are the average consumption conditions at the time of each test. These values are then averaged across the entire season of transition tests to develop an estimate for daily average savings. From this, a CVR factor can be developed which can be used to estimate savings due to different changes in voltages. See Equation 3-8 for more on how CVR factor values are calculated.

Note that, because voltage step change implemented in each transition test does not reach the true baseline voltage, final savings estimates are developed by applying the voltage profile used in the on/off testing analysis.

3.8.3 Net-to-Gross Methodology

A net-to-gross ratio of 100% is assumed for this program, as it is impossible for a premise to receive reduced voltage due to CVR in the absence of the program.

3.8.4 Impact Evaluation Results

The evaluation of CVR includes an impact evaluation to determine the gross verified typical year annual energy savings (kWh) and gross verified typical year coincident peak demand reduction (kW). These results are presented from the industry standard evaluation method utilizing CVR system “OFF” days to develop CVR Factors (as described in Section 3.8.2). As additional improvements were made to each electrical circuit, baseline voltage condition was derived from the full year before CVR installation. Net impacts are equivalent to gross impacts for the CVR program due to the nature of implementation at the distribution level with no incentives provided.

3.8.4.1 Verified Annual Energy Savings (kWh)

The gross verified annual energy savings (kWh) at the substation for PY2021 are 16,771,745 kWh. This represents an overall annual percent energy savings of 2.66% relative to the evaluated circuit demand. Table 3-162 and Table 3-163 below show the summary of a typical year's gross verified annual energy savings separated by season (Cooling versus Heating) due to operation of CVR on each circuit.

Table 3-162: CVR Cooling Season Verified Energy Savings (kWh)

Substation	Circuit	% Savings	Cooling Season Savings (kWh)	Cooling Season Annual Baseline Consumption (kWh)
Bartlesville Southeast	85731	2.29%	396,214	17,319,584
	85732	2.16%	341,925	15,795,731
	85733	2.27%	189,637	8,344,901
	85734	2.74%	390,333	14,244,091
	85735	1.72%	238,026	13,828,533
	85736	1.58%	248,626	15,777,039
Yale & Archer	J1	1.64%	257,120	15,676,443
	J2	1.56%	425,341	27,326,818
	J3	2.73%	172,612	6,313,706
	J4	2.25%	236,008	10,487,902
	J5	2.08%	347,747	16,681,141
	J6	1.55%	231,209	14,877,532
	J7	1.66%	287,671	17,311,862
Weatherford Junction	WJ13	2.47%	416,474	16,832,191
	WJ16	3.00%	253,703	8,466,568
	WJ19	1.83%	127,030	6,934,440
Broken Arrow & 101st	ZJ1	3.29%	556,133	16,926,653
	ZJ2	1.80%	91,423	5,092,235
	ZJ3	2.71%	503,256	18,570,042
	ZJ4	1.45%	321,638	22,192,595
	ZJ5	2.29%	214,486	9,383,357
	ZJ6	2.58%	180,014	6,974,776
	ZJ7	2.78%	447,012	16,103,662
	ZJ8	1.93%	405,090	20,989,693
Total		**2.13%**	**7,278,727**	**342,451,493**

Table 3-163: PY2021 CVR Heating Season Verified Energy Savings (kWh)

Substation	Circuit	% Savings	Heating Season Savings (kWh)	Heating Season Annual Baseline Consumption (kWh)
Bartlesville Southeast	85731	2.39%	354,235	14,824,727
	85732	3.37%	411,566	12,217,677
	85733	2.90%	217,929	7,522,633
	85734	3.49%	501,374	14,363,618
	85735	2.25%	223,905	9,967,998
	85736	3.27%	300,695	9,189,832
Yale & Archer	J1	3.65%	517,914	14,192,263
	J2	2.12%	579,462	27,299,359
	J3	3.19%	154,343	4,840,034
	J4	2.56%	256,102	10,018,842
	J5	3.05%	445,920	14,615,800
	J6	3.12%	433,098	13,862,931
	J7	5.36%	800,882	14,948,806
Weatherford Junction	WJ13	3.78%	714,520	18,917,050
	WJ16	2.93%	282,585	9,640,116
	WJ19	2.62%	207,131	7,897,047
Broken Arrow & 101st	ZJ1	5.22%	539,012	10,316,977
	ZJ2	2.55%	119,236	4,679,462
	ZJ3	4.12%	464,289	11,266,149
	ZJ4	3.33%	586,415	17,594,374
	ZJ5	3.38%	243,516	7,200,535
	ZJ6	2.94%	163,038	5,554,197
	ZJ7	3.56%	351,251	9,875,680
	ZJ8	3.41%	624,599	18,330,066
Total		**3.28%**	**9,493,018**	**289,136,172**

In cases where no circuits in a substation achieved sufficient evaluation testing for a given season, an estimate was calculated by applying an average ratio adjustment to that substation's other season CVR factor. More detailed results, reported for each distinct circuit, phase, and season combination can be seen in Section 3.8.6.

3.8.4.2 Verified Coincident Peak Demand Reduction (kW)

The gross verified coincident peak demand reduction (kW) for PY2021 is 3,569.01 kW. This represents 75.2% of the projected peak demand reduction. Results per circuit are shown in Table 3-164.

Table 3-164: Verified Peak Demand Reduction

Substation	Circuit	Peak Demand Reduction (kW)
Bartlesville Southeast	85731	226.39
	85732	198.45
	85733	109.40
	85734	200.70
	85735	128.49
	85736	126.24
Yale & Archer	J1	114.87
	J2	179.61
	J3	82.59
	J4	102.05
	J5	154.18
	J6	98.85
	J7	132.86
Weatherford Junction	WJ13	191.55
	WJ16	119.75
	WJ19	37.55
Broken Arrow & 101st	ZJ1	277.04
	ZJ2	46.10
	ZJ3	251.24
	ZJ4	185.66
	ZJ5	95.18
	ZJ6	91.34
	ZJ7	218.14
	ZJ8	200.80
Total		**3,569.03**

3.8.4.3 Transition Test Analysis Results

Transition tests are instances in which CVR operation mode is turned “off” for several short intervals throughout the day (rather than turning it off for a full day). The change in load during these intervals (transition tests) may be used to estimate CVR program energy savings. ADM performed a separate analysis of savings using data from these transition tests, as described in Section 3.8.2.3.

In a typical year, results would be estimated for each circuit, phase, and season combination as they are for the on/off testing analysis. However, due to a lack of data

ADM was unable to perform a transition test analysis on any circuits for the cooling season months. Additionally, four circuits on the Broken Arrow & 101st substation (ZJ2, ZJ4, ZJ6, and ZJ8) did not have any transition test data available, and thus received no savings estimates from the transition test analysis.

Table 3-165 shows the transition test heating season savings estimates for each circuit where data was available. Only circuits where testing data was available under both methodologies were included in this comparison.

Table 3-165: Transition Test Savings Comparison – Heating Season

Substation	Circuit	Transition Testing		On/Off Testing	
		CVR Factor	% Savings	CVR Factor	% Savings
Bartlesville Southeast	85731	0.84	2.39%	0.85	2.39%
	85732	0.81	2.27%	1.20	3.37%
	85733	0.90	2.50%	1.03	2.90%
	85734	0.66	2.29%	0.99	3.49%
	85735	0.90	3.14%	0.64	2.25%
	85736	0.90	2.92%	1.01	3.27%
Yale & Archer	J1	0.66	2.15%	1.16	3.65%
	J2	0.73	2.28%	0.68	2.12%
	J3	0.60	2.30%	0.81	3.19%
	J4	0.76	3.02%	0.64	2.56%
	J5	0.47	1.88%	0.77	3.05%
	J6	1.00	3.17%	0.98	3.12%
	J7	0.94	3.74%	1.35	5.36%
Weatherford Junction	WJ13	0.79	2.58%	1.18	3.78%
	WJ16	0.48	1.62%	0.90	2.93%
	WJ19	0.38	1.21%	0.81	2.62%
Broken Arrow & 101st	ZJ1	1.12	4.26%	1.36	5.22%
	ZJ3	0.74	2.83%	1.06	4.12%
	ZJ5	0.52	2.11%	0.87	3.38%
	ZJ7	0.63	2.49%	0.92	3.41%
Total / Average		**0.74**	**2.57%**	**0.96**	**3.28%**

More detailed results, reported for each distinct circuit, phase, and season combination can be seen in Section 3.8.7.

Results between the industry standard on/off regression methodology and the transition test approach are compared in Table 3-166. Note that the results comparison below only includes results for circuits that had results from the on/off analysis and the transition test analysis. Because of this, the on/off results in the comparison table below do not match the overall results from the on/off analysis.

Table 3-166: CVR Methodology Summary Comparison

Season	Methodology	Daily Average Savings	Percent Savings	CVR Factor	Projected Full Season Savings
Heating	On / Off	36,198	3.29%	0.96	7,999,730
	Transition Test	29,428	2.57%	0.74	6,238,691

Evaluation results have continuously showed reduced savings using transition tests. While there are many variables that could be influencing the results, the method in which these strategies are employed is most likely the cause. The software allows for voltage adjustments to take place while CVR is operational. These voltages are known as step changes, and while a user can input step changes as they desire, the software has the capability to override the number of step changes requested if they destabilize the circuit. Therefore, transition tests may sometimes be limited in the magnitude of voltage increase across the short transition test window. The operational procedure for ON/OFF days allows for increased user control and reliance on the baseline condition of traditional voltage regulation.

3.8.5 Conclusions and Recommendations

PY2021 was the third full year of evaluation for the PSO CVR program. The following summarizes the key findings of the evaluation of the CVR Program.

- Program annual energy savings were verified to be greater than estimated, with a 105% realization. The greater than expected energy savings may be the cause of applying regression analysis to data recorded during evaluation testing to accurately represent the baseline condition. In addition, verified CVR factors are applied to actual energy consumption on each circuit.
- The overall average reduction in distributed energy due to CVR across the evaluated circuits is 2.66%. Table 3-167 shows a comparison of how overall percent reduction compared to previous years' evaluations.

Table 3-167: On/Off Overall Percent Reduction; Year-to-Year Comparison

Season	PY2019	PY2020	PY2021
Cooling	2.69%	3.16%	2.13%
Heating	2.66%	2.54%	3.29%

- The average CVR factor is 0.82 (0.71 during the cooling season, and 0.92 during the heating season). Table 3-168 shows a comparison of how the average CVR factors from this year compared to previous years' evaluations. CVR factors are known to range from zero to above one if the load is mostly unconverted (in-phase) electrical consumption (such as electric resistance heating and incandescent light bulbs).

Table 3-168: On/Off CVR Factors; Year-to-Year Comparison

Season	PY2019	PY2020	PY2021
Cooling	0.63	0.73	0.71
Heating	0.62	0.54	0.92

- The average CVR factor estimated from transition tests was 0.74 in the heating season. ADM was unable to calculate any results from the cooling season due to a lack of data.
- Comparison of the CVR factors estimated by transition tests have, over the past few program years, consistently shown slightly smaller values compared to CVR factors estimated by on/off testing. Table 3-169 shows a comparison of average transition test CVR factors by season, for each year since PY2019.

Table 3-169: Transition Test CVR Factors; Year-to-Year Comparison

Season	PY2019	PY2020	PY2021
Cooling	0.53	0.51	N/A
Heating	0.72	0.73	0.74

The following recommendations are offered for continued improvement of the CVR program.

- As more circuits are upgraded each year to include this new technology, PSO may want to consider the evaluation include facilitated discussions with program staff. Facilitated discussion can be used to develop and improve internal processes and procedures, as well as perform a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis for program feedback.
- Continue working towards providing CVR evaluation testing operation status data (whether CVR was on or off) in the upcoming program years. Historically, evaluators classified CVR status (whether on or off for evaluation testing) based on a data analysis. PSO is working on a means to provide status to ensure certainty of CVR operation in the evaluation analysis.
- Complex logistics for the operation of substation energy loads can complicate evaluation testing schedules and understanding of CVR operation. A change log

to track operational changes related to the CVR operability would benefit the evaluation methodology.

3.8.6 Detailed Circuit Level On/Off Results

Table 3-170: Bartlesville Southeast Substation Savings by Phase – Cooling Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
85731	A	122.88	119.86	780.39	33,620	2.32%	0.94
	B	123.43	120.34	1,022.13	39,735	2.57%	1.03
	C	123.71	120.63	787.12	39,846	1.98%	0.79
Total / Average		**123.34**	**120.28**	**2,589.63**	**113,200**	**2.29%**	**0.92**
85732	A	122.91	119.88	939.08	37,898	2.48%	1.01
	B	123.44	120.35	757.38	32,552	2.33%	0.93
	C	123.75	120.67	538.35	32,791	1.64%	0.66
Total / Average		**123.37**	**120.30**	**2,234.81**	**103,240**	**2.15%**	**0.86**
85733	A	122.91	119.81	438.37	19,570	2.24%	0.89
	B	123.43	120.28	394.20	17,870	2.21%	0.86
	C	123.80	120.68	406.89	17,101	2.38%	0.94
Total / Average		**123.38**	**120.26**	**1,239.46**	**54,542**	**2.28%**	**0.90**
85734	A	124.10	119.66	1,002.53	33,048	3.03%	0.85
	B	124.72	120.34	821.64	30,246	2.72%	0.77
	C	124.97	120.61	727.02	29,805	2.44%	0.70
Total / Average		**124.60**	**120.21**	**2,551.20**	**93,099**	**2.73%**	**0.77**
85735	A	124.09	119.64	655.46	32,088	2.04%	0.57
	B	124.66	120.30	445.52	27,291	1.63%	0.47
	C	124.86	120.51	454.74	31,004	1.47%	0.42
Total / Average		**124.54**	**120.15**	**1,555.72**	**90,383**	**1.71%**	**0.49**
85736	A	124.32	119.96	361.07	34,281	1.05%	0.30
	B	124.90	120.60	619.08	37,426	1.65%	0.48
	C	125.06	120.80	644.85	31,410	2.05%	0.60

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
Total / Average		**124.76**	**120.45**	**1,625.01**	**103,118**	**1.59%**	**0.46**

Table 3-171: Bartlesville Southeast Substation Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
85731	A	122.63	119.22	462.69	20,186	2.29%	0.82
	B	123.26	119.80	682.58	26,958	2.53%	0.90
	C	123.70	120.20	525.65	22,784	2.31%	0.82
Total / Average		**123.20**	**119.74**	**1,670.92**	**69,928**	**2.38%**	**0.85**
85732	A	122.65	119.24	735.61	20,470	3.59%	1.29
	B	123.27	119.80	733.06	18,919	3.87%	1.38
	C	123.73	120.24	472.68	18,242	2.59%	0.92
Total / Average		**123.22**	**119.76**	**1,941.35**	**57,631**	**3.35%**	**1.20**
85733	A	122.64	119.22	365.58	12,852	2.84%	1.02
	B	123.24	119.77	334.76	11,637	2.88%	1.02
	C	123.81	120.29	327.63	10,996	2.98%	1.05
Total / Average		**123.23**	**119.76**	**1,027.97**	**35,484**	**2.90%**	**1.03**
85734	A	123.57	119.28	999.26	25,778	3.88%	1.12
	B	124.18	119.87	751.52	21,503	3.49%	1.01
	C	124.45	120.10	614.19	20,472	3.00%	0.86
Total / Average		**124.07**	**119.75**	**2,364.97**	**67,753**	**3.46%**	**0.99**
85735	A	123.53	119.25	435.42	16,756	2.60%	0.75
	B	124.11	119.81	272.87	14,049	1.94%	0.56
	C	124.33	120.00	347.86	16,214	2.15%	0.62
Total / Average		**123.99**	**119.69**	**1,056.15**	**47,019**	**2.23%**	**0.64**
85736	A	123.41	119.45	350.05	11,968	2.92%	0.91
	B	124.03	120.05	552.83	16,595	3.33%	1.04
	C	124.13	120.12	515.49	14,786	3.49%	1.08
Total / Average		**123.86**	**119.87**	**1,418.37**	**43,348**	**3.25%**	**1.01**

Table 3-172: Yale & Archer Substation Savings by Phase – Cooling Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
J1	A	123.32	120.11	582.29	36,068	1.61%	0.62

	B	123.57	120.50	479.90	31,094	1.54%	0.62
	C	123.42	119.94	618.33	35,299	1.75%	0.62
Total / Average		**123.44**	**120.18**	**1,680.52**	**102,460.41**	**1.64%**	**0.62**
J2	A	123.16	120.11	891.75	58,193	1.53%	0.62
	B	123.43	120.32	968.49	61,969	1.56%	0.62
	C	124.15	120.99	919.76	58,445	1.57%	0.62
Total / Average		**123.58**	**120.48**	**2,780.01**	**178,606.65**	**1.56%**	**0.62**
J3	A	124.45	119.73	283.31	11,403	2.48%	0.66
	B	124.36	119.64	469.37	16,062	2.92%	0.77
	C	124.59	119.88	375.50	13,800	2.72%	0.72
Total / Average		**124.47**	**119.75**	**1,128.19**	**41,266.05**	**2.71%**	**0.72**
J4	A	124.38	119.66	646.35	27,909	2.32%	0.61
	B	124.34	119.64	454.23	18,435	2.46%	0.65
	C	124.43	119.73	441.96	22,205	1.99%	0.53
Total / Average		**124.39**	**119.68**	**1,542.54**	**68,548.38**	**2.26%**	**0.60**
J5	A	124.45	119.73	777.07	37,675	2.06%	0.54
	B	124.41	119.69	757.12	37,667	2.01%	0.53
	C	124.49	119.79	738.66	33,686	2.19%	0.58
Total / Average		**124.45**	**119.74**	**2,272.85**	**109,027.07**	**2.09%**	**0.55**
J6	A	123.15	120.11	483.65	31,576	1.53%	0.62
	B	123.43	120.34	514.19	33,035	1.56%	0.62
	C	124.16	121.01	513.33	32,628	1.57%	0.62
Total / Average		**123.58**	**120.48**	**1,511.17**	**97,238.77**	**1.55%**	**0.62**
J7	A	124.42	119.68	833.02	37,787	2.20%	0.58
	B	124.34	119.62	417.71	39,671	1.05%	0.28
	C	124.37	119.65	629.47	35,691	1.76%	0.46
Total / Average		**124.38**	**119.65**	**1,880.20**	**113,149.42**	**1.67%**	**0.44**

Table 3-173: Yale & Archer Substation Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
J1	A	122.93	119.16	878.92	25,420	3.46%	1.13
	B	123.60	119.76	738.30	19,509	3.78%	1.22
	C	123.07	119.03	825.77	22,016	3.75%	1.14
Total / Average		**123.20**	**119.32**	**2,442.99**	**66,944.64**	**3.66%**	**1.16**
J2	A	122.93	119.16	696.34	42,434	1.64%	0.54

	B	123.58	119.74	1,027.71	44,605	2.30%	0.74
	C	124.12	120.18	1,009.26	41,732	2.42%	0.76
Total / Average		**123.54**	**119.69**	**2,733.31**	**128,770.56**	**2.12%**	**0.68**
J3	A	124.51	119.67	176.71	5,964	2.96%	0.76
	B	124.14	119.31	277.67	8,802	3.15%	0.81
	C	124.41	119.49	273.65	8,064	3.39%	0.86
Total / Average		**124.35**	**119.49**	**728.03**	**22,830.35**	**3.17%**	**0.81**
J4	A	124.49	119.59	552.97	18,743	2.95%	0.75
	B	124.14	119.33	321.81	13,680	2.35%	0.61
	C	124.30	119.36	333.25	14,835	2.25%	0.56
Total / Average		**124.31**	**119.43**	**1,208.03**	**47,258.69**	**2.52%**	**0.64**
J5	A	124.54	119.60	799.76	24,985	3.20%	0.81
	B	124.21	119.30	654.85	22,540	2.91%	0.73
	C	124.32	119.38	648.79	21,417	3.03%	0.76
Total / Average		**124.36**	**119.43**	**2,103.40**	**68,942.45**	**3.05%**	**0.77**
J6	A	122.96	119.12	676.98	21,721	3.12%	1.00
	B	123.60	119.70	554.43	21,521	2.58%	0.82
	C	124.16	120.15	811.50	22,149	3.66%	1.14
Total / Average		**123.57**	**119.66**	**2,042.92**	**65,391.18**	**3.12%**	**0.98**
J7	A	124.48	119.55	1,390.74	23,942	5.81%	1.47
	B	124.20	119.27	1,274.30	24,027	5.30%	1.34
	C	124.34	119.41	1,112.71	22,544	4.94%	1.25
Total / Average		**124.34**	**119.41**	**3,777.75**	**70,513.24**	**5.35%**	**1.35**

Table 3-174: Weatherford Junction Substation Savings by Phase – Cooling Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Average Consumption	% Savings	CVR Factor
WJ13	A	123.93	120.95	839.83	41,041	2.05%	0.85
	B	124.42	121.30	940.89	34,597	2.72%	1.09
	C	124.29	121.28	941.33	34,376	2.74%	1.13
Total / Average		**124.21**	**121.18**	**2,722.05**	**110,014**	**2.50%**	**1.02**
WJ16	A	123.92	120.61	748.41	20,246	3.70%	1.38
	B	124.37	120.90	358.39	16,414	2.18%	0.78
	C	124.25	120.89	551.39	18,677	2.95%	1.09
Total / Average		**124.18**	**120.80**	**1,658.19**	**55,337**	**2.94%**	**1.09**

WJ19	A	123.85	120.37	249.08	14,480	1.72%	0.61
	B	124.30	120.70	327.68	14,864	2.20%	0.76
	C	124.19	120.66	253.49	15,979	1.59%	0.56
Total / Average		**124.11**	**120.58**	**830.26**	**45,323**	**1.84%**	**0.64**

Table 3-175: Weatherford Junction Substation Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Average Consumption	% Savings	CVR Factor
WJ13	A	123.71	119.75	1,164.36	32,456	3.59%	1.12
	B	124.43	120.42	1,063.62	28,223	3.77%	1.17
	C	123.97	120.01	1,142.39	28,552	4.00%	1.25
Total / Average		**124.04**	**120.06**	**3,370.38**	**89,231**	**3.79%**	**1.18**
WJ16	A	123.70	119.73	613.81	16,578	3.70%	1.15
	B	124.41	120.40	375.65	13,856	2.71%	0.84
	C	123.93	119.97	343.49	15,039	2.28%	0.72
Total / Average		**124.01**	**120.03**	**1,332.95**	**45,472**	**2.90%**	**0.90**
WJ19	A	123.66	119.66	287.17	11,976	2.40%	0.74
	B	124.37	120.34	379.43	12,336	3.08%	0.95
	C	123.90	119.95	310.43	12,939	2.40%	0.75
Total / Average		**123.98**	**119.99**	**977.04**	**37,250**	**2.62%**	**0.81**

Table 3-176: 46th Broken Arrow & 101st Substation Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
ZJ1	A	123.99	119.81	1,053.25	31,975	3.29%	0.98
	B	123.90	119.73	1,257.39	40,219	3.13%	0.93
	C	124.00	119.77	1,324.22	38,438	3.45%	1.01
Total / Average		**123.96**	**119.77**	**3,634.86**	**110,632**	**3.29%**	**0.97**
ZJ2	A	124.43	120.34	223.65	11,721	1.91%	0.58
	B	124.79	120.70	159.23	9,198	1.73%	0.53
	C	124.44	120.40	214.65	12,364	1.74%	0.54
Total / Average		**124.55**	**120.48**	**597.54**	**33,283**	**1.79%**	**0.55**
ZJ3	A	124.41	120.23	1,167.62	42,291	2.76%	0.82
	B	123.90	119.73	1,086.18	39,469	2.75%	0.82
	C	124.01	119.79	1,035.46	39,613	2.61%	0.77

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
Total / Average		**124.11**	**119.92**	**3,289.26**	**121,373**	**2.71%**	**0.80**
ZJ4	A	124.52	120.37	567.43	44,875	1.26%	0.38
	B	124.89	120.71	764.64	48,304	1.58%	0.47
	C	124.48	120.38	770.15	51,871	1.48%	0.45
Total / Average		**124.63**	**120.49**	**2,102.21**	**145,050**	**1.44%**	**0.43**
ZJ5	A	124.48	120.29	492.80	19,905	2.48%	0.74
	B	123.98	119.79	516.53	24,576	2.10%	0.62
	C	123.88	119.64	392.53	16,848	2.33%	0.68
Total / Average		**124.12**	**119.91**	**1,401.87**	**61,329**	**2.30%**	**0.68**
ZJ6	A	124.49	120.32	396.76	16,951	2.34%	0.70
	B	124.86	120.66	446.73	15,202	2.94%	0.88
	C	124.47	120.37	333.07	13,433	2.48%	0.75
Total / Average		**124.61**	**120.45**	**1,176.56**	**45,587**	**2.59%**	**0.77**
ZJ7	A	124.47	120.28	885.86	33,245	2.66%	0.79
	B	123.99	119.82	984.90	32,460	3.03%	0.90
	C	124.03	119.81	1,050.88	39,547	2.66%	0.78
Total / Average		**124.16**	**119.97**	**2,921.65**	**105,253**	**2.79%**	**0.82**
ZJ8	A	124.45	120.40	988.47	41,632	2.37%	0.73
	B	124.78	120.69	818.93	45,650	1.79%	0.55
	C	124.47	120.44	840.25	49,905	1.68%	0.52
Total / Average		**124.57**	**120.51**	**2,647.65**	**137,188**	**1.95%**	**0.60**

Table 3-177: 46th Broken Arrow & 101st Substation Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
ZJ1	A	123.66	118.88	810	14,332	5.65%	1.46
	B	123.82	119.11	911	17,474	5.22%	1.37
	C	124.17	119.34	821	16,859	4.87%	1.25
Total / Average		**123.88**	**119.11**	**2,543**	**48,665**	**5.25%**	**1.36**
ZJ2	A	124.19	119.22	203	7,552	2.69%	0.67
	B	124.31	119.41	127	6,159	2.07%	0.52
	C	124.52	119.52	232	8,362	2.77%	0.69
Total / Average		**124.34**	**119.38**	**562**	**22,073**	**2.51%**	**0.63**
ZJ3	A	124.08	119.28	952	19,913	4.78%	1.24

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Avg. Consumption	% Savings	CVR Factor
	B	123.86	119.14	586	16,789	3.49%	0.92
	C	124.18	119.35	652	16,441	3.97%	1.02
Total / Average		**124.04**	**119.26**	**2,190**	**53,142**	**4.08%**	**1.06**
ZJ4	A	124.23	119.20	878	25,713	3.41%	0.84
	B	124.40	119.42	952	28,135	3.38%	0.84
	C	124.53	119.53	937	29,144	3.21%	0.80
Total / Average		**124.39**	**119.39**	**2,766**	**82,992**	**3.34%**	**0.83**
ZJ5	A	124.14	119.34	308	10,404	2.96%	0.76
	B	123.89	119.17	507	13,897	3.65%	0.96
	C	124.02	119.27	334	9,664	3.45%	0.90
Total / Average		**124.02**	**119.26**	**1,149**	**33,965**	**3.35%**	**0.87**
ZJ6	A	124.22	119.19	260	9,368	2.78%	0.69
	B	124.37	119.42	278	8,701	3.20%	0.80
	C	124.51	119.52	230	8,130	2.83%	0.71
Total / Average		**124.37**	**119.37**	**769**	**26,199**	**2.94%**	**0.73**
ZJ7	A	124.12	119.32	521	14,839	3.51%	0.91
	B	123.90	119.17	518	14,025	3.69%	0.97
	C	124.21	119.38	618	17,719	3.49%	0.90
Total / Average		**124.08**	**119.29**	**1,657**	**46,583**	**3.56%**	**0.92**
ZJ8	A	124.22	119.23	897	5,378,357	3.54%	0.88
	B	124.37	119.38	1,002	6,634,396	3.20%	0.80
	C	124.52	119.56	1,048	6,317,312	3.52%	0.88
Total / Average		**124.37**	**119.39**	**2,946**	**18,330,066**	**3.42%**	**0.85**

3.8.7 Detailed Transition Test Results

Table 3-178: Bartlesville Southeast Substation Transition Test Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Average Consumption	% Savings	CVR Factor
85731	A	122.63	119.22	424.27	20,186	2.10%	0.76
	B	123.26	119.80	666.83	26,958	2.47%	0.88
	C	123.70	120.20	579.35	22,784	2.54%	0.90
Total / Average		**123.20**	**119.74**	**1,670.44**	**69,928**	**2.37%**	**0.84**
85732	A	122.65	119.24	518.34	20,470	2.53%	0.91
	B	123.27	119.80	379.97	18,919	2.01%	0.71
	C	123.73	120.24	411.10	18,242	2.25%	0.80
Total / Average		**123.22**	**119.76**	**1,309.40**	**57,631**	**2.26%**	**0.81**
85733	A	122.64	119.22	258.42	12,852	2.01%	0.72
	B	123.24	119.77	307.57	11,637	2.64%	0.94
	C	123.81	120.29	322.47	10,996	2.93%	1.03
Total / Average		**123.23**	**119.76**	**888.45**	**35,484**	**2.53%**	**0.90**
85734	A	123.57	119.28	581.81	25,778	2.26%	0.65
	B	124.18	119.87	484.84	21,503	2.25%	0.65
	C	124.45	120.10	482.44	20,472	2.36%	0.67
Total / Average		**124.07**	**119.75**	**1,549.09**	**67,753**	**2.29%**	**0.66**
85735	A	123.53	119.25	490.60	16,756	2.93%	0.85
	B	124.11	119.81	375.16	14,049	2.67%	0.77
	C	124.33	120.00	610.66	16,214	3.77%	1.08
Total / Average		**123.99**	**119.69**	**1,476.43**	**47,019**	**3.12%**	**0.90**
85736	A	123.41	119.45	280.86	11,968	2.35%	0.73
	B	124.03	120.05	490.64	16,595	2.96%	0.92
	C	124.13	120.12	494.43	14,786	3.34%	1.03
Total / Average		**123.86**	**119.87**	**1,265.93**	**43,348**	**2.88%**	**0.90**

Table 3-179: Yale & Archer Substation Transition Test Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Average Consumption	% Savings	CVR Factor
J1	A	122.93	119.16	756.73	25,420	2.98%	0.97
	B	123.60	119.76	264.54	19,509	1.36%	0.44
	C	123.07	119.03	417.63	22,016	1.90%	0.58
Total / Average		**123.20**	**119.32**	**1,438.90**	**66,944.64**	**2.08%**	**0.66**
J2	A	122.93	119.16	730.97	42,434	1.72%	0.56
	B	123.58	119.74	1,181.69	44,605	2.65%	0.85
	C	124.12	120.18	1,022.40	41,732	2.45%	0.77
Total / Average		**123.54**	**119.69**	**2,935.06**	**128,770.56**	**2.27%**	**0.73**
J3	A	124.51	119.67	155.40	5,964	2.61%	0.67
	B	124.14	119.31	178.67	8,802	2.03%	0.52
	C	124.41	119.49	190.22	8,064	2.36%	0.60
Total / Average		**124.35**	**119.49**	**524.30**	**22,830.35**	**2.33%**	**0.60**
J4	A	124.49	119.59	590.08	18,743	3.15%	0.80
	B	124.14	119.33	388.05	13,680	2.84%	0.73
	C	124.30	119.36	449.34	14,835	3.03%	0.76
Total / Average		**124.31**	**119.43**	**1,427.47**	**47,258.69**	**3.00%**	**0.76**
J5	A	124.54	119.60	439.68	24,985	1.76%	0.44
	B	124.21	119.30	557.77	22,540	2.47%	0.63
	C	124.32	119.38	297.77	21,417	1.39%	0.35
Total / Average		**124.36**	**119.43**	**1,295.22**	**68,942.45**	**1.87%**	**0.47**
J6	A	122.96	119.12	670.16	21,721	3.09%	0.99
	B	123.60	119.70	779.96	21,521	3.62%	1.15
	C	124.16	120.15	619.95	22,149	2.80%	0.87
Total / Average		**123.57**	**119.66**	**2,070.07**	**65,391.18**	**3.17%**	**1.00**
J7	A	124.48	119.55	853.57	23,942	3.57%	0.90
	B	124.20	119.27	939.77	24,027	3.91%	0.98
	C	124.34	119.41	845.97	22,544	3.75%	0.95
Total / Average		**124.34**	**119.41**	**2,639.32**	**70,513.24**	**3.74%**	**0.94**

Table 3-180: Weatherford Junction Substation Transition Test Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Average Consumption	% Savings	CVR Factor
WJ13	A	123.71	119.75	1,050.18	32,456	3.24%	1.01
	B	124.43	120.42	475.77	28,223	1.69%	0.52
	C	123.97	120.01	772.54	28,552	2.71%	0.85
Total / Average		**124.04**	**120.06**	**2,298.49**	**89,231**	**2.54%**	**0.79**
WJ16	A	123.70	119.73	432.24	16,578	2.61%	0.81
	B	124.41	120.40	50.17	13,856	0.36%	0.11
	C	123.93	119.97	253.36	15,039	1.68%	0.53
Total / Average		**124.01**	**120.03**	**735.76**	**45,472**	**1.55%**	**0.48**
WJ19	A	123.66	119.66	104.01	11,976	0.87%	0.27
	B	124.37	120.34	162.82	12,336	1.32%	0.41
	C	123.90	119.95	185.70	12,939	1.44%	0.45
Total / Average		**123.98**	**119.99**	**452.52**	**37,250**	**1.21%**	**0.38**

Table 3-181: 46th Broken Arrow & 101st Substation Transition Test Savings by Phase – Heating Season

Circuit	Phase	Baseline OFF Voltage	ON Voltage	Daily Avg kWh Savings	Daily Average Consumption	% Savings	CVR Factor
ZJ1	A	123.66	118.88	725	14,332	5.06%	1.31
	B	123.82	119.11	736	17,474	4.21%	1.11
	C	124.17	119.34	612	16,859	3.63%	0.93
Total / Average		**123.88**	**119.11**	**2,072**	**48,665**	**4.30%**	**1.11**
ZJ3	A	124.08	119.28	530	19,913	2.66%	0.69
	B	123.86	119.14	287	16,789	1.71%	0.45
	C	124.18	119.35	685	16,441	4.17%	1.07
Total / Average		**124.04**	**119.26**	**1,502**	**53,142**	**2.85%**	**0.74**
ZJ5	A	124.14	119.34	294	10,404	2.82%	0.73
	B	123.89	119.17	369	13,897	2.66%	0.70
	C	124.02	119.27	55	9,664	0.57%	0.15
Total / Average		**124.02**	**119.26**	**717**	**33,965**	**2.01%**	**0.52**
ZJ7	A	124.12	119.32	386	14,839	2.60%	0.67
	B	123.90	119.17	253	14,025	1.80%	0.47
	C	124.21	119.38	520	17,719	2.94%	0.75

Total / Average	**124.08**	**119.29**	**1,159**	**46,583**	**2.45%**	**0.63**

4 Demand Response Programs

PSO's demand response (DR) portfolio in the program year consisted of two programs, one that targeted residential customers and one that targeted commercial and industrial customers. Program-level annual savings are summarized in Table 4-1.

Table 4-1: Annual Energy Savings – Demand Response Programs

Program	Gross Annual Energy Savings (MWh)					Net Impacts	
	Projected	Reported	Verified	Gross Realization Rate	Verified Lifetime Savings	NTG Ratio	Net Annual Energy Savings (MWh)
Power Hours	2,047	1,255	1,649	131%	16,134,853	87%	1,442
Peak Performers	134	514	1,361	265%	1,360,734	100%	1,361
Demand Response Totals	**2,181**	**1,769**	**3,010**	**170%**	**17,495,587**	**93%**	**2,803**

Program-level peak demand reduction is summarized in Table 4-2.

Table 4-2: Peak Demand Reduction – Demand Response Programs

Program	Gross Peak Demand Reduction (MW)				Net Impacts	
	Projected	Reported	Verified	Gross Realization Rate	NTG Ratio	Net Peak Demand Reduction (MW)
Power Hours	20.69	13.83	16.14	117%	1.00	16.10
Peak Performers	53.58	73.48	45.56	62%	1.00	45.56
Demand Response Totals	**74.27**	**87.31**	**61.71**	**71%**	**1.00**	**61.67**

4.1 Power Hours Program

This chapter presents findings from the 2021 impact and process evaluation of the of Power Hours program.

4.1.1 Program Overview

The Power Hours program provided ways to reduce energy usage of residential customers during peak demand periods by offering customers the option of participating in direct load control (DLC) events and providing full rebates for the purchase of a new smart thermostat. DLC events reduce energy usage when demand is highest by communicating with registered Wi-Fi enabled thermostats installed in the homes of participants. Smart thermostats help lower electricity usage by providing customers with improved real-time information about HVAC usage and cost, improved user interfaces, and algorithm optimization (such as occupancy detection and prediction).

Table 4-3 shows the performance metrics achieved by the program. Over two gigawatt-hours (GWh) of energy was saved by this program in 2021 because of the smart thermostats and DLC events. Because of the DLC events, a peak demand reduction of over sixteen megawatts (MW) was realized.

Table 4-3: Performance Metrics – Power Hours Program

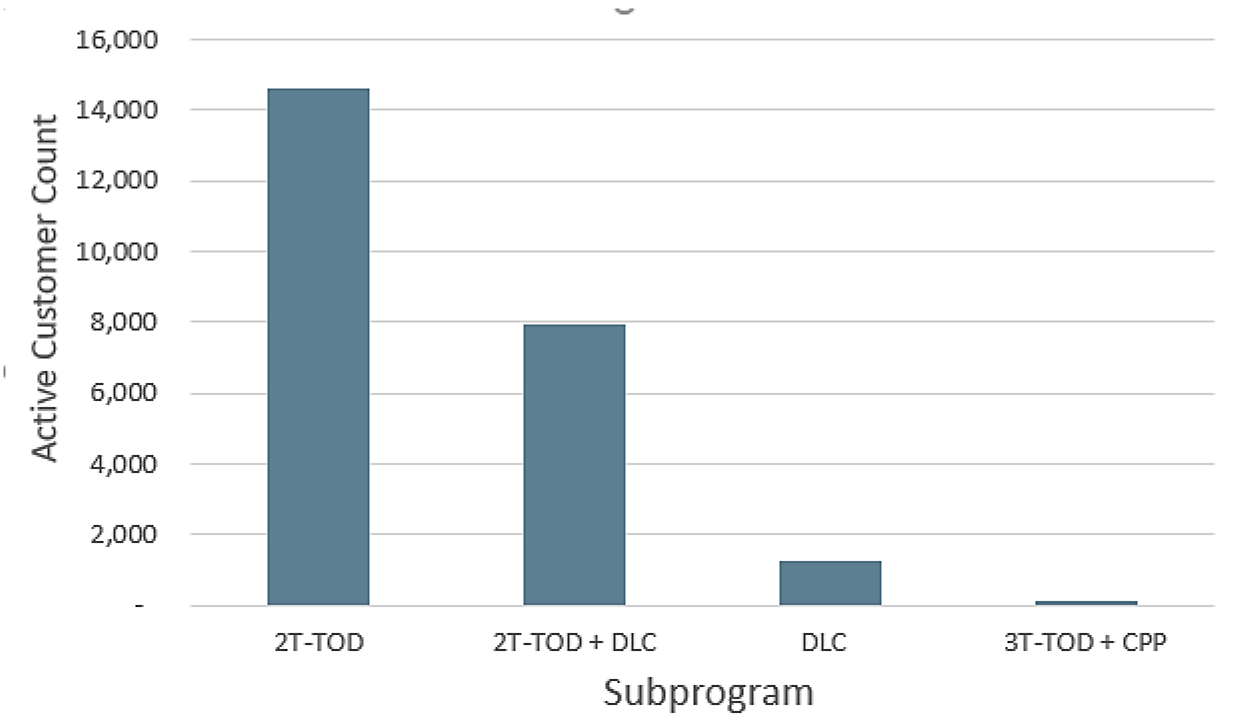
Metric	PY2021
Number of Customers	23,891
Budgeted Expenditures	$2,367,669
Actual Expenditures	$1,603,148
Energy Impacts (kWh)	
Projected Energy Savings	2,046,870
Reported Energy Savings	1,255,129
Gross Verified Energy Savings	1,649,043
Net Verified Energy Savings	1,441,896
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	20,686
Reported Peak Demand Savings	13,834
Gross Verified Peak Demand Savings	16,141.60
Net Verified Peak Demand Savings	16,103.34
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	2.29
Utility Cost Test Ratio	2.16

Annual energy efficiency savings (kWh) were calculated for all new customers that joined the program in PY2021 and used program rebates to purchase a smart thermostat. Peak demand reduction was calculated for all participants in the program. Peak demand reduction (kW) and annual energy savings (kWh) for each DLC event were calculated for customers in the DLC and DLC + 2T-TOD subprograms. Details on subprogram paths are described later in this chapter.

All PSO residential customers with an Advanced Metering Infrastructure (AMI) installed are eligible to participate in the program. Households participating in DLC events are also required to have central air conditioning, active Wi-Fi service, and have at least one program-eligible Wi-Fi enabled thermostat installed. All customers that participate in the Power Hours program are eligible to receive rebates for the full cost of up to two of Wi-Fi enabled thermostats per home, even if they do not participate in DLC events.

PY2021 was the sixth year PSO administered the program. At the end of PY2021 there were 23,891 active participants, with 3,532 new customers joining the program in 2021. The program has four subprograms, which are detailed in the following sections. Figure 4-1 shows the number of active customers participating in each subprogram.

Figure 4-1: Subprogram Active Customer Counts



4.1.1.1 Direct Load Control

The Direct Load Control (DLC) subprogram allows customers to participate in DLC events. Households participating in DLC events are required to have central air conditioning, Wi-Fi service, and have at least one program-eligible Wi-Fi enabled thermostat installed. Thermostats are registered with Honeywell, allowing them to receive a load curtailment signal. There are two load curtailment strategies used for DLC events; temperature offset, and duty-cycling described as:

- The temperature offset option changes participants' thermostat setpoint at the beginning of the event period. Setpoints can be increased by up to four degrees. Once the event period is over, the thermostats' setpoints are returned to the setpoint before the event occurred.
- The duty-cycling strategy changes the duration in which an air conditioner (A/C) compressor is on or off during the event period. All duty-cycling events this year used a 50% cycling ratio with a 60-minute cycling period; meaning the A/C compressor is shut off for 30 minutes, then turned back on for the next 30 minutes. This pattern repeats until the event is over.

Eight DLC event occurred in PY2021. All events used a temperature offset curtailment strategy, with an offset of three degrees.

Participants can override the DLC curtailment if they do not wish to participate in an event. Participants can override (or opt-out of) the curtailment either by using the Honeywell "Total Connect Comfort" mobile application or by manually changing the setpoint on the thermostat. During 2021, all customers in the subprogram received a bill credit of $2.50 for each event they fully participated in.

4.1.1.2 Two-Tier Time of Day Pricing

Two-Tier Time of Day Pricing (2T-TOD) is a rate schedule available to individual residential customers in this program. The rate was broken into two tiers, with each tier having unique electricity pricing.

- For non-holiday weekdays for June through October, two different rates are charged depending on the time of day. From 2 PM to 7 PM a higher cost tier was in effect, charged at a rate of 14.100₵/kWh. For all other hours during those months, a lower cost tier was in effect, charged at a rate 2.895₵/kWh.
- For all other times, a low-cost declining block rate schedule applies for all hours of all days, with the price in this period the same as in the standard tariff. Rates were as follows: 4.3220 ₵/kWh for first 475 kWh, 2.865 ₵/kWh for the next 775 kWh, and 1.921₵/kWh for all additional kWh.

4.1.1.3 Direct Load Control and Two-Tier Time of Day Pricing

Customers can participate in DLC events as well as the 2T-TOD rate schedule. Customers who do this are considered a part of a separate subprogram called Direct Load Control and Two-Tier Time of Day Pricing (DLC + 2T-TOD). All eligibility requirements of the DLC and 2T-TOD subprograms apply to this subprogram as well.

4.1.1.4 Three-Tier Time of Day Plus Critical Peak Pricing

The final subprogram offered to residential customers is the Three Tier Time of Day pricing plus Critical Peak Pricing (3T-TOD + CPP). Unlike the 2T-TOD subprogram, customers participating in this subprogram are not eligible to participate in the DLC subprogram. This rate tariff charges different rates for electricity during the billing months of June through October. The rates were as follows:

- A rate of 2.334₵/kWh was applied for all hours on weekends and holidays and for non-holiday weekdays from 11 p.m. to 10 a.m.
- A rate of 3.850₵/kWh was applied to hours from 10 a.m. to 2 p.m. and from 7 p.m. to 11 p.m. on non-holiday weekdays.

- A rate of 14.100₵/kWh was applied to hours from 2 p.m. to 7 p.m. on non-holiday weekdays.
- A rate of 0.750₵/kWh is typically applied during hours when PSO called a critical peak event. This had no effect in PY2021, however, as no critical peak events were called.

4.1.2 EM&V Methodologies

The impact of the Power Hours program is measured in two parts. The first is measuring the peak reduction (kW) and annual energy savings (kWh) during DLC events. The second is measuring the annual energy savings (kWh) from the smart thermostat incentives. The following section defines how these savings are calculated.

4.1.2.1 Direct Load Control Events

The impact of DLC events is analyzed using 15-minute interval AMI billing consumption data provided by PSO. Software written in the statistical programming language R is used to process and analyze the data. Various data processing steps are applied to the data before analyzed. These steps include:

- Validating that the files are not corrupt and of a consistent size.
- Extracting and transferring data from these files.
- Updating PSO with remaining data needs (i.e., if files were missing or corrupted).

After the necessary files are validated, the data is cleaned and prepared for analysis. This includes:

- Performing data completeness checks on all data.
- Aggregating 15-minute consumption data to 30-minute consumption data. This is done for a better match with weather data and to improve statistical model effectiveness.

Local temperature data was retrieved from the National Oceanic and Atmospheric Administration (NOAA). Temperature values were converted to cooling degree days (CDD). This was done because CDD values can quantify how power consumption relates to the weather more effectively than temperature values. Equation 4-1 shows how temperature is converted to CDD.

Equation 4-1: Temperature to CDD Conversion

$$CDD_t = \begin{cases} 0 & if\ temp_t < cddbase \\ (temp_t - cddbase)\ /\ 48 & if\ temp_t \geq cddbase \end{cases}$$

Where:

$temp_t$ = temperature at time t

$cddbase$ = determined CDD base temperature

To calculate the most accurate CDD values, the optimal CDD base temperature for the evaluated population was determined. For a detailed description of how optimal CDD base temperatures are determined, see Appendix G.

Once the necessary data is processed, the devices that participate in the DLC events are identified. Two Power Hours subprograms include a direct load control component: DLC and DLC + 2T-TOD. Tracking data for these subprograms, provided by PSO, is used to identify which devices are available to participate in each event. An available device is defined as a device registered with Honeywell as part of either the DLC or DLC + 2T-TOD subprogram. An available device could become unavailable only if the customer in possession of the device decided to permanently opt out of the subprogram.

Because customers can manually override the DLC curtailment signal or various technical failures may occur, not every available device participates in the events. Thus, devices that are non-responsive to the called events need to be identified so that the calculation of energy savings included only devices that participate in the event.

A device is considered a non-responsive device (NRD) if it does not respond to the curtailment signal sent by PSO. NRDs are identified using a combination of three tests, each of which is a different method of identifying if a drop in energy usage occurred at the start of a DLC event. A device is considered non-responding for an event day only if all three tests identify the device as non-responding. See Appendix G for a more detailed description of each of these tests and how they are applied.

Next, baseline energy usage curves are developed. These are used to estimate what energy usage would have been during an event day had the event not occurred. For each event, this counterfactual baseline is developed using AMI data from all responding devices during non-event, non-holiday weekdays that had similar weather to that of the event day being analyzed.

The k-means clustering algorithm is used to identify similar weather days to each event day. Average daily temperature and humidity is calculated for every non-holiday weekday for every month in which a DLC event was called (in PY2021, this was June through August). Then the k-means clustering algorithm is applied to the daily weather data. This method splits every day into one of three clusters (or similar groups) of dates. Any non-event day that was placed into the same cluster as the event day is used to calculate that event's baseline.

When appropriate data has been determined to calculate each event's baseline curve, a linear regression model is calculated using that data (Equation 4-2).

Equation 4-2: Baseline Energy Usage Curve Regression Model

$$kW_t = CDD_t + CDD_{t-2} + t$$

Where:

t = the 30-minute interval for which kW usage is being predicted

CDD_t = cooling degree days at time t

CDD_{t-2} = cooling degree days one hour before t

To ensure the baseline curves are as accurate as possible, a normalizing factor is calculated and applied to the baseline curve of each event day (Equation 4-3).

Equation 4-3: Normalization Factor Calculation

$$nf = kW_{actual.hour=es-2} \,/\, kW_{baseline.hour=es-2}$$

Where:

$kW_{actual.hour=es-2}$ = kW measured two hours before the event

$kW_{baseline.hour=es-2}$ = kW predicted by the baseline two hours before the event

With the baseline curve determined, demand reduction can be calculated. Demand reduction represents the average decrease in energy usage that occurs for the average event participant during a given time interval. Demand reduction is calculated for the event period and the snapback period. The event period is the time from when the event starts to when the event ends. The snapback period is the time from when the event ends to two hours after the event ends. The snapback period represents the time when all devices are resuming normal function and, as a result, typically have a small spike in energy usage before returning to normal. Equation 4-4 shows the formula for calculating demand reduction.

Equation 4-4: Demand Reduction Calculation

$$kW_t^{reduction} = kW_t^{baseline} - kW_t^{actual}$$

Where:

t = the 30-minute interval for which demand reduction is being calculated

$kW_t^{baseline}$ = kW demand predicted by the baseline at time t

kW_t^{actual} = kW demand measured at time t

Demand reduction is then used to calculate average hourly energy savings for each event. The equation is shown in Equation 4-5.

Equation 4-5: DLC Event Energy Savings (kWh) Calculation

$$kWh_{saved} = \sum_{t \in EventPeriod} \left(\frac{kW_t^{reduction}}{2}\right)$$

Where:

t = the 30-minute interval for which energy savings is being calculated

$EventPeriod$ = all time intervals from event start to two hours after the event end
$kW_t^{reduction}$ = demand reduction calculated at time t

Peak reduction is calculated for each event, representing the maximum drop in energy usage that occurred for the average event participant. The equation is shown in Equation 4-6.

Equation 4-6: Verified Peak Reduction (kW) Calculation

$$kW_{reduced} = max_{\,t \in EventPeriod}\,(kW_t^{reduction})$$

Where:

t = the 30-minute interval for which energy savings is being calculated
$EventPeriod$ = all time intervals from event start hour to the event end hour
$kW_t^{reduction}$ = demand reduction calculated at time t

4.1.2.2 Smart Thermostats

The use of smart thermostats can lead to an annual reduction in energy use. This reduction is due to occupancy sensors, sophisticated setpoint algorithms, advanced scheduling options, remote programming capability, and available information that optimizes energy use. Savings are calculated for customers that joined the program in PY2021 and received a rebate on the purchase of at least one smart thermostat. A thermostat model was considered smart if it met all the requirements for a smart thermostat listed in the Arkansas Technical Reference Manual (AR TRM)[101] or if the thermostat model was listed as an EnergyStar® certified smart thermostat at any point in PY2021.[102] Table 4-4 lists every thermostat model incentivized by the program in PY2021, as well as which of those models qualify as a smart thermostat.

Table 4-4: Thermostat Models Incentivized by the Program

Thermostat Model	Qualifies as Smart
Honeywell Wi-Fi VisionPRO	Yes
Honeywell Wi-Fi 9000	Yes
Honeywell Lyric T5/T6	Yes
Honeywell Home T9	Yes
Emerson Sensi	Yes
Emerson Sensi Touch	Yes

Annual energy savings are calculated as a deemed value for each new participant, based on the methodology offered for smart thermostats in the AR TRM.

[101] Arkansas Technical Reference Manual, version 7.0 volume 1: See Section 2.1.12
[102] Accessible via: https://www.energystar.gov/products/certified-products/detail/set

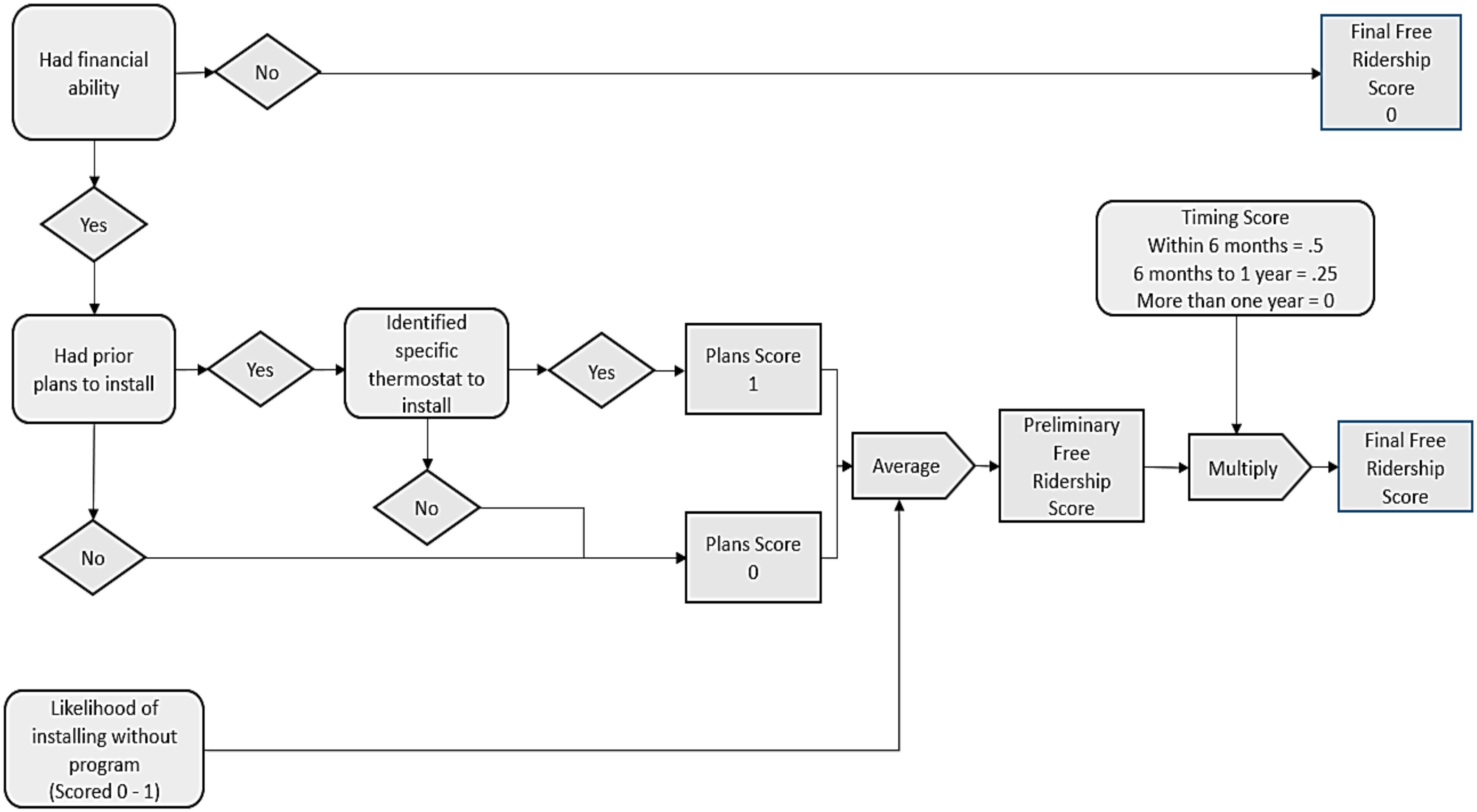
4.1.2.3 Net-to-Gross Estimation

A net-to-gross ratio is calculated to take into consideration the effect of free ridership on energy savings. Free ridership is the estimated proportion of participants that would have participated in the energy saving behavior incentivized by the program regardless of whether the program existed. A net-to-gross ratio was only calculated and applied to savings resulting from smart thermostat incentives. Demand response programs are not likely to have net-to-gross effects because customers are unlikely to curtail load in absence of the program. For this reason, a net-to-gross ratio of 100% was assumed for all savings resulting from demand response events.

Information collected from a sample of participant decision makers is used to estimate the net savings resulting from the rebated smart thermostats. Information is collected through online survey efforts with the number of respondents representing a statistically representative sample of the population. This program was not expected to generate significant spillover effects; therefore, the evaluators did not assess spillover.

Decision makers were asked a series of questions on their financial ability to implement the measure without program incentives, plans to implement the project before learning of the program, the likelihood of implementing the measure in the absence of the program, and the impact of the program on the timing of the project to assess free ridership. Each respondent is then assigned a free ridership score based on a consistent free ridership scoring algorithm. The free ridership scoring algorithm for the surveys is shown in Figure 4-2. Survey responses were not weighted. That is, each response had equal weight in estimating the average free ridership level for the program.

Figure 4-2: Free Ridership Scoring for Smart Thermostats Based on Survey Responses



4.1.2.4 Process Evaluation

ADM's process evaluation activities include a review of program materials, participant surveys and a with program staff (at PSO and implementation firms) on the program's strengths, weaknesses, opportunities, and threats (SWOT). The participant surveys will be implemented as online surveys with telephone follow-up as needed. ADM provided a process evaluation memo describing methodologies and findings in detail. This section summarizes these findings.

Table 4-5 below summarizes the data collection activities and corresponding process evaluation research objectives.

Table 4-5: Process Evaluation Data Collection Activities Summary

Data Collection Activity	Process Evaluation Research Objectives
Program Materials Review	Review reports and support materials for clarity and consistency with program objectives.
Program Staff Interviews	Assess program staff perspectives regarding program operations, strengths, weaknesses, barriers to success, and opportunities for improvement.
Participant Survey	Assess participant's reasons for participating and experience with the program, including satisfaction.

4.1.3 Impact Evaluation Findings

The methods described in the EM&V Methodologies section were used to determine the impacts on customer energy use for the various subprograms of the Power Hours program. The goal of the impact evaluation is to determine verified annual energy savings (kWh) and peak demand reduction (kW). Findings are presented and discussed in this section.

4.1.3.1 Direct Load Control Event Impact

In 2021, eight Direct Load Control (DLC) event were called. The schedule of these events is summarized in Table 4-6.

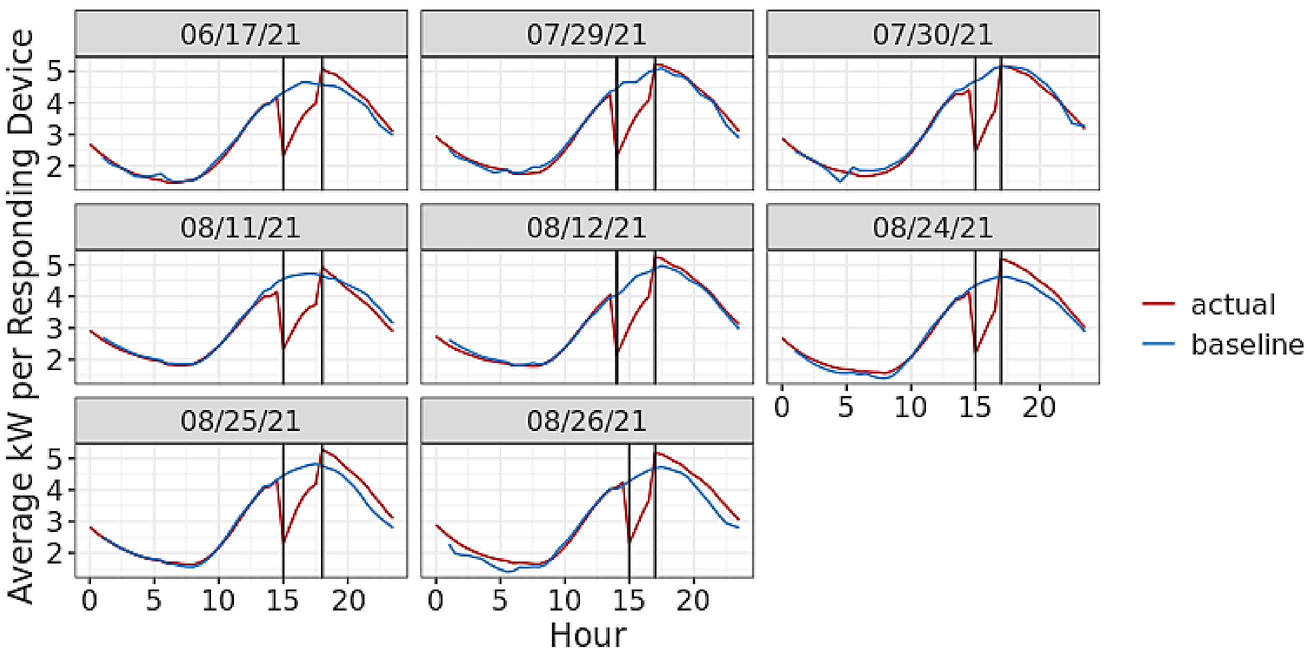
Table 4-6: Summary of Events

Date	Event Start Hour	Event End Hour	Duration (Hours)	Curtailment Strategy
06/17/2020	15	18	3	Temperature Offset
07/29/2021	14	17	3	Temperature Offset
07/30/2021	15	17	2	Temperature Offset
08/11/2021	15	18	3	Temperature Offset

Date	Event Start Hour	Event End Hour	Duration (Hours)	Curtailment Strategy
08/12/2021	14	17	3	Temperature Offset
08/24/2021	15	17	2	Temperature Offset
08/25/2021	15	18	3	Temperature Offset
08/26/2021	15	17	2	Temperature Offset

Using the methodology described previously in this chapter, a baseline consumption curve was developed for each event day to represent a typical residences performance. This were used to estimate what energy usage would have been during the event day had the event not occurred. The baseline consumption curve used for the demand reduction calculations are shown in Figure 4-3. Vertical lines represent the start and end time of the event.

Figure 4-3: Actual vs. Baseline Energy Usage per Responding Device



Non-responsive device (NRD) identification was performed on all available devices using the methods discussed in the EM&V Methodologies section. Any device that was identified as an NRD for the event was removed from the analysis. The response rate is defined as the percentage of available devices that were not identified as an NRD. Table 4-7 shows the response rates for each event.

Table 4-7: Active and Responsive Device Counts per Event

Date	Available Devices	Responsive Devices	Response Rate
06/17/2021	9,136	7,799	85.37%
07/29/2021	9,144	7,973	87.19%
07/30/2021	9,070	7,764	85.60%
08/11/2021	9,145	8,136	88.97%
08/12/2021	9,146	7,889	86.26%
08/24/2021	9,159	7,694	84.00%
08/25/2021	9,160	7,685	83.90%
08/26/2021	9,160	7,704	84.91%

Demand reduction was calculated by comparing the hourly consumption predicted by the baseline consumption curve to the actual hourly consumption during the event. Results include demand reduction from the event period and the snapback period. The event period is the time from when the event starts to when the event ends. The snapback period is the time from when the event ends to two hours after the event ends.

Demand reduction was calculated in 30-minute increments as shown in Table 4-8. Each column represents the average kW reduction per responding device during the specified time interval. Time intervals during the snapback period are identified with grey cells.

Table 4-8: Demand Reduction (kW) per 30-Minute Interval

Date	14	14.5	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5
06/17/2021	--	--	1.99	1.69	1.36	1.10	0.85	0.62	-0.50	-0.42	-0.38	-0.31
07/29/2021	2.15	1.92	1.47	1.08	0.96	0.91	-0.16	-0.11	-0.12	-0.15	--	--
07/30/2021	--	--	2.22	1.85	1.54	1.36	-0.04	-0.01	0.06	0.13	--	--
08/11/2021	--	--	2.22	1.92	1.56	1.26	1.08	0.98	-0.28	-0.17	-0.05	0.07
08/12/2021	1.87	1.61	1.36	1.19	0.96	0.78	-0.37	-0.23	-0.16	-0.11	--	--
08/24/2021	--	--	2.14	1.80	1.38	1.03	-0.57	-0.50	-0.47	-0.43	--	--
08/25/2021	--	--	2.14	1.75	1.30	0.98	0.78	0.65	-0.51	-0.49	-0.44	-0.36
08/26/2021	--	--	1.96	1.63	1.25	0.97	-0.48	-0.40	-0.35	-0.30	--	--

Average annual energy savings per responding device was calculated for each event, using the demand reduction results above. Total energy savings for each event was calculated by multiplying the average energy savings per responding device by the number of responding devices for that event. Table 4-9 shows average annual energy savings per device and total savings for the duration of each event. Curtailment event duration varied from 2-3 hours.

Table 4-9: Energy Savings (kWh) per Event

Date	Responsive Devices	Savings During Event Hours, per Device (kWh)	Savings During Snapback Hours, per Device (kWh)	Energy Savings per Device (kWh)	Total Energy Savings (kWh)
06/17/2021	7,799	3.80	-0.81	3.00	23,382
07/29/2021	7,973	4.25	-0.27	3.98	31,712
07/30/2021	7,764	3.48	0.07	3.55	27,592
08/11/2021	8,136	4.51	-0.22	4.29	34,933
08/12/2021	7,889	3.89	-0.44	3.45	27,227
08/24/2021	7,694	3.17	-0.99	2.18	16,798
08/25/2021	7,685	3.80	-0.90	2.90	22,276
08/26/2021	7,704	2.91	-0.76	2.15	16,541
Total					**200,462**

Peak reduction per device was calculated by finding the largest difference between the baseline curve and the actual usage curve that occurred during event hours (see Equation 4-6). Peak reduction per event was then calculated by multiplying the peak reduction per device by the number of responsive devices for that event.

Table 4-10: Program-Level Peak Reduction (kW) per Event

Date	Responsive Devices	Peak Reduction per Device (kW)	Peak Reduction per Event (kW)
06/17/2021	7,799	1.99	15,556.49
07/29/2021	7,973	1.92	15,333.87
07/30/2021	7,764	2.22	17,271.84
08/11/2021	8,136	2.22	18,101.51
08/12/2021	7,889	1.61	12,721.33
08/24/2021	7,694	2.14	16,429.92
08/25/2021	7,685	2.14	16,464.98
08/26/2021	7,704	1.96	15,112.54
Total			**15,874.06**

Program level peak reduction was calculated by taking the average peak reduction across all events. Max peak reduction was calculated by finding the maximum peak reduction per event. These results are shown in Table 4-11.

Table 4-11: Total Peak Reduction

Verified Peak Reduction (kW)	Max Peak Reduction (kW)
15,874.06	18,101.51

4.1.3.2 Smart Thermostat Rebates Impact

The annual energy savings for the Power Hours program was calculated based on the savings associated with the smart thermostat program incentive. Savings from smart thermostats are derived from improved real-time information about HVAC usage and cost, improved user interfaces, and algorithm optimization (such as occupancy detection and prediction).

Savings were calculated for customers that joined the program in PY2021 and received a rebate on the purchase of at least one smart thermostat. A thermostat model was considered smart if it met all the requirements for a smart thermostat listed in the AR TRM. In PY2021, 1,769 new smart thermostats were purchased by new program participants using rebates from the program.

Information collected from a sample of participants was used to estimate the net savings resulting from the free or rebated smart thermostats. This program offering does not generate significant spillover effects; therefore, evaluators did not assess spillover for this program. Residents were asked a series of questions on their financial ability to implement the measure without program incentives, plans to implement the project before learning of the program, the likelihood of implementing the measure in the absence of the program, and the impact of the program on the timing of the project to assess free ridership. The net-to-gross ratio was found to be 85.7%. This is slightly lower than the net-to-gross ratio in 2020, which was 87.8%. Net savings are shown in Table 4-12.

Table 4-12: Thermostat Incentive Energy Savings

Rebated Smart Thermostats	Gross Energy Savings (kWh)	Net-to-Gross Ratio	Net Energy Savings (kWh)
1,769	1,448,581	85.7%	1,241,434

Customers who received a new thermostat and participated in the DLC events (customers in the DLC or DLC + 2T-TOD programs) had their savings calculated as part of the DLC event impact analysis (see Section 4.1.3.1). The remaining customers received peak reduction savings of 0.26 kW per device. This number was estimated in 2017 by ADM as the average peak reduction for customers in the 2T-TOD subprogram. Peak demand reduction is shown in Table 4-13.

Table 4-13: Smart Thermostat Incentive Peak Reduction

Rebated Smart Thermostats Purchased by New 2T-TOD Customers	Verified Peak Reduction per Device (kW)	Gross Verified Peak Reduction (kW)	Net-to-Gross Ratio	Net Verified Peak Reduction (kW)
1,029	0.26	267.54	85.7%	229.28

4.1.3.3 Total Verified Demand Reduction (kW)

Total verified demand reduction was calculated by adding the verified demand reduction from the DLC events and the smart thermostat incentives. The results are shown in Table 4-14.

Table 4-14: Total Verified Peak Reduction

Source	Total Verified Peak Reduction (kW)
DLC Events	15,874.06
Thermostat Incentives	229.28
Total	**16,103.34**

4.1.3.4 Total Net Energy Savings (kWh)

Total net energy savings was calculated by adding up the total energy savings of each DLC event and the net annual energy savings from smart thermostat incentives (new thermostats in the program). The results are shown in Table 4-15.

Table 4-15: Total Net Energy Savings

Source	Total Energy Savings (kWh)
DLC Events	200,462
Thermostat Incentives	1,241,434
Total	**1,441,896**

4.1.3.5 Total Lifetime Savings (kWh)

According to the AR TRM, the effective useful life (EUL) of a new smart thermostat is 11 years[103]. Lifetime savings were calculated by multiplying the net annual energy savings from smart thermostats with the EUL. The total lifetime savings for all smart thermostats installed in PY2021 is shown in Table 4-16.

[103] Arkansas Technical Reference Manual, version 7.0 volume 1: See Section 2.1.12

Table 4-16: Total Lifetime Savings

Source	Expected Useful Life (Years)	Total Lifetime Savings (kWh)
Smart Thermostats	11	13,655,774

4.1.4 Process Evaluation Findings

ADM's process evaluation activities included participant surveys and a SWOT discussion with Program staff. ADM provided a process evaluation memo to PSO after the completion of the 2021 program year which includes details of the methodologies and findings. This section summarizes findings from the process evaluation.

4.1.4.1 SWOT Analysis

ADM analyzed the program's strengths, weaknesses, opportunities, and threats (SWOT analysis) with program staff. The SWOT analysis involved a group discussion with key personnel responsible for discussing past program year recommendations and brainstorming possible implementation strategies. The discussion focused on 1) identifying current, internal strengths, and weaknesses within the program, 2) providing specific examples of the strengths and weaknesses within the program, 3) identifying potential or external opportunities and threats for/to the program, and 4) providing specific examples of opportunities and threats within the program.

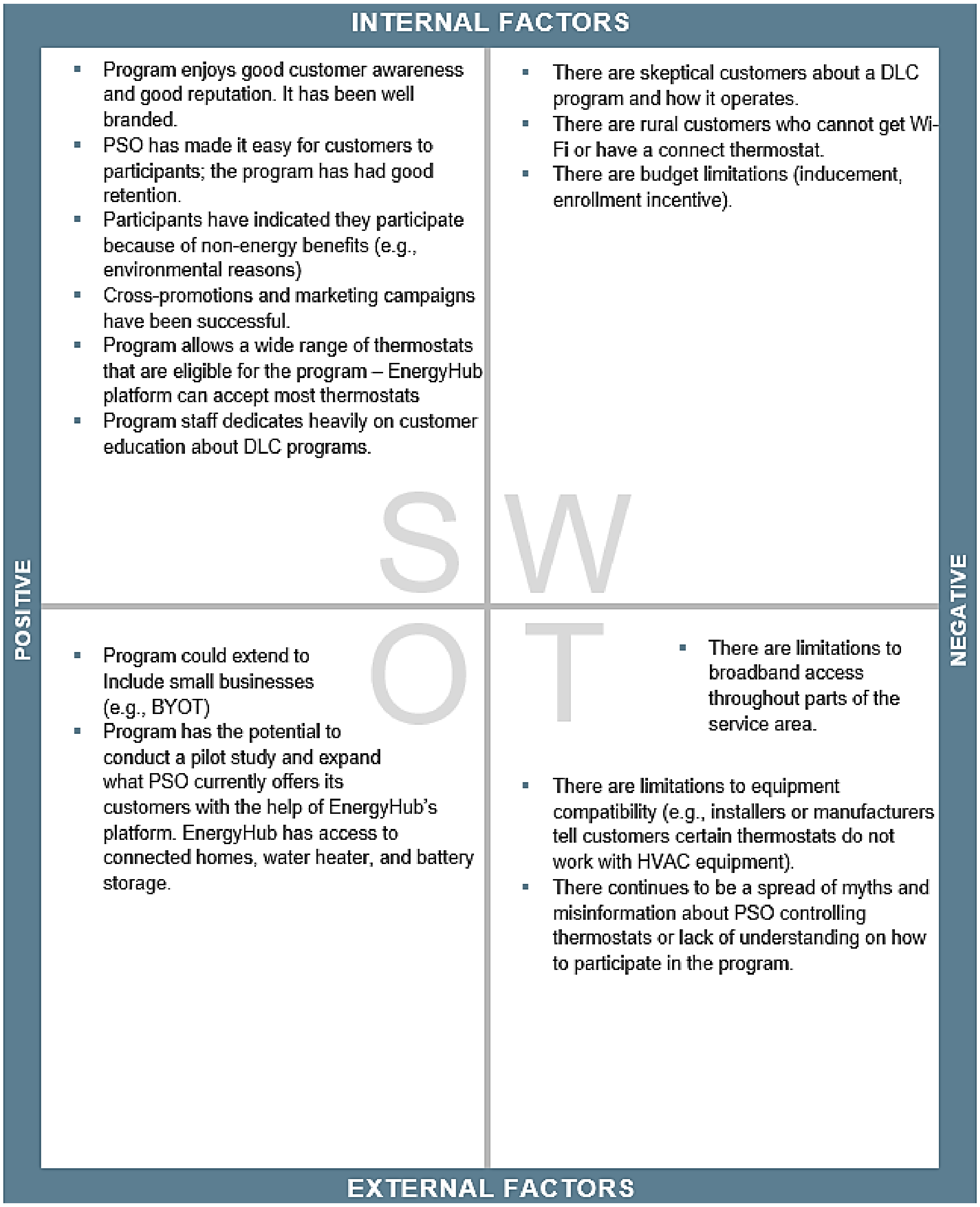
The following summarizes key findings of the SWOT analysis of the Power Hours Program.

- Power Hours is a well-branded program and has an excellent reputation. Program staff discussed the high level of customer awareness of Power Hours within the community. The program is well branded and has penetrated throughout PSO customers. Program staff stated they often hear from customers about participating in Power Hours, which affirms the program's reputation. Cross-promotion of Power Hours in other programs and the various marketing campaigns that PSO conducts helps raise awareness of the program.
- Streamlined enrollment processes and participation retention were identified as other strengths of Power Hours. According to program staff, the program has made it easier for customers to enroll. As a result, it appears that the easy enrollment process has led to a higher retention rate.
- Nonenergy benefits are strong motivators to enroll in Power Hours for some participants. Program staff discussed the various motivators for program participants. They stated that data indicates nonenergy benefits like environmental protection and combating climate change are two of the biggest motivators for customers to enroll in the program.

- The EnergyHub platform will allow for more thermostats to enroll in the program. In previous years, Power Hours had a limited number of thermostats that were eligible for the program. Switching to the EnergyHub platform will allow the expansion of eligible thermostats that can register for Power Hours during next program year.
- Customer education and skepticism about direct load control programs remain a challenge. Program staff discussed the skepticism among customers about the utility company controlling thermostats. To combat the misinformation, staff has developed educational materials to inform customers about DLC programs and the false notion associated with controlling thermostats. Furthermore, program staff discussed how some customers may not understand that they have signed up for the program when they have registered their device, which adds to the confusion.
- Lack of access to broadband internet in rural communities was identified as an external threat to the program. Program staff stated that some rural customers could not get Wi-Fi or connect a smart thermostat to the internet. Broadband access in the state is limited to more populated areas, which continues to limit the program's reach to all service territory.
- Extending the program to small businesses and potential pilots were opportunities discussed. Program staff indicated they would be interested in extending Power Hours to small businesses (e.g., BYOT offering). They stated there is the potential to enroll small businesses in the DLC program as well. Additionally, the EnergyHub platform has access to smart/connected homes, which creates an opportunity for pilot programs that include water heaters and battery storage.
- Staff discussed limitations related to equipment compatibility. Program staff explained how some installers and manufacturers believe certain smart thermostats are incompatible with various HVAC equipment. While this is rare, it does impact the program as the belief is quite common among the manufacturers and installers.

Figure 4-4 represents the topics discussed during the SWOT analysis.

Figure 4-4 SWOT Analysis



4.1.4.2 Participant Survey

ADM administered the Power Hours participant survey online in November of 2021 and sent email invitations to 1,681 participants to solicit their participation. This section summarizes the feedback received from a sample of 173 Power Hours participants who completed the 2021 survey. The following summarizes the key findings of the participant survey for the Power Hours Program.

- More than half of survey respondents were very or somewhat satisfied with the program overall. Most respondents indicated they enrolled in the program through

PSO's website. Among the survey respondents who registered their smart thermostat, most (74%) found the procedure easy. Additionally, 89% of survey participants found enrolling in Power Hours somewhat or very easy. Most of the Power Hours program participants learned about the program through a bill insert (38%), PSO email (32%), or PSO's website (15%). Other communication channels respondents identified included word-of-mouth, the program's website, or social media. Bill inserts and PSO emails were also the main channels to learn of the program for each subprogram. Finally, respondents enrolled in the program to save money on their energy bills, receive a free thermostat, or lower their electricity rates.

- Many DLC participants were not aware of peak events this year. Forty percent of survey respondents first became aware of a peak event by noticing the difference in how their home felt. Less than half (49%) of survey respondents reported that they were somewhat less comfortable during an event, 27% were at least as comfortable compared to other times, 15% reported that they were much less comfortable, and 9% were unsure. Many participants ran fans during events to remain comfortable, followed by participants who wore lighter clothing. Thirty-two percent of survey participants stated they overrode the temperature adjustment during a peak event. The most common reason for overriding the event was that the program participant's home felt too uncomfortable (71%).
- Survey respondents who participated in either the 2T-TOD or 2T-TOD + DLC subprograms provided positive feedback about their 2T-TOD subprogram experiences. Seventy-seven percent of survey participants reported either completely or somewhat understood how the 2T-TOD subprogram works. Most participants (79%) had installed a phone app (e.g., Total Comfort, ecobee app) to use with their smart thermostat. Among those who installed a phone app, 96% reported using it to adjust their home temperature. Survey responses suggest that program participants do not find reducing energy during On-Peak hours (2 pm to 7 pm) challenging. Participants made the greatest efforts to reduce energy during peak periods by avoiding drying clothes, using the dishwasher to wash dishes, and avoiding washing clothes.
- Survey results suggest that the Power Hours program influenced several participants to install a smart thermostat and install it earlier than they would have if the program were not available. The program's most popular aspect was the $110 rebate customers received for purchasing a smart thermostat. Fifty-eight percent of respondents indicated that they did not plan to install a smart thermostat had they not participated in Power Hours. Participants who had planned to install a smart thermostat had either not picked a specific device type (36%), chose Honeywell (41%), or chose Nest (11%). Fifty-seven percent of participants who

planned to install a smart thermostat said they installed it sooner than they otherwise would have because of the program. Furthermore, 35% of respondents would not have at all been likely to install the thermostat without the program, and 27% would not have been at all likely to install the thermostat without the opportunity to earn bill credits.

- Survey participants stated the pandemic had led them to consume more electricity since they spend more time at home. Seventy-one percent of survey respondents indicated they increased their time at home since the onset of the pandemic, with 43% reporting it greatly increased and 31% indicating it did not change from 2020. Less than half (37%) stated they noticed a change in their electricity bill since the start of the pandemic. Among those who noticed a change, most noticed higher bills, and increased usage. Seventy-one percent of survey respondents indicated they had not changed how they tried to save energy in their homes during the pandemic, with 19% indicating they had tried to save energy. The most common way the pandemic affected customers' ability to save energy in their homes was there was more usage due to being home more. The survey results suggest the pandemic did not significantly impact customers' ability to participate in energy-efficiency programs.

4.1.5 Conclusions and Recommendations

The following summarizes the key findings from the evaluation of the Power Hours program:

- The verified peak demand reduction was 16,103.34 kW, and the verified net annual energy savings for PY2021 was 1,441,896 kWh. Table 4-17 shows how PY2021 results compared to previous years.

Table 4-17: Power Hours Program-Level Results by Program Year

Program Year	Verified Net Peak Demand Reduction	Verified Net Annual Energy Savings
2019	11,938.00	2,024,453
2020	6,186.76	2,437,623
2021	16,103.34	1,441,896

- The program called eight DLC events in PY2021. This is a significant increase from PY2020, during which only one DLC event was called.
- 3,532 participants joined the program during PY2021 (compared to 3,369 in PY2020 and 3,463 in PY2019). Of those, 1,769 received a new smart thermostat through the program (compared to 3,357 in PY2020 and 2,694 in PY2019).

- Based on survey results, the largest source of program awareness for all sub program types was from bill inserts and utility mailers followed by program emails and the PSO website.
- Forty percent of survey respondents first became aware of an event by noticing the difference in how the temperature in the residence felt. This was followed by seeing a thermostat notice. In addition, of actions taken to maintain comfort during an event, 37% of responses turned on supplemental fans. This was followed by changing into lighter clothing. Thirty-two percent of survey respondents ended up overriding the temperature adjustment during an event.
- Approximately two-thirds of survey respondents avoided washing and drying clothes and avoided the use of the dish washer during peak periods. This demonstrates a strong awareness of energy savings but also indicates continued potential in energy efficiency education.
- Survey results indicates the program yields an overall satisfaction of 61% (representing satisfied and very satisfied). Satisfaction is high with rebate amounts and the thermostats but is only 46% satisfied with questions or concerns addressed by customer care agents.
- Only 41% of survey respondents were very satisfied or satisfied with energy bill savings.

The following recommendations are offered for continued improvement of the Power Hours program:

- Continue improving the program website and portal. As the program transitions to a new enrollment process, program staff can explore ways to improve the virtual experience customers have with the program by continuing to make the website and portal more user friendly and interactive. Survey results indicate that 75% of participants found registering a device to be very easy or easy.
- Continue to improve the education component of the Power Hours program. As the program transitions to a new enrollment process, program staff can explore different methods of better informing new and existing customers of the changes made to the program.
- The changes to implementation strategy in 2022 will offer opportunities to explore continuous improvement in program operations. ADM can support continued review strategies through customer journey mapping and surveying satisfaction levels at each customer touchpoint.
- Based on survey results, bill inserts, and utility mailers provided the highest level of program awareness. ADM recommends the continued use of bill inserts to support the program.

- As participant satisfaction has room for improvement regarding questions and concerns addressed, it may be beneficial to revisit the accessibility of information online such as Frequently Asked Questions (FAQ), thermostat operation information, and clarity in program operations. This may also address participant expectations with energy bill savings.

4.2 Peak Performers Program

This chapter presents findings from the impact and process evaluation of the 2021 Peak Performers Program.

4.2.1 Program Overview

The Peak Performers program is a demand response (DR) program for commercial and industrial customers in the PSO service territory. Non-residential PSO customers who are enrolled in the program voluntarily reduce their electricity load during load reduction, also known as peak events. Participants are paid incentives based on the average demand reduction over the course of all events and can opt-out of any event. Incentives are set at $32 per average kW reduction over all event hours and participants receive a 5% payment bonus if they participate in all reduction events throughout the year. There is no direct penalty for opting out of specific event days. PSO calls no more than three peak events per week, no more than four per month, and no more than 12 per year. The program is active during summer months when average demand typically approaches designated capacity thresholds.

A total of 252 customers comprising of 1,834 premises participated in the program during PY2021 (program year 2021). Table 4-18 shows the performance metrics achieved by the program.

Table 4-18: Performance Metrics – Peak Performers

Metric	PY2021
Number of Customers	252
Number of Premises	1,834
Budgeted Expenditures	$3,401,479
Actual Expenditures	$2,814,438
Energy Impacts (kWh)	
Projected Energy Savings	133,955
Reported Energy Savings	514,361
Gross Verified Energy Savings	1,360,734
Net Verified Energy Savings	1,360,734
Peak Demand Impacts (kW)	
Projected Peak Demand Savings	53,581.88
Reported Peak Demand Savings	73,480.19
Gross Verified Peak Demand Savings	45,563.62
Net Verified Peak Demand Savings	45,563.62
Benefit / Cost Ratios	
Total Resource Cost Test Ratio	7.18
Utility Cost Test Ratio	2.51

4.2.2 EM&V Methodologies

The section below covers ADM's impact evaluation methodology and results for the PY2021 Peak Performers program. The purpose of the impact evaluation is to determine gross verified peak demand savings as well as gross verified annual energy savings.

4.2.2.1 Data Retrieval and Review

The impact of peak events is analyzed using program tracking data and interval meter data for all program participants. This data was accessed and delivered to ADM via AEG's SQL Server Reporting Services (SSRS). Software written in the statistical programming language R was used to process and analyze the data. Various data processing steps are applied to the data before analyzed. These steps include:

- Validating that the files are not corrupt and of a consistent size.
- Extracting and transferring data from these files.
- Identifying any periods of missing interval meter data for any of the program participants.
- Updating PSO with remaining data needs (i.e., if files were missing or corrupted).

After the above steps are performed, the data is ready for analysis.

4.2.2.2 Calculating Baseline Demand Curves

Baseline demand curves are developed for each customer with the provided data. These are used to estimate what the demand would have been during an event day had the event not occurred. In PY2021, ADM employed multiple baseline methodologies and selected the best fitting models for each premise number. For a more comprehensive explanation of each baseline methodology and how they are used to create the final counterfactual baseline demand curves, see Appendix G.

To choose the most accurate baseline model for each premise, ADM evaluated each model's performance on the five weekdays over the program year where demand is highest (07/28/2021, 08/10/2021, 08/11/2021, 08/23/2021, 08/27/2021) during typical demand response hours for each premise number. These days were chosen from all non-event, non-holiday[104] weekdays during the months of June to August. These will be referred to throughout the report as "proxy event days". Performance was measured by fitting every type of baseline model to each proxy event day and calculating the residual root mean squared error (RRMSE) scores of each model's predictions.

It has been ADM's experience that baseline estimation methodologies often produce generally consistent results, but in some cases, these estimations can produce divergent results. To minimize calculation bias, we combined results as a weighted average of the best three models for each premise number. The weights were the inverse squares of the model RRMSEs. For example, if the three best fitting models have RRMSEs of 5%, 11%, and 52% respectively, their relative weights will be 79%, 20%, and 1% respectively.

4.2.2.3 Savings Calculations

With baseline demand curves determined for each participant, demand reduction can be calculated by comparing to actual demand. Demand reduction represents the average decrease in demand that occurs for an event participant during an hourly period. Demand reductions during peak events are estimated on a premise-by-premise basis. Equation 4-7 shows the formula for calculating demand reduction.

Equation 4-7: Hourly Demand Reduction Calculation

$$kW_t^{reduction} = kW_t^{baseline} - kW_t^{actual}$$

Where:

t = the hourly interval for which demand reduction is being calculated

$kW_t^{baseline}$ = kW demand predicted by the baseline at time t

[104] ADM defined a "holiday" as any date that falls on a U.S. federal holiday or observed U.S. federal holiday. See https://www.opm.gov/policy-data-oversight/pay-leave/federal-holidays/#url=2021 for a complete list.

kW_t^{actual} = kW demand measured at time t

Peak demand reduction is calculated by taking the mean of every hourly demand reduction that occurred during the event period; the event period being the time from when the event starts to when the event ends. The equation is shown in Equation 4-8.

Equation 4-8: DR Event Peak Demand Reduction (kW) Calculation

$$kW_{reduced} = \frac{1}{|EventPeriod|} \sum_{t \in EventPeriod} kW_t^{reduction}$$

Where:

t = an hourly interval

$EventPeriod$ = all time intervals from event start hour to the event ending hour

$kW_t^{reduction}$ = hourly demand reduction calculated at time period t

Hourly demand reduction is also used to calculate the energy savings for a given premise/event. The total DR event energy savings for a premise/event is calculated by summing together the hourly demand reduction that occurred at every hour during a DR event day[105]. The equation is shown in Equation 4-9.

Equation 4-9: DR Event Energy Savings (kWh) Calculation

$$kWh_{saved} = \sum_{t \in EventDay} kW_t^{reduction}$$

Where:

t = an hourly interval

$EventDay$ = all hourly time intervals that occur during a DR event day

$kW_t^{reduction}$ = hourly demand reduction calculated at time period t

4.2.3 Net-to-Gross Methodology

Demand response programs are not likely to have net-to-gross effects because customers are unlikely to curtail load in absence of the program. A net-to-gross ratio of 100% is assumed for this program.

[105] Note that the entire day is used for calculating energy savings because previous years have indicated that some load shifting was occurring during the event day. Therefore, the whole day must be used as the evaluation period to accurately capture energy savings.

4.2.4 Impact Evaluation Results

The methods described in the EM&V Methodologies section were used to determine the impacts on customer energy use for the Peak Performers program. These results are used to determine the peak demand reduction (kW) and energy savings (kWh). Findings are presented and discussed in this section.

4.2.4.1 Peak Events

In 2021, seven DR events were called. The schedule of these events is summarized in Table 4-19.

Table 4-19: Summary of DR Events

Date	Event Start Hour	Event End Hour	Duration (Hours)
06/17/2020	15	18	3
07/29/2021	14	17	3
07/30/2021	15	17	2
08/12/2021	14	17	3
08/24/2021	15	17	2
08/25/2021	15	18	3
08/26/2021	15	17	2

A baseline demand curve was developed for each premise for each event day. These were used to estimate what the demand would have been during the event day had the event not occurred.

ADM chose five proxy event days based on which non-event; non-holiday weekdays had the highest overall energy demand within the participant population. Proxy event days are meant to closely represent the conditions of a regular event day. Therefore, an accurate baseline methodology should be able to closely predict actual demand during each of the proxy event days. Figure 4-5 shows the sum of actual demand (all premises) as well as the sum of predicted baseline demand during each proxy event day, for the entire participant population.

Figure 4-5: Actual vs. Baseline Energy Demand -- Proxy Event Days

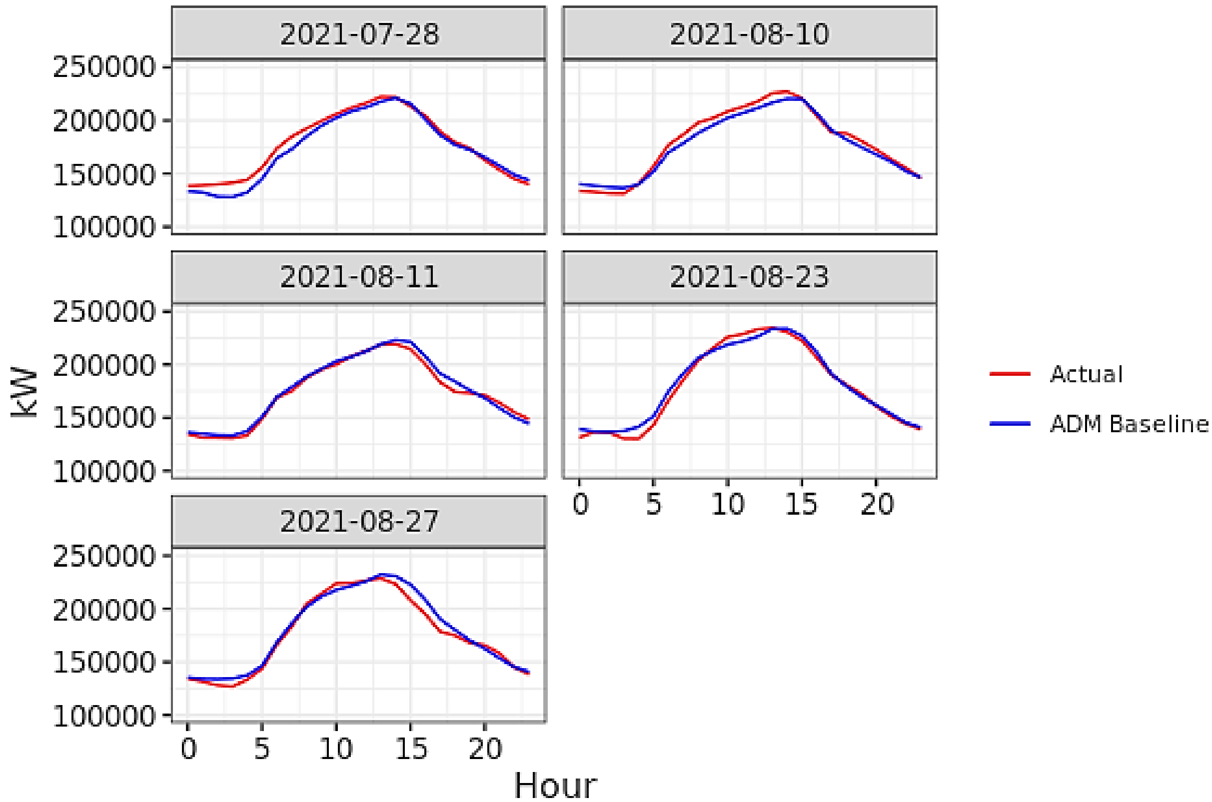
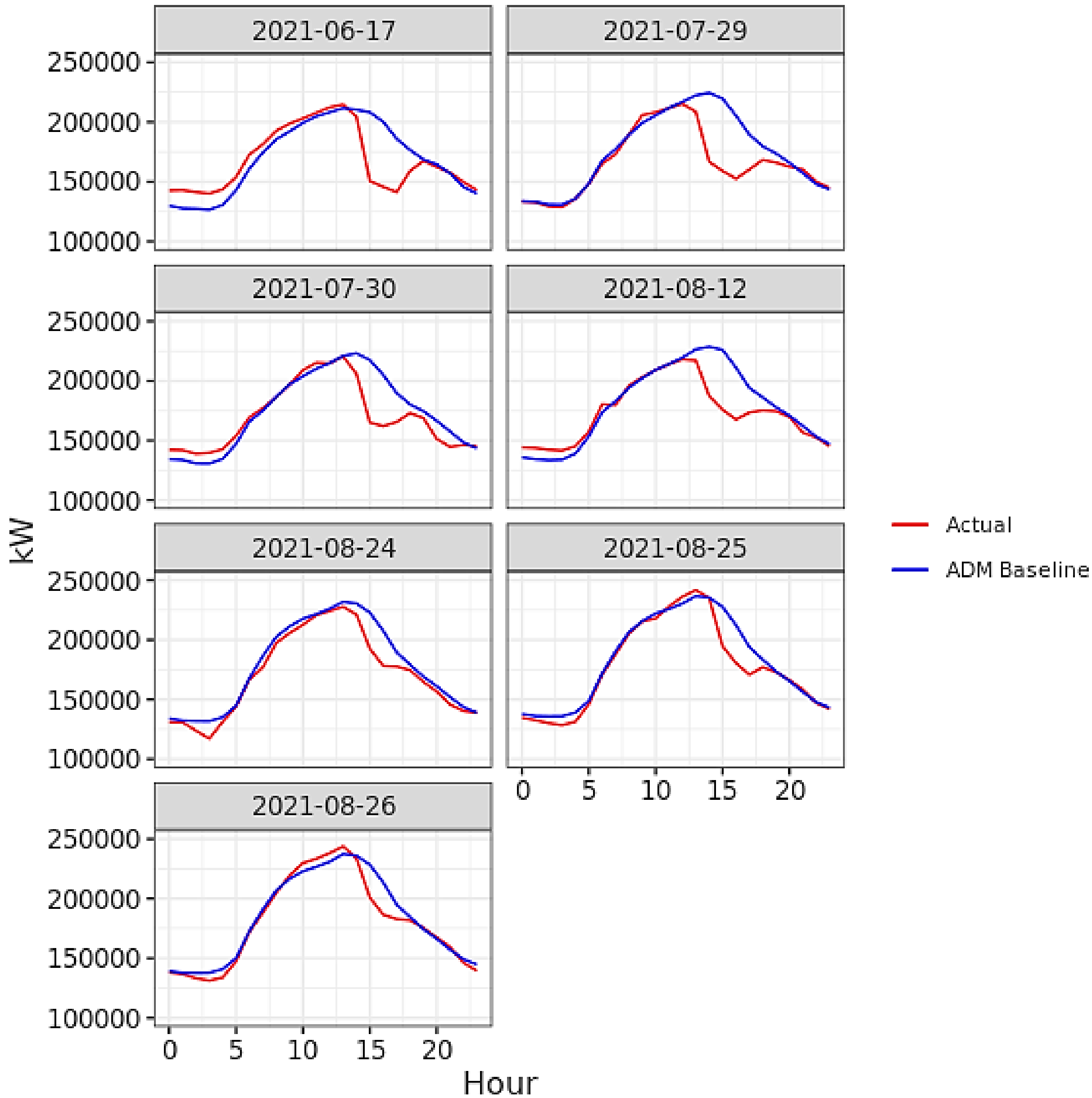


Figure 4-6 shows the sum of actual energy demand as well as the sum of predicted baseline demand during each DR event day, for the entire participant population. The grey area represents the event period.

Figure 4-6: Actual vs. Baseline Energy Demand -- Event Days



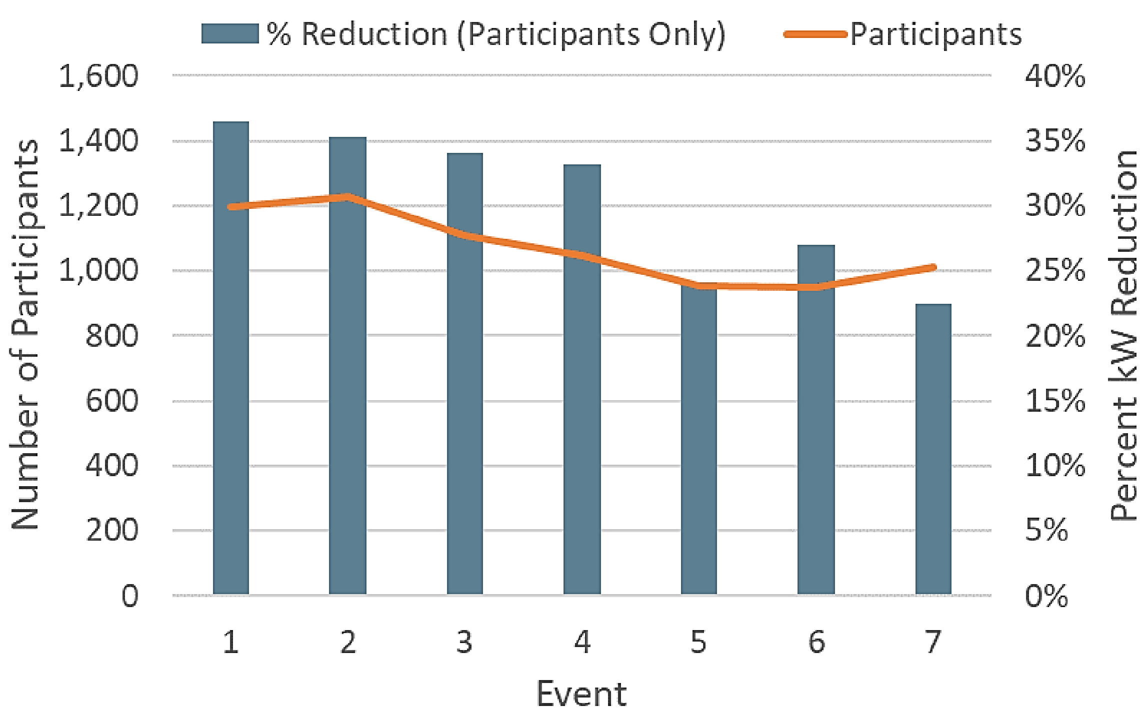
The difference between modeled baseline and actual demand for each hour of each event was calculated for each premise. Consistent with industry standards for calculating peak demand reduction, such as the Uniform Methods Project (UMP), the peak demand reduction for each event was determined as the average reduction across event hours for each premise. Therefore, the total peak demand reduction per event is the summation of each premises hourly average reduction during the event. The total peak demand reduction for the program is the average reduction across all events. Table 4-20 shows the peak demand reduction for each event.

Table 4-20: Program-Level Peak Demand Reduction (kW) per Event

Date	Participants	Non-Participants	Peak Reduction per Event (kW)
06/17/2020	1,197	634	55,308.68
07/29/2021	1,230	601	59,162.67
07/30/2021	1,110	721	51,965.74
08/12/2021	1,045	786	48,860.07
08/24/2021	954	877	34,552.11
08/25/2021	951	880	35,341.33
08/26/2021	1,013	818	33,754.77
PY2021 Verified Peak Demand Reduction (kW)			**45,563.62**

Average peak reduction for the final three events in August demonstrated a lower average curtailment per premise. Despite this, the kW reduction percentage never fell below 20%. The number of participants and the kW reduction percentage among all participants for each event is show in Figure 4-7.

Figure 4-7: Percent kW Reduction per Event



Participant incentives are determined based on ex-ante (reported) estimates of peak demand reduction. A comparison of ex-ante estimates to verified results are shown in Table 4-21.

Table 4-21: Peak Demand Reduction Results

Reported Peak kW	Verified Peak kW	Peak kW Realization Rate
73,480.19	45,563.62	62%

Energy savings were also calculated for each event. Total energy savings for each event was calculated by summing the hourly demand reduction values for each premise during every hourly period on a DR event day. Table 4-22 shows the total energy savings for each event and the total across all events.

Table 4-22: Energy Savings (kWh) per Event

Date	Total Energy Savings (kWh)
06/17/2020	229,182
07/29/2021	264,484
07/30/2021	180,846
08/12/2021	185,145
08/24/2021	198,756
08/25/2021	172,128
08/26/2021	130,193
Verified Energy Savings (kWh)	**1,360,734**

4.2.4.2 Lifetime Energy Savings

Energy impacts are determined each year and therefore an effective useful life of one year is applied to quantify the lifetime savings of participants for any given program year.

4.2.5 Process Evaluation Findings

ADM's process evaluation activities included participant surveys and a discussion with the PSO Program manager to review strengths, weaknesses, opportunities, and threats. ADM provided a process evaluation memo to PSO after the completion of the 2021 program year with detailed findings of the evaluation efforts. The following summarizes key finding from the process evaluation of the Peak Performers program. A listing of process evaluation activities is shown in Table 4-23 with a summary of findings for each activity presented in this section.

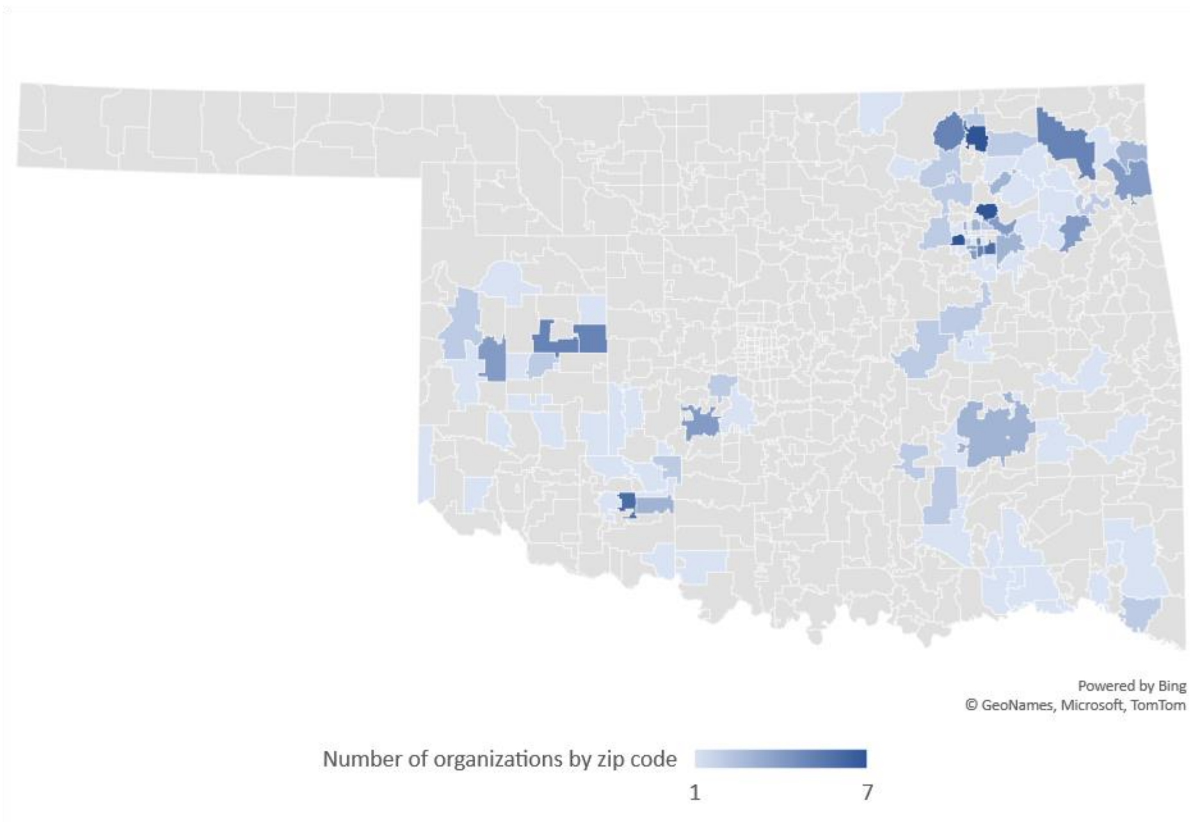
Table 4-23: Process Evaluation Data Collection Activities Summary

Data Collection Activity	Process Evaluation Research Objectives
Program Materials Review	Review reports and support materials for clarity and consistency with program objectives as well as an analysis on program participants.
Program SWOT Analysis	Assess program staff perspectives regarding program operations, strengths, weaknesses, barriers to success, and opportunities for improvement.
Participant Survey	Assess participant's reasons for participating and experience with the program, including satisfaction.

4.2.5.1 Program Participants Overview

Current program participants are located throughout the PSO territory (see Figure 4-8). Most of the organizations are operating in Tulsa (31%), Comanche (7%), and Rogers counties (5%).

Figure 4-8: Program Participant Location by Zip Code



Each organization varies in size and by industry sector. The top three facility types that participated during 2021 were K-12 schools (27%), public services or government entities (15%), and industrial/ manufacturing facilities (11%). See Table 4-24 for more details.

Table 4-24: Program Participants by Organization Type

Organization Types	Percentage of Responses (n = 252)
K - 12 School	27%
Public Services / Government	15%
Industrial / Manufacturing	11%
Religious worship	8%
Retail	6%
University / Community College / Technical School	4%
Energy / Oil and Natural Gas	4%
Recreation / Sports Facility	2%
Entertainment / Hospitality	2%
Farm / Food Producer	2%
Financial	2%
Insurance Company	2%
Mining	2%
Professional Offices	2%
Heath Facility	1%
Hotel	1%
Real Estate	1%
Supplier	1%
Non-profit Organization	1%
Restaurant (not fast food)	1%
Senior Living Community	1%
Social Services Organization	1%
Other	6%

ADM tracked the number of new participants for 2021. There were 13 new participants in the program. The new participants were in Delaware County (n = 1), Tulsa County (n = 5), Wagoner County (n = 2), Mayes County (n = 1), Comanche County (n = 1), Washington County (n = 2), and Okmulgee County (n = 1).

4.2.5.2 SWOT Analysis

ADM conducted an analysis of the program strengths, weaknesses, opportunities, and threats (SWOT analysis) with program staff. The SWOT analysis involved a group discussion with key personnel responsible for discussing past program years' recommendations and brainstorming possible implementation strategies. The discussion focused on 1) identifying current internal strengths and weaknesses within the program,

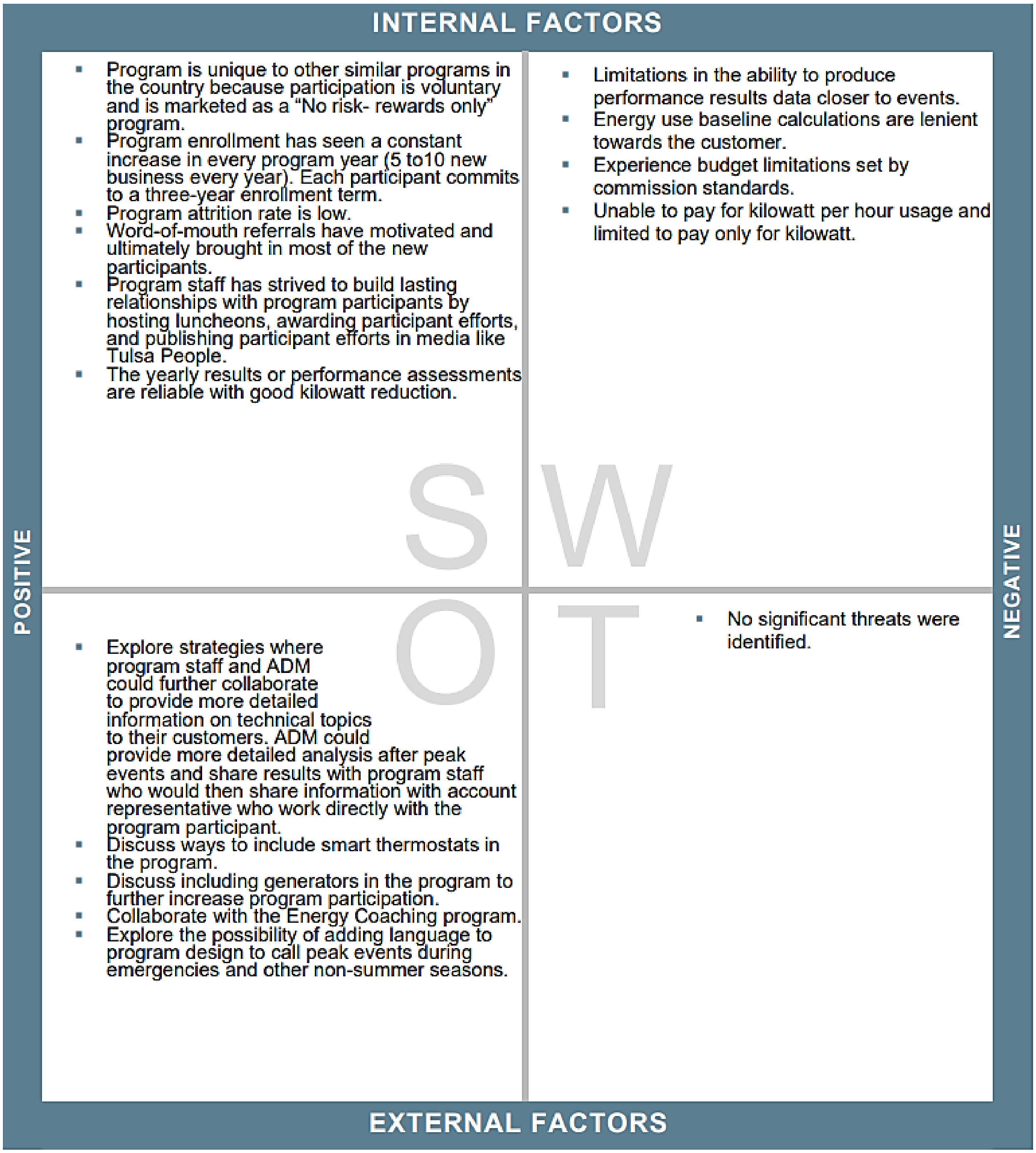
2) providing specific examples of the strengths and weaknesses within the program, 3) identifying potential internal or external opportunities and weaknesses within the program, and 4) providing specific examples of opportunities and threats within the program. An illustration was constructed during the discussion to retain focus and increase productivity. This illustration was later cleaned up and is presented in Figure 4-9.

The following summarizes key findings of the SWOT analysis of the Peak Performers Program.

- The strengths of the Peak Performers program's design include voluntary participation, no penalties, and not performance based. Peak Performers is marketed as a "no risk, rewards-only program" because participation is voluntary, participants are not penalized, and the program is not performance based. Over the years, program enrollment has seen a constant increase of five to ten new business enrolls every year. Most new participants learn about the program through word-of-mouth. Each participant commits to a three-year enrollment term. The duration of the commitment has helped streamline administrative processes for program staff. Program attrition rate is low. Finally, program staff indicated they have strived to build lasting relationships with program participants by hosting luncheons, awarding participant efforts, and publishing participant efforts in media like Tulsa People. Publication of these events provides positive public relations for companies that promote themselves as "green" or "environmentally conscious" businesses.
- Limitations in the ability to produce performance results data closer to events poses a challenge to the program. For example, program staff indicated they are limited in what performance data they can provide as close to the peak event as possible. Baseline calculations pose a challenge to the program because ex-post analysis tends to be more rigorous than estimates.
- Other limitations to program design include only paying for kW and budget limitations. Program staff discussed how they are limited to only paying for demand response (kW) savings and are unable to pay for energy efficiency (kWh) savings. Finally, Peak Performers experiences certain budget limitations set by the commission.
- Program staff provide insight to energy consumption for program participants and are always exploring opportunities to expand the offering. One of the ways program staff believe they could expand on the program was by including the use of smart thermostats or by adding additional peak events during system emergencies to prevent or mitigate issues like black or brownouts. They also discussed engaging in further collaborations with the Energy Coaching program and ADM. Program staff would like to work with ADM on finding ways of providing more detailed information on technical topics to their customers. It was discussed

during the SWOT that ADM could provide more detailed analysis after peak events and share results with program staff who could share information with the program participants through the appropriate channels.

Figure 4-9: SWOT Analysis Figure

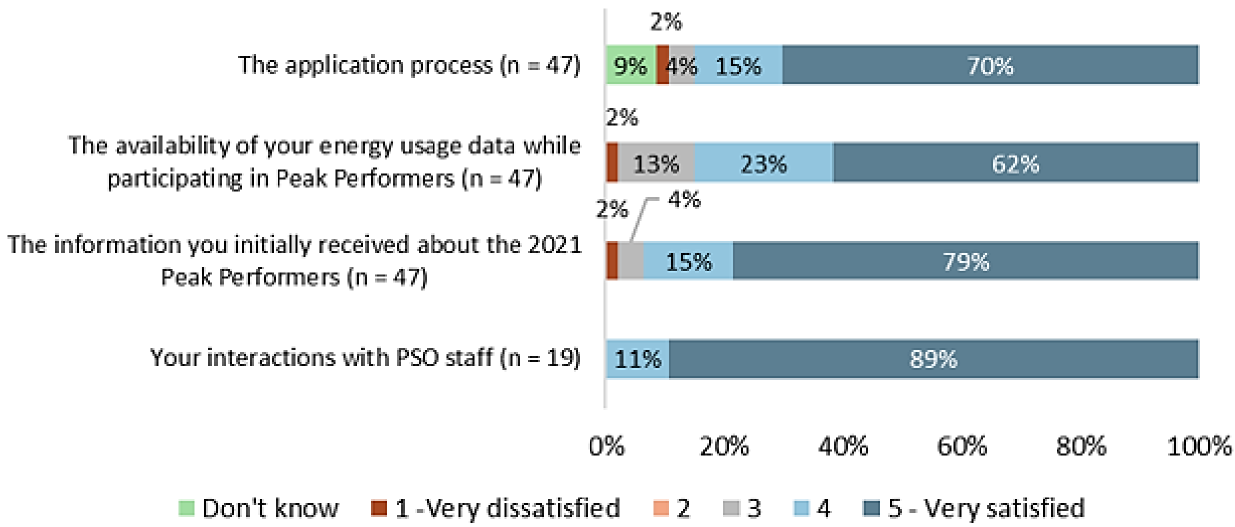


4.2.5.3 Program Survey Results

ADM administered an online survey to program participants during November 2021. The survey was conducted to collect data on how participants learned of the program, motivations for participating, and overall program satisfaction. ADM administered the survey to 252 program participant contacts. Forty-eight participants completed the survey.

Of the participants who completed the survey, 85% to 91% are somewhat or very satisfied with aspects of the program. Seventy-eight percent claim to have already recommended the program to others. Additionally, 94% of respondents are very likely or likely to participate in future years. Details on participant satisfaction is shown in Figure 4-10.

Figure 4-10 Participant Satisfaction



The following summarizes the key findings of the participant survey for the Peak Performers program.

- Program participants would like to see an average of five events per year. The Peak Performers program description states there could be up to 12 events conducted in a program year. Organization representatives provided feedback on their preferred number of events per year. On average, organization indicated they would like to participate in about five events per year. Answers ranged from calling one peak event to as many as needed.
- Most participants are satisfied with the Peak Performers program. Ninety-one percent of participants are somewhat or very satisfied with the program. Most survey respondents indicated they were somewhat or very satisfied with the energy demand data available to them while participating in the program (85%).

4.2.6 Conclusions and Recommendations

The following summarizes the key findings of the evaluation of the Peak Performers Program.

- The verified peak demand reduction for the 2021 program year is 45,563.62 kW, and the verified energy savings for the year is 1,360,734 kWh.
- Average peak demand reduction per participant was lower for the three consecutive day events in August. The percentage of load reduction ranged from 22% to 36% across seven events.
- The program called seven DR events in PY2021. This is a significant increase from PY2020, during which only test events were called.
- The top three facility types that participated during PY2021 were K-12 schools (27%), public services or government entities (15%), and industrial/ manufacturing facilities (11%).
- Most participants are satisfied with the Peak Performers program. Ninety-one percent of participants are somewhat or very satisfied with the program.
- On average, surveyed organizations indicated they would like to participate in about five events per year.

The following recommendations are offered for continued improvement of the Peak Performers program.

- Work with ADM to frequently produce data and results. The Peak Performers program could potentially benefit from working with ADM evaluators to provide more frequent access to data and results. ADM will work with PSO staff in the future to determine the most productive means of communication.
- Investigate the impact of energy aggregators on PSO offerings to SPP. Research the procedures set forth by FERC 2222 (ADM support) for energy aggregators to make offerings to SPP from PSO customers who participate in Peak Performers. It may be possible to work with aggregators as there may be additional benefit for the customer and the aggregator beyond event day reduction. For example, at least one other territory uses an energy aggregator as the implementer for demand response, where the energy aggregator utilizes various revenue streams.[106] In addition, energy aggregators may be able to support PSO goals for activities such as Energy Coaching and Non-Wires Solutions.
- The percentage of load reduction seen across events indicates there may be additional potential for curtailment. While some events saw a high load reduction,

[106] https://www.mdpi.com/1996-1073/14/12/3441/pdf

other events indicate that there is additional potential. There may be an opportunity to work with participants to help identify ways in which load can be further reduced.

- While advanced notice of events may not be feasible, increased communication about any key indicators influencing the timing of events and/or reminders about the program may lead to higher satisfaction as well as potentially increased curtailment.
- Increased training for PSO account managers who have regular contact with participants may help identify strategies for increased curtailment.

5 Research & Development Pilot Programs

PSO performed three energy efficiency and demand response pilot program studies in the portfolio cycle 2019-2021. The three pilots included a pool pump demand response pilot, a smart street lighting pilot and a non-wires solutions pilot. Results from these pilot programs are discussed in this chapter.

5.1 Pool Pump Demand Response

For this study, PSO installed remote triggering electrical switches on pool pump wiring to investigate the demand response potential during periods of high electricity demand. Ten participants were identified for the pilot with four events during the summer peak period window in 2020 and eight events in 2021 (eight of the ten participants contributed in 2021). Switch installation did not include any changes to the pool pump such as pool pump settings or additional controls. The switches leverage the same network and technology as PSO's existing AMI meter network. A table of event dates and times is shown in Table 5-1.

Table 5-1: Pool Pump Demand Response Events

Date	Start Time	End Time
July 7, 2020	4:00 PM	7:00 PM
August 10, 2020	4:00 PM	6:00 PM
September 14, 2020	4:00 PM	6:00 PM
September 16, 2020	4:00 PM	6:00 PM
June 17, 2021	3:00 PM	6:00 PM
July 29, 2021	2:00 PM	5:00 PM
July 30, 2021	3:00 PM	5:00 PM
August 11, 2021	3:00 PM	6:00 PM
August 12, 2021	2:00 PM	5:00 PM
August 24, 2021	3:00 PM	5:00 PM
August 25, 2021	3:00 PM	6:00 PM
August 26, 2021	3:00 PM	5:00 PM

ADM performed an impact evaluation effort to determine the potential peak demand reduction based on the demand response events. PSO collected information from each site (meter ID, pool pump size, event date, event start time, and event end time). ADM used this data along with customer AMI consumption data to determine peak demand reduction estimates.

5.1.1 Evaluation Methodology

This analysis was performed for three different groups: the pool pump accounts that were also participants in the Power Hours program (PP + PP group), the pool pump accounts that were not participants in the Power Hours program (PP group), and the group of control matched accounts that were in the Power Hours program were not participating in the pool pumps DR events (control group).

The following section covers how the control matched accounts were determined, and the methodology used to determine savings for each DR event and group.

5.1.1.1 Control Matching with Power Hours Sites

Most Pool Pump Program participants are also participants in the Power Hours Program (which will be referred to as the PP + PP group from now on). In 2021, the Power Hours DLC events and the pool pumps DR events were scheduled to run at the exact same time. This presented an analytical challenge, as usage would be reduced by both thermostat setpoint changes and turning off the pool pump during the same period. To evaluate this program, there needed to be a way to isolate the demand reduction of the pool pumps specifically.

To do this, ADM used a control matching strategy to find premises with similar usage patterns to the pool pump premises that were in the Power Hours program but not in the pool pumps pilot program. The following process was applied to all 6 of the PP + PP premises.

- All Power Hours participants within the PP + PP premise's zip code were identified.
- Average hourly usage on non-event days from in the months of June – August 2021 was calculated for each premise.
- A control matching was applied to find 5 Power Hours participants with the most similar usage patterns to the PP + PP premise. Specifically, a nearest neighbors matching method was used with a logistic regression model used to determine propensity scores.

The result was that 30 Power Hours participants were identified as the "control group" to the PP + PP participants. This group was evaluated along with the PP + PP participants. Once results for each event were calculated for each group, savings from the control group were subtracted from the savings from the PP + PP group to isolate the effects the pool pumps specifically had on demand reduction.

5.1.1.2 Data Preparation

The impact of pool pump demand response (DR) events is analyzed using 15-minute AMI meter data provided by PSO. This data was then aggregated to hourly time intervals and checked for completeness. Any meters that were did not have usage data for every hour of an event day were removed from that event days analysis.

Local temperature data was retrieved from the National Oceanic and Atmospheric Administration (NOAA). These temperature values were recorded at the airport in Tulsa, OK. Temperature values were converted to cooling degree days (CDD). This was done because CDD values can quantify how power consumption relates to the weather more effectively than temperature values. Equation 10 shows how temperature is converted to CDD. The CDD base temperature used for this analysis was 70 degrees.

Equation 10: Temperature to CDD Conversion

$$CDD_t = \begin{cases} 0 & if\ temp_t < cddbase \\ (temp_t - cddbase)\ /\ 24 & if\ temp_t \geq cddbase \end{cases}$$

Where:

$temp_t$ = temperature at time t

$cddbase$ = determined CDD base temperature

5.1.1.3 Generating Baseline Curves

With data prepared, baseline energy usage curves were developed at hourly intervals. These were used to estimate what energy usage would have been during an event day had the event not occurred. For each event, this counterfactual baseline is developed using AMI data from all responding devices during non-event, non-holiday weekdays that had similar weather to that of the event day being analyzed.

The k-means clustering algorithm is used to identify similar weather days to each event day. Average daily temperature and humidity is calculated for every non-holiday weekday from June to August. Then the k-means clustering algorithm is applied to the daily weather data. This method splits every day into one of three clusters (or similar groups) of dates. Any non-event day that was placed into the same cluster as the event day is used to calculate that event's baseline.

When determined what data is used to calculate each event's baseline curve, a linear regression model is calculated using that data (Equation 11).

Equation 11: Baseline Energy Usage Curve Regression Model

$$kW_t = CDD_t + t$$

Where:

t = the 30-minute interval for which kW usage is being predicted

CDD_t = cooling degree days at time t

To ensure the baseline curves are as accurate as possible, a normalizing factor is calculated and applied to the baseline curve of each event day (Equation 12).

Equation 12: Normalization Factor Calculation

$$nf = kW_{actual.hour=es-2} \ / \ kW_{baseline.hour=es-2}$$

Where:

$kW_{actual.hour=es-2}$ = kW measured 2 hours before the event

$kW_{baseline.hour=es-2}$ = kW predicted by the baseline 2 hours before the event

5.1.1.4 Demand Reduction Calculation

With the baseline curve determined, demand reduction can be calculated. Demand reduction represents the average hourly decrease in energy usage that occurs for the average event participant during a given time interval. Demand reduction is calculated for the event period and the snapback period. The event period is the time from when the event starts to when the event ends. The snapback period is the time from when the event ends to two hours after the event ends. The snapback period represents the time when all devices are resuming normal function and, as a result, typically have a small spike in energy usage before returning to normal. Equation 13 shows the formula for calculating demand reduction.

Equation 13: Demand Reduction Calculation

$$kW_t^{reduction} = kW_t^{baseline} - kW_t^{actual}$$

Where:

t = the hourly interval for which demand reduction is being calculated

$kW_t^{baseline}$ = kW demand predicted by the baseline at time t

kW_t^{actual} = kW demand measured at time t

Peak reduction is calculated for each event, representing the maximum hourly drop in energy usage that occurred for the average event participant. The equation is shown in Equation 14.

Equation 14: Verified Peak Reduction (kW) Calculation

$$kW_{reduced} = mean_{\, t \in FirstHour} \, (kW_t^{reduction})$$

Where:

t = the 30-minute interval for which energy savings is being calculated

$FirstHour$ = all time intervals from event start to one hour after event start

$kW_t^{reduction}$ = demand reduction calculated at time t

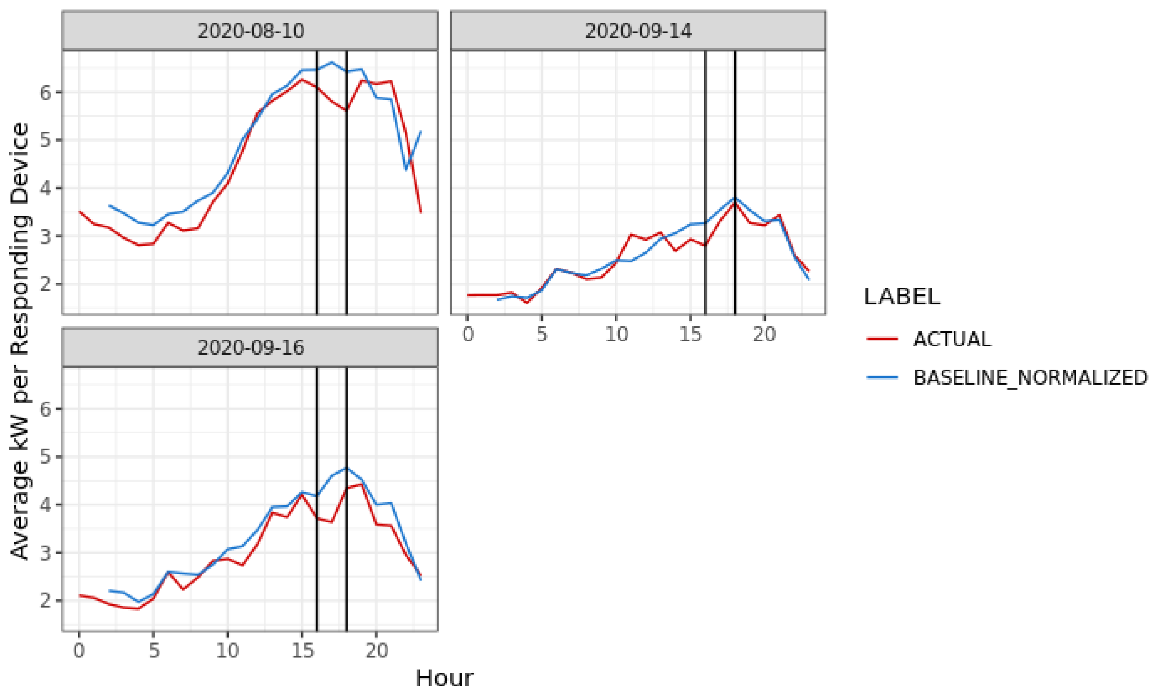
5.1.2 Evaluation Findings

There were four pool pump DR events called in 2020 and eight events called in 2021. The 2021 dates and times were identical to the schedule of DLC events for the Power Hours program. A summary is shown in Figure 5-1.

5.1.2.1 2020 Consumption Profiles

Analysis of the participants was conducted on three of the four events. Only five of the ten sites participated in the event on July 7, 2020, which also represented the single event to coincide with the Power Hours Program. The average hourly calculated baseline consumption versus the average hourly consumption on event days is shown in Figure 5-1 for each event day. Vertical lines represent the start and end time of each event.

Figure 5-1: Baseline vs. Actual Energy Usage per Event – 2020



5.1.2.2 2021 Consumption Profiles

Analysis of the 2021 participants was conducted on six of the eight events. AMI data was not available for the dates of July 30, 2021, and August 26, 2021. Eight sites participated in these six events. A baseline curve was developed for the event day for both the PP+PP group and the control group. These were used to estimate what energy usage would have been during the event day had the event not occurred. The average hourly baseline curve used for the demand reduction calculations as well as hourly consumption are shown in Figure 5-2 and Figure 5-3. Vertical lines represent the start and end time of the event.

Figure 5-2: Baseline vs. Actual Energy Usage per Event – 2021 (PP + PP Group)

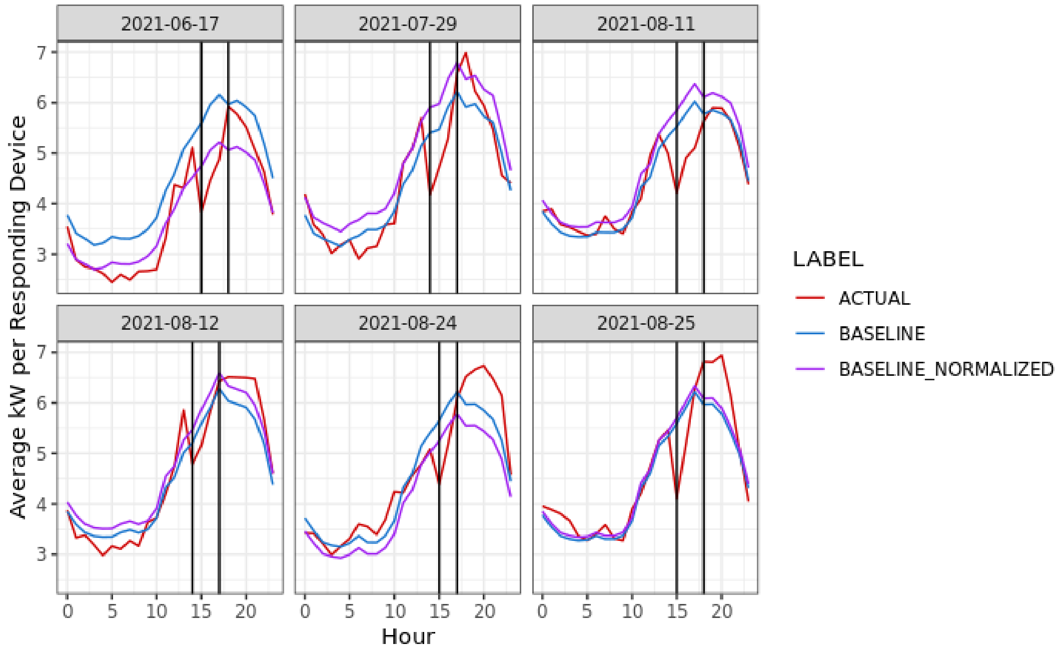
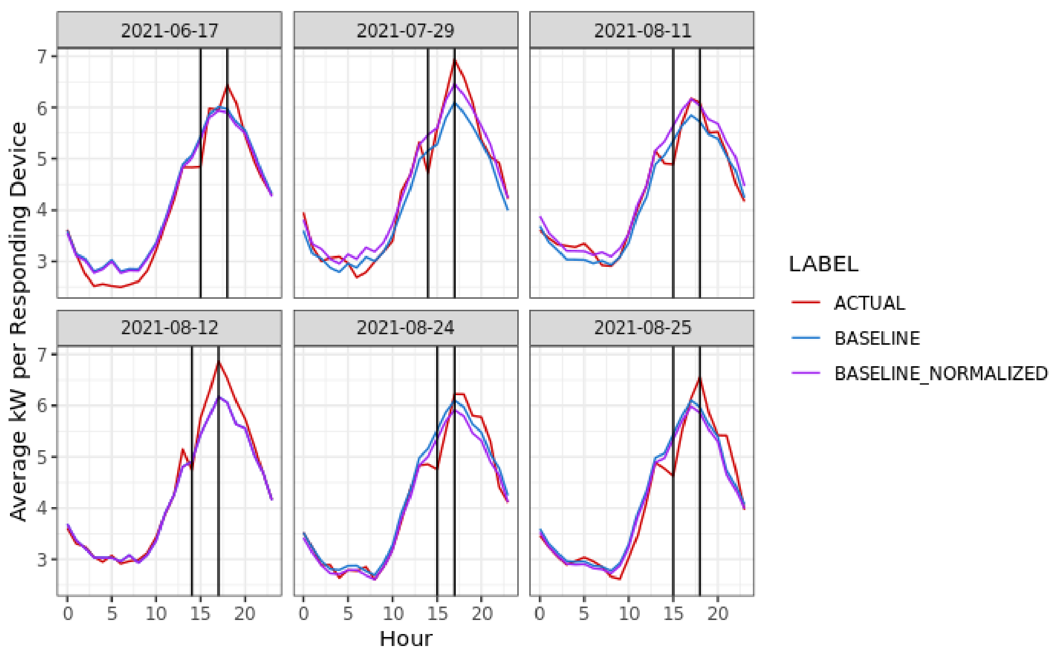


Figure 5-3: Baseline vs. Actual Energy Usage per Event – Control Group



5.1.2.1 Demand Response Results

Demand reduction was calculated by comparing the hourly consumption predicted by the baseline curve to the actual hourly consumption during the event for each participant. Results include demand reduction from the event period and the snapback period. The event period is the time from when the event starts to when the event ends. The snapback period is the time from when the event ends to two hours after the event ends. Demand reduction was calculated in hourly increments.

For the events in 2021, these values were calculated by subtracting the demand reduction values of the PP + PP from the demand reduction values of the control group. This was done to isolate the effects the pool pumps had on the demand reduction of the entire premise. Each column in Table 5-2 represents the average kW reduction of a pool pump during the specified time interval. Time intervals during the snapback period are identified with grey cells.

Table 5-2: Demand Reduction per Hour by Event

Date	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM
August 10, 2020			0.37	0.87	0.87	0.24
September 14, 2020			0.47	0.23	0.11	0.27
September 16, 2020			0.46	0.96	0.43	0.10
June 17, 2021	-	0.37	0.77	0.34	-0.32	-0.21
July 29, 2021	0.99	1.25	1.28	0.69	-0.18	-
July 30, 2021	-	-	-	-	-	-
August 11, 2021	-	0.88	0.97	1.28	0.54	0.03
August 12, 2021	0.52	1.04	0.85	0.86	0.30	-
August 24, 2021	-	0.27	0.20	0.00	-0.54	-
August 25, 2021	-	0.87	0.65	0.23	-0.03	-0.37
August 26, 2021	-	-	-	-	-	-

Peak reduction per pool pump was calculated for each event. Peak reductions for each event are shown in Table 5-3.

Table 5-3: Peak Demand Reduction per Pool Pump -- PP + PP Group

Date	Number of Residences	Peak Reduction per Device (kW)
August 10, 2020	10	0.87
September 14, 2020	10	0.47
September 16, 2020	10	0.96
June 17, 2021	8	0.77
July 29, 2021	8	0.99
July 30, 2021	8	-
August 11, 2021	8	1.28
August 12, 2021	8	1.04
August 24, 2021	8	0.27
August 25, 2021	8	0.87
August 26, 2021	8	-

The pool pump demand response events that took place during the PSO peak demand period in 2020 and 2021 results in an estimated maximum demand reduction of 1.28 kW per pump. Given that the average pool pump load at each site is 1.49 kW, this is a reasonable expectation. The estimated peak demand reduction for the program is 0.84 kW per participant for a total peak demand reduction of 8.4 kW across the pilot.

5.1.2.2 Discussion of Results

Given the small number of sites participating in the pool pumps events, it is difficult to develop an accurate estimate of what savings values to expect if this program were to be rolled out to a larger number of customers. The small number of customers results in large variability in the data across the participants. It is possible that adding more customers would average out the variability and potentially reduce the overall demand reduction values for each event.

All this is to say, there is evidence here to support that the pool pumps can create demand reduction savings, but the specific number identified in this evaluation may not be representative of what this program would look like with a larger number of participants.

5.2 Smart Street Lighting

As part of the smart street lighting pilot study, PSO installed smart controls on streetlights at four schools, with approximately 135 Telecells. Some of the lights are in parking lots, while others are on the street. The smart system provides the benefit of remote operation and feedback from each streetlight as well as smart controls for multiple dimming conditions. The equipment and provided software are made by Telensa.

The "Telecell" is a wireless control node for a given streetlight that includes revenue grade metering, on-board dimming, low power requirement of 0.8W, integral GPS, and runs without network connection. The "UNB" acronym, regarding the UNB base station, stands for Ultra Narrow Band radio system, which has the unique combination of low cost, long range, long battery life, and 2-way communication for massive numbers of devices. The Central System used to remotely manage the streetlights is called "PLANet" and is accessible via an online interface. Additional information, provided by Telensa, can be seen in Appendix H.

ADM conducted Measurement and Verification (M&V) through remote access to the PLANet® user interface. In addition, stakeholder interviews were conducted as a reduced scope process evaluation. Energy savings are generated from two aspects of this smart street lighting. Installation of the new equipment required a lamp upgrade to LED fixtures, and the controls component results in reduced consumption during hours of operation. The dimming schedule used is called "Photocontrol stepped 100% full on-80%-60%-80%-off". This schedule results in the lights turning on at 100% power using photocontrol at sunset, then dimming to 80% power at 20:00, 60% at 22:00, 80% at 05:00, and off using photocontrol at sunrise. All (135) retrofitted lights utilize this schedule.

5.2.1 Impact Evaluation Methodology

ADM collaborated with PSO and Telensa over the course of several months to learn about the scope of work, gain clarity on savings components, attend training for navigating the PLANet® system, develop an M&V Plan, and obtain data including make and model of retrofitted light fixtures, as well as quantities. ADM used the make and model information to download spec sheets for each pre and post-implementation fixture, including power requirements. ADM also obtained a data export from Telensa on 9-30-2020, which contained information about each Telecell, including lamp type and power readings. This information was cross-referenced with the retrofit fixture tally provided by PSO on 9-29-2020. During this process, two Telecells were identified as potentially having mislabeled fixture descriptions in the PLANet® system, based on power readings. Descriptions of the two are as follows:

Telecell 3958512 was showing a low power draw of 119W. This fixture is a 122W LED Cobrahead lamp type and was mislabeled as a 146W LED Medium Output Flood EFM1 in the PLANet system.

Telecell 3958523 was showing a low power draw of 147W. This fixture is a 146W LED Medium Output Flood EFM1 and was mislabeled as a 297W GE Evolve LED EFH1 in the PLANet system.

ADM verified both labeling corrections had been made, as of 10-7-21, via the PLANet® interface. In addition, ADM performed an updated data export in PLANet® to obtain an updated list of all Telecells and associated parameters. A pivot table was then run to tally fixture quantities by lamp type.

Energy savings from lighting efficiency projects can generally be formulated as follows:

$$Savings(kWh) = \sum_{i=1}^{All\ Portions} \left((kW_{Base} \times hours_{Base}) - (kW_{Efficient} \times hours_{Efficient}) \right)_i \times IEF_{E,i}$$

$$Demand\ Reduction(kW) = \sum_{i=1}^{All\ Spaces} \left((kW_{Base} \times CF_{Base}) - (kW_{Efficient} \times CF_{Efficient}) \right)_i \times IEF_{D,i}$$

Where:

i denotes the i^{th} portion involved in the lighting project. For M&V purposes, a project must be broken down into i distinct portions, with the portion generally defined by separate hours of use, separate spaces, or separate fixture types.

All parameters defined below may take on separate values for each of the i portions of the project:

kW_{Base} is the total connected lighting load in the base case. For retrofit projects this is the product of the quantity of base (pre-retrofit) fixtures, and the per-fixture alternating current wattage . For new construction, it is usually the product of the lighting wattage allowance and the area (though sometimes length or enumeration) of the affected space.

$kW_{Efficient}$ is the total connected lighting load in the efficient case. This is the product of the quantity of efficient (post-retrofit, or new construction) fixtures, and the per-fixture alternating current wattage.

$hours_{Base}$ is the total annual hours of operation for the given fixture group in the base case. The hours of use must account for the control type (e.g., for pre-existing occupancy sensors or other controls).

$hours_{Efficient}$ is the total annual hours of operation for the given fixture group in the efficient or "as built" case. The hours of use must account for the control type (e.g., for occupancy sensors or other controls).

CF_{Base} is the peak demand coincidence factor for the given fixture group in the base case. The hours of use must account for the control type (e.g., for pre-existing occupancy sensors or other controls).

$CF_{Efficient}$ is the peak demand coincidence factor for the given fixture group in the efficient or "as built" case. The hours of use must account for the control type (e.g., for occupancy sensors or other controls).

IEF_E is the average annual heating and cooling interactive effect for the space. If the total wattage inside a space is reduced by X watts, then the cooling system would have a lower cooling load (some fraction of X watts) as a result. Likewise, due to the reduction of "waste heat" of X watts, the heating system will have to work harder (again, by some fraction of X watts) to maintain the desired space temperature. IEF_{kWh} values are usually provided in the applicable Technical Reference Manual (TRM). A summary of achieved M&V is shown in Table 5-4.

Table 5-4: Summary of M&V Activities

Parameter	Data Acquisition Mode			
Baseline kW	Visual Verification Electrical Plans (New Construction)	Interview	Utility Meter /EMS Analysis	Invoice/Cut Sheet Review
Efficient kW	Visual Verification	Interview	Utility Meter /EMS Analysis	Invoice/Cut Sheet Review
Baseline Hours/CF	Logging	Interview / Posted Hours	Utility Meter /EMS Analysis	TRM
Efficient Hours/CF	Logging	Interview / Posted Hours	Utility Meter /EMS Analysis	TRM
IEF_E and IEF_D	Visual Inspection of HVAC Types	Interview	Utility Meter /EMS Analysis	Other N/A (lights are outside)

Power requirements for the new LEDs were taken from the specification sheets, whereas power requirements for the baseline fixtures were taken from standard wattage tables using the lamp type and nominal power requirement shown on the specification sheet. Savings associated with the dimming schedule implemented were accounted for by creating and applying a separate hourly percentage profile schedule based on the setpoints from PLANet®.

Baseline operating schedule was assumed to be typical photocell operation. 3,996 annual hours of use for outdoor lights was taken from the Arkansas TRM v6.1. To determine savings associated with the dimming schedule, an equivalent reduction in annual hours of use of 1,135 hours was calculated and applied to the new LED light fixture 100% power requirements. Interactive effects, or waste heat factor, is not applicable as all lighting fixtures are in unconditioned space.

5.2.2 Process Evaluation Methodology

In April and May 2021, ADM conducted phone interviews with PSO and Tulsa Public Schools staff that had been involved with the Smart Street Lighting Pilot ("SSL Pilot") in 2020 and 2021. The interviews were short, focused conversations that covered staff roles and responsibilities, satisfaction with the smart streetlight equipment and PLANet software, smart street lighting pilot benefits, and any concerns about future SSL Pilot operations.

5.2.3 Impact Evaluation Findings

ADM used available consumption and schedule data from Telensa's software to determine annual energy savings (kWh) and peak demand reduction (kW). Power requirements for the new LEDs were taken from acquired specification sheets. Baseline fixture wattages were sourced from the Arkansas TRM based on information gathered from PSO staff. Energy impacts from the fixture retrofits (installation of LEDs) are shown in Table 5-5.

Table 5-5: Detailed Energy Impact Results from Retrofit

Measure[1]	Quantity (Fixtures)		Wattage		Pre Hours	Post Hours	Realized kWh Savings	EUL	Lifetime Savings
	Old	New	Old	New					
250W HPS to 122W LED Cobra head	44	44	295	122	3,996	3,996	30,418	15	456,263
400W HPS to 146W LED Medium Output Flood	28	28	465	146	3,996	3,996	35,692	15	535,384
1,000W HPS to 297W GE Evolve LED	46	46	1,100	297	3,996	3,996	147,604	15	2,214,064
100W HPS to 39W LED Cobra head	16	16	138	39	3,996	3,996	6,330	15	94,945
100W HPS to 65W LED Post Top Salem	2	2	138	65	3,996	3,996	583	15	8,751
Total							**220,627**		**3,309,407**

Energy impacts from the addition of advanced network controls using the Telensa system are shown in Table 5-6.

Table 5-6: Detailed Energy Impact Results from Advanced Controls

Measure[1]	Quantity (Fixtures)		Wattage		Pre Hours	Post Hours	Realized kWh Savings	EUL	Lifetime Savings
	Old	New	Old	New					
250W HPS to 122W LED Cobra head	44	44	295	122	3,996	2,864	6,078	15	91,165
400W HPS to 146W LED Medium Output Flood	28	28	465	146	3,996	2,864	4,628	15	69,427
1,000W HPS to 297W GE Evolve LED	46	46	1,100	297	3,996	2,864	15,468	15	232,022
100W HPS to 39W LED Cobra head	16	16	138	39	3,996	2,864	706	15	10,597
100W HPS to 65W LED Post Top Salem	2	2	138	65	3,996	2,864	147	15	2,208
Total							**27,027**		**405,419**

The combined energy impacts from the lighting retrofit and advanced controls are shown in Table 5-7. The Smart Streetlighting Pilot Program was included in the 2019-2021 portfolio plan with energy impact estimates shown in Table 5-7.

Table 5-7: Energy Impacts of the SSL Pilot

Project Savings	Verified Energy Savings (kWh)	Portfolio Plan Estimates
Retrofit Energy Savings (kWh)	220,627	151,318
Controls Energy Savings (kWh)	27,028	0
Total Energy Savings (kWh)	**247,655**	**151,318**
Demand Reduction (kW)	**0**	**0**

5.2.4 Process Evaluation Findings

This section presents summary information gathered from speaking with five PSO SSL Pilot staff. ADM spoke with a senior coordinator, functional system analyst, customer services supervisor, engineer technician, and customer service account representative.

- PSO contacts' roles, responsibilities, and level of involvement with the SSL pilot varied. The PSO contacts explained their roles and responsibilities broadly and their roles as they related to the SSL Pilot. The senior coordinator, customer service account representative, and customer services supervisor noted that they had observed the pilot or had been involved in a limited capacity. The engineer technician and functional systems analyst noted having been more directly involved with the SSL Pilot. The engineer technician said that they had been involved with project coordination, equipment installation, troubleshooting, and customer relations for the pilot. He noted that PSO relies on Telensa staff to maintain the PLANet® software. The functional system analyst noted that he monitors Telecells and if they stop functioning, he notifies the PSO repair department staff.

- All five contacts said they were satisfied with the Telensa smart street lighting equipment. The customer services supervisor said that the main benefits for the customer are being able to monitor the status of the lights and to be able to adjust the timing and level of lights. The engineer technician said the main benefits are being able to control lights remotely and troubleshoot any issues that arise. Similarly, the functional systems analyst observed that the main benefit of the SSL equipment is immediate knowledge of fixture status.
- The PSO contacts noted that the equipment had been installed successfully, though there were opportunities to improve the process. The customer services supervisor and engineer technician communicated three potential areas for improvement.
- Ensure there is adequate and clear communication. The customer services supervisor stated there had been an issue coordinating the installation of the lighting with Tulsa Public Schools. He said that because of the miscommunication lights had been installed at Tulsa Public School's East Central High School, and then had to be removed because they had been installed in an area slated for construction. He also relayed that it was important to communicate effectively with the customer about dimming schedules and different time of day and lighting level needs were met.
- Locate fixtures away from transmission lines. The engineering technician observed that some fixtures in the pilot had been installed near transmission lines and these fixtures were displaying errors in the system as the node was picking up static from the voltage feed.
- Consider purchasing a barcode scanner tool. The engineering technician and customer services supervisor noted that the installation process could be improved by obtaining and utilizing a barcode scanner tool. The engineer technician observed that this process currently requires a "human element" because technicians are required to initialize the nodes and base stations by manually inputting node serial numbers, amperage, and wattage. During this process, data entry errors are possible. A technician may input data incorrectly and put a fixture on the wrong node or input the wrong power requirement for a fixture and thus cause the software to indicate errors or power issues. He observed that during the Pilot they were able to resolve most issues, though it had been a confusing and somewhat onerous process. The customer services supervisor echoed this

sentiment and noted this barcode scanner tool could ease the installation process for new light fixtures into the system.

- The contacts all observed that the lighting controls and fixtures were functioning properly, though the functional systems analyst, senior coordinator, and engineer technician noted some challenges. The functional systems analyst and engineer technician noted that there had been a lightning strike that hit the equipment, but because of the system nodes' overlap, it was able to continue operations uninterrupted. The functional systems analyst also said that there was an antennae issue early in the pilot. He stated that the engineer technician's team replaced a base station and that remedied the issue. The senior coordinator noted that the SSL Pilot controls are sensitive and sometimes indicate voltage problems when there are not any. Regarding maintenance and repairs of SSL Pilot fixtures, the engineer technician said that PSO technicians do not work on individual fixture components. He noted that if the software indicates that a component of the smart street lighting fixtures is not functional, the staff is trained to replace the whole fixture. Therefore, the software may indicate an entire fixture needs attention though only a component needs attention.
- PSO staff reported varying levels of interaction with the PLANet® Software; the engineer technician offered feedback on its features and user design. The engineer technician and functional systems analyst noted using the PLANet® Software, while the Senior Coordinator and Customer Service Account Representative said they observed it being used. The customer services supervisor reported having no experience with the software. The engineer technician noted that the software had many exceptional capabilities but rated its ease of use as being "middle of the road" and described it as very layered and difficult to navigate. He also observed that the software required remembering several distinct steps to achieve desired tasks and felt it had been "expensive to learn and remember" as he worked with software intermittently. He suggested that the system be made more "plug and play" and to rely less on field technicians completing data entry; he specifically suggested that the base station be able to address nodes and be able to auto-detect and report fixtures and serial numbers of fixtures attached to them. The functional systems analyst stated that they used the software every morning to check the system status page. He said that if there are error codes on multiple days, he sends orders for those fixtures to be serviced to the engineering technician's group. He noted that this has only occurred once when a fixture was struck by lightning.
- The contacts indicated that they did not have any significant concerns about expanding the SSL Pilot and generally showed support for future installations. None of the contacts voiced strong opposition to future installations of smart street

lighting equipment. The engineer technician stated that they believe smart street lighting will increase fixture life. The customer services supervisor recommended future installations and said that figuring out tariffs and reduced usage, scheduling, and paying for the installations were only minor concerns. The senior coordinator did not share any concern about future operations of the smart street lighting fixtures but voiced some concern about the future of the IoT ("internet of things") and how PSO will be able to utilize these fixtures and when it will make sense to fully implement.

Customer Perspective

ADM spoke with a maintenance manager and an energy education specialist at Tulsa Public Schools. We also attempted to contact the Tulsa Public Schools Executive Director of Bond Management with two emails and two phone calls. The energy education specialist stated that PSO selected the locations that would install the SSL equipment and that a total of five schools had been involved with the pilot.

- The Tulsa Public Schools contacts' roles, responsibilities, and level of involvement with the SSL Pilot varied. The maintenance manager stated that he oversees maintenance and energy usage across all school campuses, while the energy education specialist said that he is responsible for monitoring energy and gas usage for a subset of Tulsa Public Schools' locations. For the SSL Pilot, the energy education specialist took inventory of Tula Public Schools' lighting with information such as the number of lights, lumen efficiency, age of light, degraded nature of the light and coordinated with schools and PSO to install the lights and manage the timing of their operations.
- Both contacts indicated they were satisfied, and the equipment was functioning properly. The energy education specialist noted that lightning had struck and damaged one of the SSL controllers. Despite the lightning strike breaking the equipment, the lighting remained operational because it switched to using a different controller on the network. The staff was able to observe this using the PLANet® Software.
- The Tulsa Public Schools contacts noted that the LEDs installed through the pilot were unable to illuminate the same area as their previous equipment. Moreover, the energy education specialist observed that the new lighting was "not quite the amount of lumens" they desired, and the maintenance manager stated that they may need to install more lighting because of the newly installed LEDs smaller footprint. Although both contacts noted these concerns, they also alluded to the benefit of less lighting spillover into adjacent or nearby neighborhood homes.
- Tulsa Public Schools staff noted several key benefits of participating in the pilot including the ability to control lights' schedules and output levels, monitor

operational status, and save energy. Both contacts observed that the pilot may be able to benefit the district by enabling them to recoup electricity costs and that the SSL equipment had helped them to address neighbors' complaints of light spillover.

- The maintenance manager said they were interested in investigating the software and its capabilities further themselves but had not been granted access or user abilities yet. He stated that PSO currently controls the lighting that was installed through the pilot but that after the pilot "rolls out completely" Tulsa Public Schools would be able to access controls.

Neither contact indicated they had any current concerns with the equipment, though the maintenance manager said they were concerned about a lack of information on the timeline and cost of future SSL installations. The energy education specialist said that Tulsa Public Schools was investigating several smart lighting control options and that the school district was interested in recouping some of the savings that lighting controls may generate from PSO.

5.3 Non-Wires Solution

Under contract with PSO, ADM is performing evaluation, measurement, and verification (EM&V) activities to confirm the annual energy savings (kWh), summer peak demand reductions (kW), and winter morning ramp-up reduction (kW) being realized through the Non-Wires Solutions Pilot program that PSO is implementing in 2020-2021.

This pilot program seeks to implement site-specific energy efficiency measures using recommendations from the implementer team's Phase 2 Non-Wires Solutions (NWS) Study to reduce the demand peak on circuit 83831 in the Boswell, Soper, Hugo area. The Phase 2 report suggests that a 588 peak winter lead reduction (kW) is feasible and cost effective through traditional energy efficiency and demand response solutions compared to a $4 million distribution investment. Energy efficiency measures will be implemented based on current program offerings and additional measures. These include:

- Residential Weatherization (air sealing, duct sealing, attic insulation, low-flow showerheads, faucet aerators, hot water pipe insulation)
- Residential LED light bulbs (through the Residential Weatherization Program)
- Efficient heat pumps (through the Home Rebates Single Upgrades Program)
- Small Business Lighting and Refrigeration (through the Small Business Energy Solutions Program)
- Commercial and Industrial Measures (targeting lighting, refrigeration seals, and strip curtains through the Business Rebates Program)
- Energy Coaching

- Residential HVAC Tune-Up

Evaluation of these measures will result in verification of net annual energy savings, net peak demand reduction, and net winter ramp-up demand reduction.

5.3.1 Evaluation Methodology

ADM evaluated the NWS program impacts. Measures incorporated into energy-efficiency programs were evaluated through those program evaluations for annual energy savings (kWh), summer peak demand reduction (kW), and lifetime energy savings (kWh). The scope of this analysis and report is the determination of Verified winter peak savings (kW). The goal of this program evaluation is to determine the reduction in consumption on circuit 83831 due to the installation of energy efficient equipment through PSO's portfolio of energy-efficiency programs.

Winter peak savings (kW) are to be determined based on the peak load specific to PSO circuit 83831. The peak period for this circuit has been determined to be from 7-8 AM CT on non-holiday weekdays in the months of December and January. This evaluation will report estimates for the hours of 7-8 AM as well as average reductions from 6-9 AM due to installation of energy efficiency equipment.

Winter peak savings (kW) were determined through various analytical approaches as described in this section. These results will be considered both gross and net impacts due to the nature of implementation. All residences and business were targeted for implementation and further incentivized through a bonus. The result of these practices yields a net-to-gross ratio of 100%.

5.3.1.1 Measure Targeting Support

ADM supported the implementation of energy efficiency measures through collaboration of a consumption targeting analysis as well as analytical support on the determination of winter peak savings to mitigate evaluation risk.

ADM receives daily Advanced Metering Infrastructure (AMI) data from PSO that includes meters on the circuit 83831. ADM utilized this data to provide visual representation of load shapes for industrial, commercial, and residential meters on the circuit. ADM provided visual representation of both individual meters as well as aggregated load shapes across sectors. ADM provided information to PSO and ICF as requested in support of ICF's implementation strategies. ADM was also provided circuit level data back to 2017 directly from PSO to support this analysis.

Using AMI data, ADM was able to identify meters with both the largest magnitude of usage during the winter peak period as well as the largest impact on the identified winter peak morning ramp-up. ADM assessed each C&I meter on the circuit to identify the top uses by the following four criteria:

- Average consumption between 6-11 AM on Weekdays in December and January
- Average consumption between 6-9 AM on Weekdays in December and January
- Average consumption between 7-8 AM on Weekdays in December and January
- Consumption changes between 6am and 8am (time stamps 6am and 8am) on weekdays in December and January

ADM met with ICF to review applicable approaches used to determine an hourly and average hourly reduction during the winter peak period. ICF used the following general approaches to determine winter peak savings estimates.

For the residential measures considered in the Implementation strategy, ICF ran single family energy simulations calibrated to a load shape from aggregated customer usage. The load shapes generated by the calibrated models were then used to determine impacts of setpoint changes due the installation of a range of energy efficiency measures.

For commercial measures, ICF utilized engineering algorithms specific to measures implemented. For lighting measures, 8,760 energy savings curves were developed based on the facilities lighting operating schedule.

5.3.1.2 Tracking Data Review

ADM performed a review of tracking data from Sightline and routinely referred to tracking data to determine participation throughout the implementation period. Tracking data was used to develop load shapes through energy simulations such that analytical methods were in place upon completion of the implementation period.

5.3.1.3 Engineering Analysis

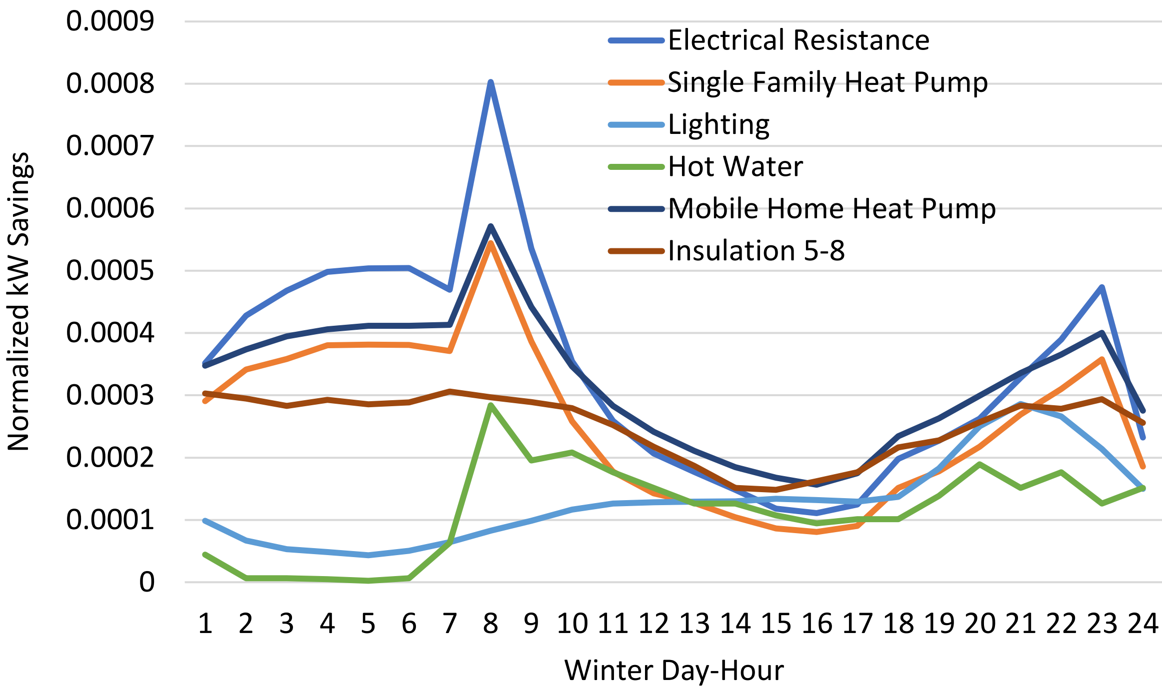
ADM’s approach to the determination of winter peak savings during the identified winter peak period for circuit 83831 was to use applicable energy simulations and ADM’s library of end-use load shapes. Energy simulations for mechanical systems were used to develop normalized load shapes in which deemed or as-found annual energy savings (using industry standard references such as the Arkansas Technical Reference Manual) could be applied to the developed load shapes to determine an hourly reduction over the course of a year. Previously developed load shapes based on end-use consumption were used for lighting, motors, and water heating.

Residential

ADM utilized prototypical eQUEST energy simulations developed for the Database of Energy Efficiency Resources (DEER) to develop applicable load shapes (for mechanical systems) based on the structure type and energy efficiency measure. Energy simulations were developed for single family residences as well as mobile homes in both baseline and efficient conditions. Energy simulations were run using typical meteorological year

(TMY3) weather data for Paris, Texas; identified as the most representative weather to determine weather-normalized results. Load shapes were reviewed for comparison against expected hourly consumption during the winter peak period for residences on circuit 83831. Figure 5-4 shows normalized average kW savings on weekdays and non-holidays in December and January for various end-use conditions used in the analysis.

Figure 5-4: Residential Simulation Results



Load shapes were generated for the expected baseline condition as well as the expected efficient condition. The load shapes were compared on an hourly basis to determine an hourly reduction across a typical meteorological year. The resultant reduction curve was then normalized such that each hour represents a weighted fraction of the total annual reduction.

For example, a residential energy simulation configured for a heat pump with a known efficiency will provide an hourly energy consumption (8,760 load shape) for both the heat pump and supply fan. These two end-use hourly energy consumptions are added together to show a heat pump load shape. The same model is run for the baseline condition (heat pump SEER and HSPF based on the AR TRM) and the efficient condition (known heat pump SEER and HSPF). The installed or efficient condition model load shape is subtracted from the baseline load shape to determine an annual savings curve. The savings curve is normalized by dividing each hourly consumption by the annual energy savings such that a fraction represents each hour. Normalizing the savings curve allows for an annual energy savings value to be applied across the fraction of consumption for each hour of the year to determine an hourly savings value.

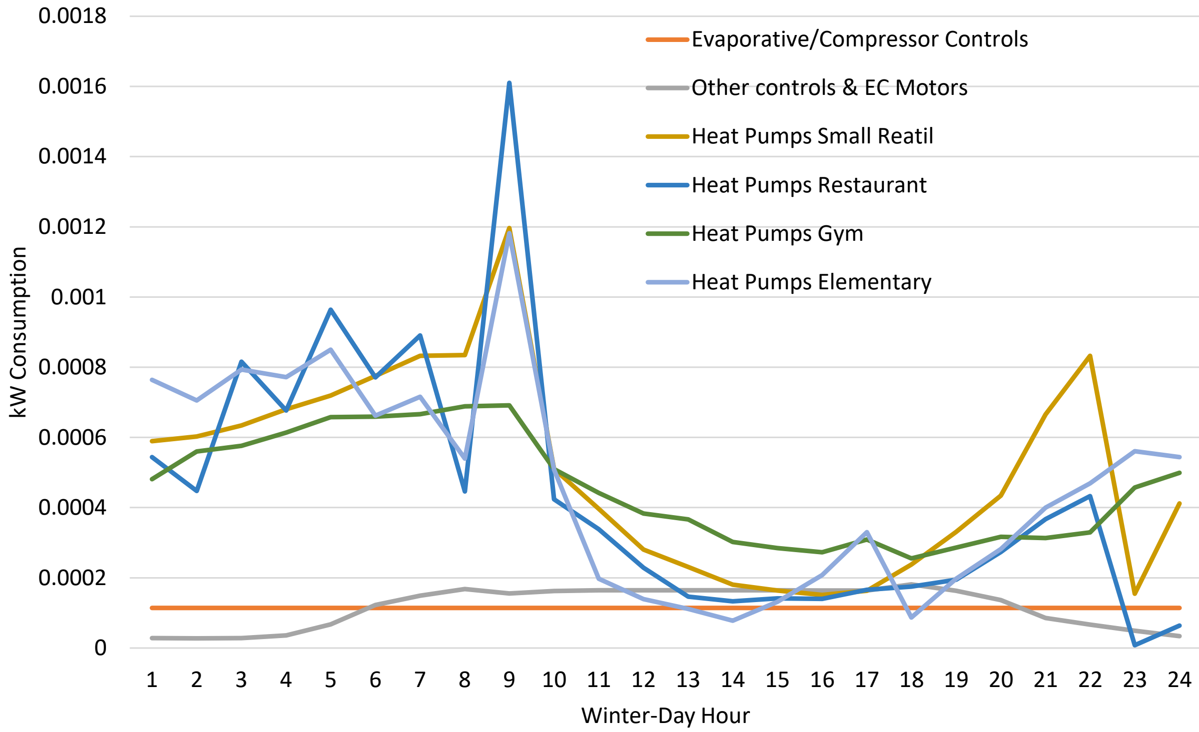
As all measures installed were included in PSO's portfolio of Energy-efficiency programs, ADM utilized Verified 2020 portfolio evaluation results to apply to the normalized savings curve based on a typical meteorological year. Annual energy savings for residential program are based on deemed algorithms from various sources, such as the Arkansas Technical Reference Manual (AR TRM). The result is a fraction of annual energy savings associated with each hour of the year.

The winter peak savings is defined as the average hourly value across the winter peak period. ADM is reporting on winter peak savings for the given hour with the highest load as well as an average hourly value including the hour before and the hour after. The result is a winter peak savings representing 7-8 AM on non-holiday weekdays in December and January and the average hourly value between 6-9 AM on non-holiday weekdays in December and January.

Commercial

ADM utilized an approach like the residential engineering analysis for the commercial and industrial measures. Energy simulations using eQUEST were developed to represent energy efficient equipment installed. Commercial load shapes are highly dependent on the business type as well as operating schedule of the business. Thus, commercial measures require the application of appropriate business types along with accurate weather data and installed energy efficiency measure. Figure 5-5 shows normalized average kW consumption on non-holiday weekdays in December and January for various end-uses and facility types.

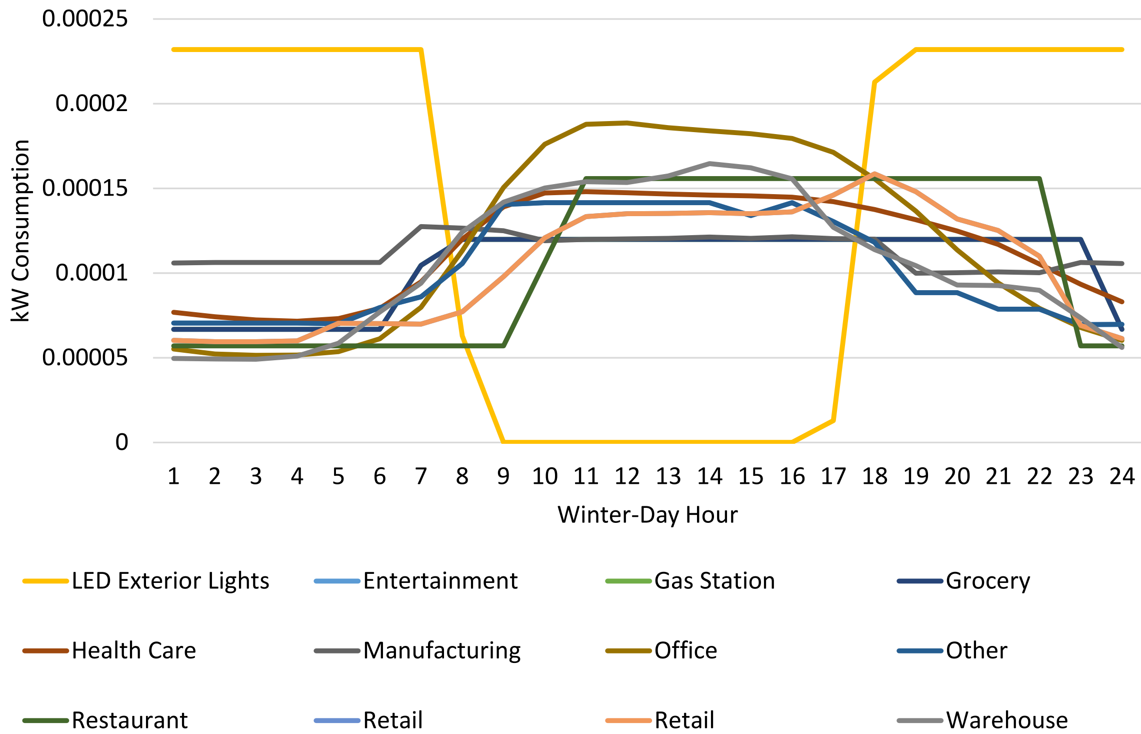
Figure 5-5: Commercial Simulation Results



As all measures installed were included in PSO's portfolio of energy-efficiency programs, ADM utilized Verified 2020 evaluation results to apply to the normalized load shape based on a typical meteorological year. Verified evaluation results come from a combination of deemed savings approaches, custom analyses, and as-found engineering algorithms for measures such as lighting. Verified evaluation results for the population of program projects is derived from extrapolation of verification results from a sample of projects. Projects that fall within ADM's random evaluation sample will be based on verified results. Projects that do not fall within ADM's random evaluation sample will use the applicable realization rate extrapolated based on measure type and project size (as is standard practice for energy-efficiency program evaluation).

Commercial lighting consumption profiles vary by facility type and location. As ADM may not have access to each projects lighting operating schedules, a series of lighting load shapes were developed. Each commercial lighting project will have an applicable load shape applied to savings by fixture location and facility type. A demonstration of the variation in generated load shapes is shown in Figure 5-6.

Figure 5-6: Commercial Lighting Simulation Results



This methodology is like the implementation methodology, so it can be directly compared to the implementation estimates. Differences in the two methodologies will stem from the use of Verified evaluation results and energy simulation assumptions.

Verified winter peak savings is determined from energy simulation results as described in the Residential portion of this section.

5.3.1.4 Circuit Level Analysis

Billing data was available to ADM using routinely transferred AMI data (for evaluation purposes) and aggregated circuit level data from the PSO program manager. A circuit level analysis has been confirmed to support the goal of determining the overall winter peak reduction on circuit 83831.

Bin Analysis

Aggregated circuit level billing data was provided by the PSO program manager by sector (Residential, Commercial, and Industrial) for this analysis. Data was provided at a 15-minute interval and aggregated to hourly for comparative weather data. Billing data was provided from January 2017 through March 2021.

The data was broken out into winter-time periods representing November through March at an hourly basis with bins developed based on total hourly heating degree days (HDD) for each day using a base temperature of 60 °F. Each HDD bin accounts for a range of 3

HDD's. An hourly HDD is determined by subtracting the hourly temperature from the HDD base and dividing by 24 hours. As customer counts vary, ADM performed this analysis on a per customer basis (using the customer counts provided) for each winter period. The latest winter period, November 2020 – March 2021 is considered the post or efficient condition. Bin selection resulted in the winter days represented by bin as shown in Table 5-8.

Table 5-8 Hourly Bin Summary

HDD Bin Number	HDD Range	Pre-Installation Days in Bin	Post Installation Days in Bin	TMY3 Days in Bin
1	0-1	11%	3%	6%
2	1 -3	11%	7%	6%
3	4 - 6	13%	10%	5%
4	7 - 9	12%	15%	8%
5	10 - 12	12%	13%	13%
6	13 - 15	10%	14%	5%
7	16 - 18	10%	8%	6%
8	19 - 21	8%	9%	13%
9	22 - 24	7%	11%	13%
10	25 - 27	3%	3%	5%
11	28 - 30	2%	2%	6%
12	31 - 33	1%	1%	5%
13	34 - 36	0%	3%	5%
14	37 - 39	1%	2%	3%
15	40 - 42	1%	0%	6%
16	43 - 45	0%	0%	0
17	46 - 48	0%	0%	0
18	49 - 51	0%	0%	0
19	52 - 54	0%	2%	0
Total		**100%**	**100%**	**100%**

A weighted average consumption per customer for each bin is determined for both the pre-installation period and the post-installation period (a single winter represents the post condition). The difference between these two values represents consumption savings for each bin. Total consumption savings per customer is determined by applying the fraction of time each bin represents in a typical meteorological year (TMY3) during December and January and aggregating across all relevant bins. The total consumption savings per customer is multiplied by the average number of post installation customers to represent savings on the circuit in the efficient condition.

This analysis was conducted for the 7-8 AM winter weekday period for each sector as well as an average hourly value across 6-9 AM in the winter weekday period. Results were also explored using an average value of the faction of hours in each bin from 2017 through 2021.

Regression Analysis

A linear regression analysis was performed on the provided circuit level data. ADM performed linear regressions by sector and on the total circuit consumption across the entire time of available data (January 2017 – February 2022). Factors considered in regression include:

- Pre/Post condition binary factor
- HDD (Paris, TX, and Hugo OK)
- CDD (Paris, TX, and Hugo OK)
- Residence Schedule (binary whether at home or work/school)
- Weekday

5.3.1.5 Residential Treatment Group Billing Analysis

To identify the impact on billing data energy consumption related to the installed energy efficiency measures, an analysis was performed considering a comparison of residential participants to a control group of residences. The control group was developed by comparing energy usage from customers who received the energy savings measures to a similar group of residential customers being fed by the same substation circuit (known as the control group). Energy usage data for the period of January 1, 2019, to February 28, 2022, was retrieved for all residential customers that are fed from the substation circuit 83831. This usage data comes from the daily AMI meter data transfer we receive from PSO. This usage data is in 15-minute intervals, which we aggregate to hourly data for this analysis. Data was removed outside of the winter peak days to ensure the control group matched the treatment group in the pre-installation period during the time of year considered for this analysis.

This analysis was performed using a difference-in-difference regression analysis (specifically a linear mixed effects regression model was used). The equation below shows the regression model applied.

$$kWh_{i,t} = \beta_0 + \beta_1 HDD_t + \beta_2 CDD_t + \beta_3 Post_{i,t} + \beta_4 (Post_{i,t} * Treatment_i) + \alpha_i Customer_i + \varepsilon_{i,t}$$

Where:

t = monthly time interval

$kWh_{i,t}$ = average daily electricity use (in kWh) during period *t*

$Post_{i,t}$ = a dummy variable identifying the post-treatment period (beginning on January 1, 2021)

$Treatment_i$ = a dummy variable identifying the treatment group customers

$Post_{i,t} * Treatment_i$ = an interaction term that identified customers in the treatment group after January 1, 2021

HDD_t = average daily *HDD* during time *t*

CDD_t = average daily *CDD* during time *t*

$Customer_i$ = mixed effects variable, meaning this value is unique to each premise

The model is defined as "mixed effects" because the model decomposes its parameters into fixed-effects (i.e., HDD, CDD, Post, Treatment, and interaction term) and random effects (i.e., the individual customer's base usage, as captured by α). Put simply, a fixed effect is assumed to be constant and independent of the sample, while random effects are assumed to be sources of variation (other than natural measurement error) that are uncorrelated with the fixed effects.

The model is intended to explain the factors impacting energy use. To identify the impact of the energy efficiency measures, the model controls for non-data presentment factors including weather. In this case, β4 is the coefficient of interest, the value of which represents the average kW increase/decrease during the target period that can be associated with the energy efficiency measures.

5.3.1.6 Estimating Net Savings

Due to the implementation plan structure, participants on circuit 83831 for the Non-Wires Solution program are considered to have zero free ridership. This pilot program has offered bonus incentives to entice participation for a segment of PSO customers who have had previous opportunity to participate in PSO energy-efficiency programs but have not. Spillover will not be accounted for in this analysis. A net-to-gross ratio of 100% will be considered for all measures.

5.3.2 Evaluation Findings

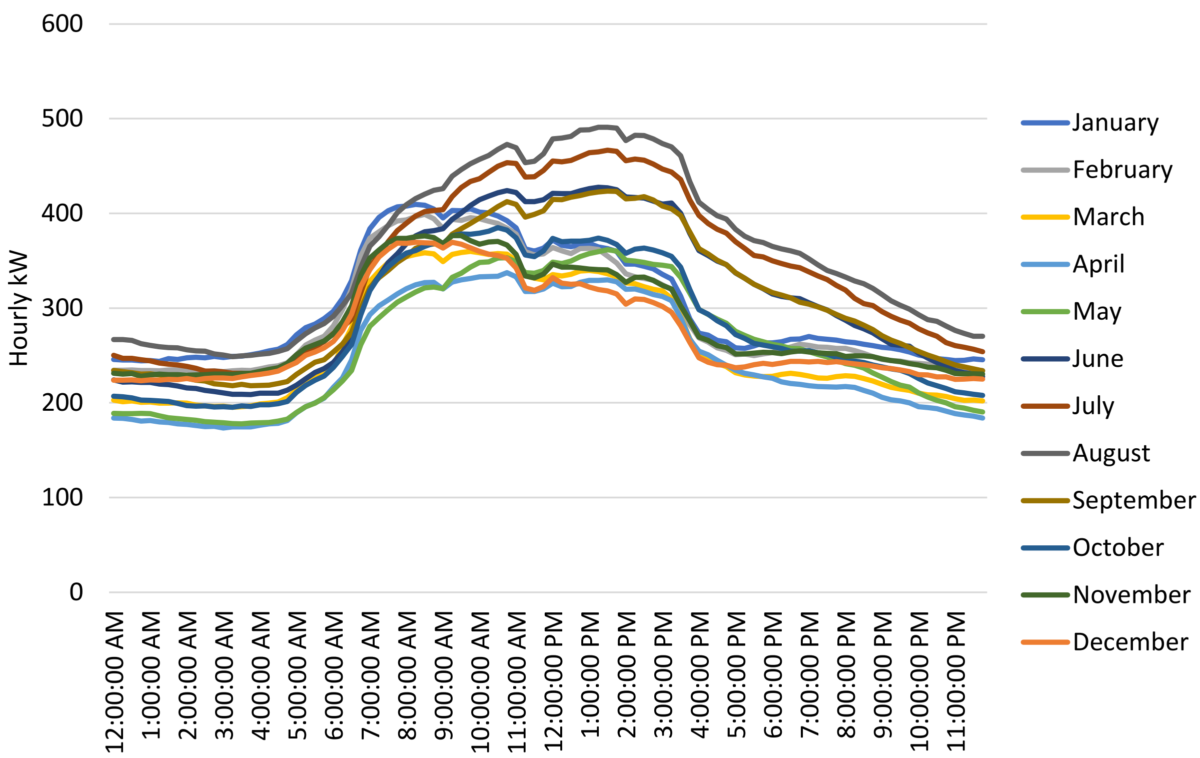
The Non-Wires Solution Pilot Program has been designed to offset capital investment for capacity improvements on circuit 83831. The program has implemented residential, commercial, and industrial energy efficiency measures within PSO portfolio of energy-efficiency programs to reduce the circuit load during the peak period. The peak period has been defined as non-holiday weekdays in December and January from 7-8 AM, referred to as the winter peak.

To address the program goals, evaluation is focused on assessing the impacts the energy efficiency measures have on the circuit load during the winter peak period. To do so, ADM has employed several methodologies looking at site specific impacts of installed measures as well as circuit-level impacts. This section presents findings from the analysis methods described in the Evaluation Methodology section of this report to determine the winter peak savings (kW).

5.3.2.1 Measure Targeting Support

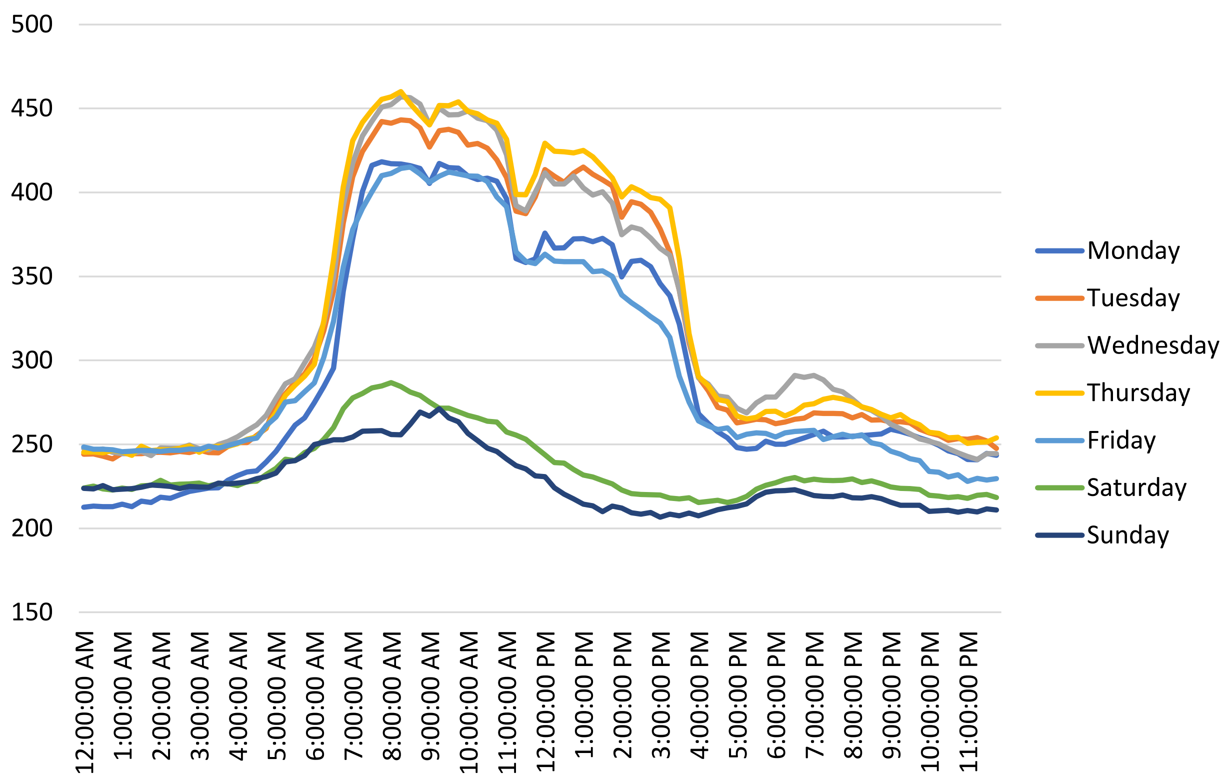
ADM's efforts were focused on commercial and industrial potential to support the implementation team. ADM identified that while aggregated C&I billing data showed higher usage outside the winter peak period, the morning ramp-up is consistently the highest load throughout a winter day. Figure 5-7 shows hourly consumption by month aggregated for all available C&I meters in AMI data. Each line represents a month of the year.

Figure 5-7: Circuit 83831 C&I AMI Daily Profile



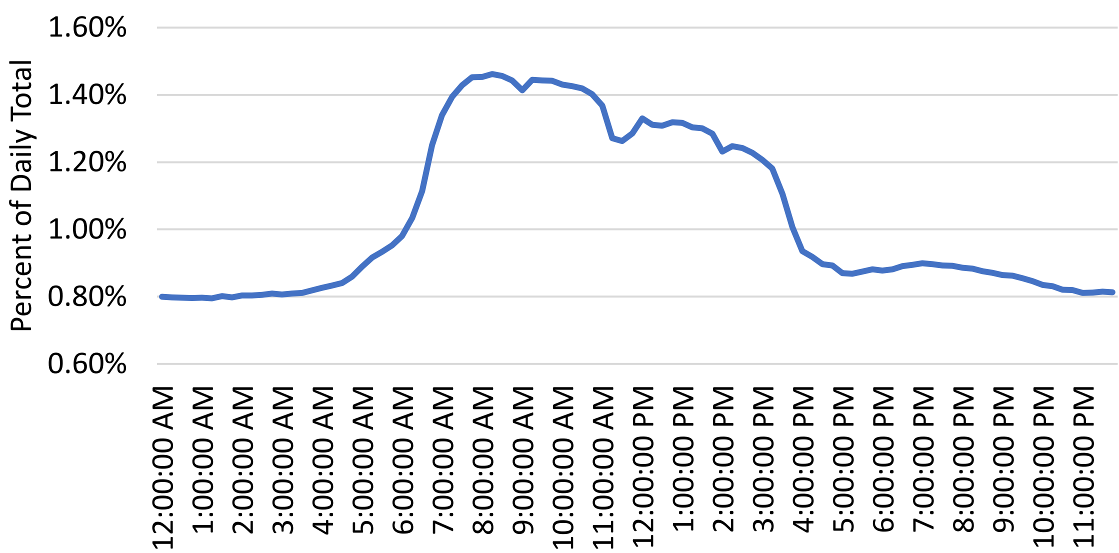
In addition, weekdays present a higher C&I load compared to weekends during December and January, as shown in Figure 5-8.

Figure 5-8: Circuit 83831 C&I AMI Day of Week Profile



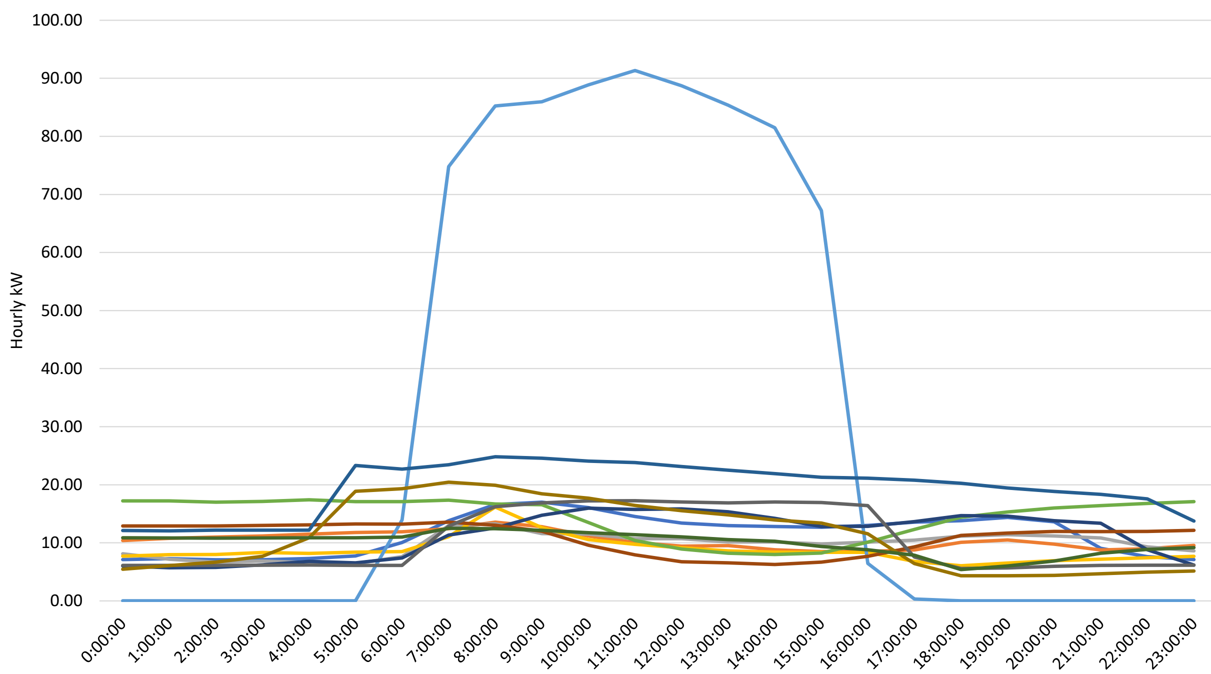
For analysis purposes, ADM is considering weekdays averaged together over the winter months of December and January. The average winter weekday profile for businesses on circuit 83831 is shown in Figure 5-9.

Figure 5-9: Circuit 83831 C&I Average Weekday Profile



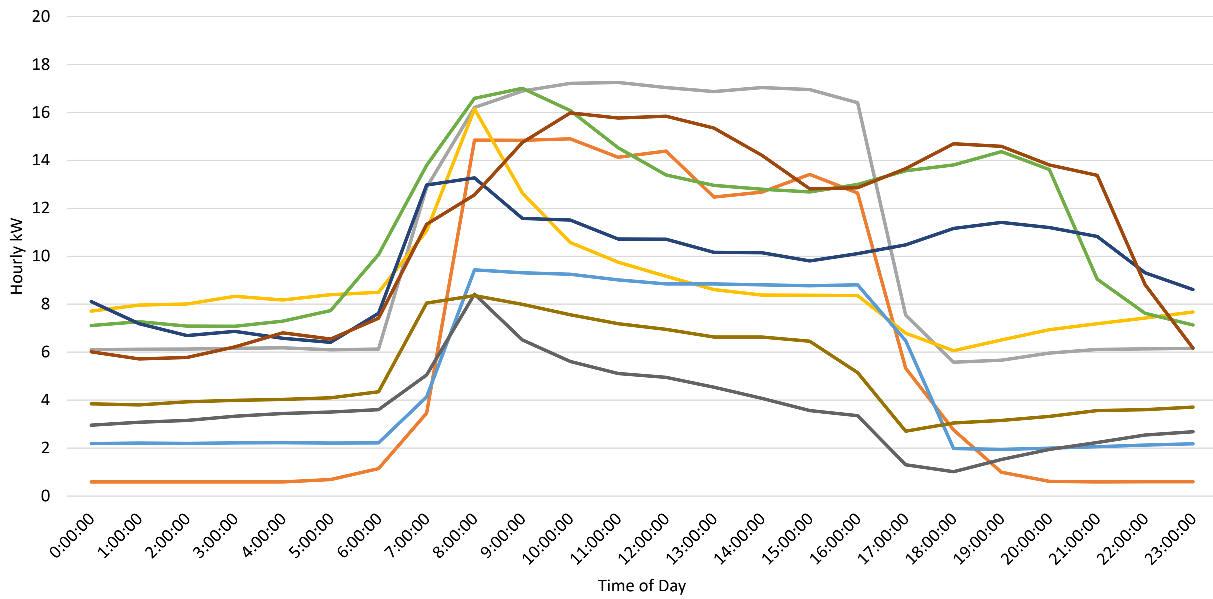
An analysis was performed to identify the commercial and industrial accounts in which energy efficiency could yield the most productive results. This was accomplished by reviewing consumption during the winter peak period as well as the rate of increase in consumption across the winter peak period. When comparing results from the four tests (as described in the Methodology section), twelve unique accounts stood out as having the greatest influence. A single account demonstrated a usage pattern larger than the other top businesses combined (in which AMI data was available). The top consumers from 6 AM through 11 AM on winter weekday mornings are shown in Figure 5-10. Findings were shared with the implementation team to support site visit and energy auditing assessments.

Figure 5-10: Circuit 83831 C&I Top Consumers



Excluding the largest consumer, the remaining businesses with a substantial rate of increase were identified and shared with the implementation team to further assist with energy auditing efforts. Daily profiles of these businesses are shown in Figure 5-11.

Figure 5-11: Circuit 83831 C&I Top Winter Ramp Up Consumers



Based on review of C&I usage patterns and discussion on residential usage patterns, there is a clear identification of the winter peak window. This peak appears to show there is an overlap between residences increasing energy consumption in the morning and businesses starting operations for the day.

5.3.2.2 Engineering Analysis

ADM performed a site and project specific engineering algorithm approach to validate winter peak savings for all measure considered within the program. This section will review results based on customer sector. The implementer determined estimated winter peak demand reduction through similar methodologies. These results, reported savings, will be compared to verified savings found by ADM.

Residential

The Residential measures installed on circuit 83831 fell into the Weatherization and Home Rebates PSO Energy-Efficiency Programs. ADM applied energy savings curves (as described in the methodology section) to verified evaluated annual energy savings (kWh) to determine winter peak savings (kW).

Home Weatherization measures implemented during the fall of 2020 and winter of 2021 on the circuit that resulted in winter peak savings include Air infiltration, Attic Insulation, Duct Sealing, Faucet Aerators, LED Lighting, Low Flow Showerheads, and Water Heater Pipe Insulation. Results are shown in Table 5-9. Realization rates are based off the 7-8 AM Winter peak savings.

Table 5-9 Residential Weatherization Results

Measure	Winter kW Savings (7-8 AM)	Winter kW Savings (6-9 AM)	Reported Winter kW Savings	Realization Rate
Air Infiltration	21.32	17.37	36.19	59%
Attic insulation R5 - R8	5.55	5.40	16.79	33%
Attic insulation R9 - R14	8.92	8.67	28.07	32%
Duct Sealing	21.60	16.88	31.29	69%
Faucet Aerator	0.35	0.22	0.29	124%
LED Lighting	0.43	0.43	0.40	108%
Low Flow Showerhead	1.25	0.80	1.26	100%
Water Heater Pipe Insulation	0.14	0.09	0.17	83%
Total	**59.57**	**49.86**	**114.45**	**52%**

Home Rebates measures implemented during the fall of 2020 and winter of 2021 on the circuit that resulted in winter peak savings include LED lighting, Air Source Heat Pumps, Heat Pump Tune-Ups, and Mobile Home Duct Sealing. Results are shown in Table 5-10.

Table 5-10 Home Rebates Results

Measure	Winter kW Savings (7-8 AM)	Winter kW Savings (6-9 AM)	Reported Winter kW Savings	Realization Rate
9-Watt LED	0.07	0.07	0.07	107%
AC Tune-Up	0.00	0.00	0.00	n/a
Air Source Heat Pumps	27.96	22.31	49.86	56%
Heat Pump Tune-Up	13.32	10.62	4.00	333%
Mobile Home Duct Sealing	48.99	39.08	22.05	222%
Total	**90.35**	**72.08**	**75.98**	**119%**

Combined winter peak savings for the Residential measures are shown in Table 5-11.

Table 5-11 Residential Winter Peak Savings Results

Measure	Winter kW Savings (7-8 AM)	Winter kW Savings (6-9 AM)	Reported Winter kW Savings	Realization Rate
Total	149.92	121.95	190.42	79%

The variation in results can be attributed to differences in energy simulation models as ADM results were derived independently. Small changes in energy simulation assumptions can result in varying results. In addition, small differences were caused using Verified annual energy savings values applied to ADM energy savings curves.

Commercial

Commercial projects were completed within the Small Business Energy Solutions and Custom and Prescriptive Business Rebates Program. In all, 29 projects have been completed to date. Commercial projects included LED lighting, refrigeration door heater controls, refrigeration evaporator/compressor controls, EC motors, and HVAC equipment. ADM applied load shapes (as described in the methodology section) to verified evaluated annual energy savings (kWh) to determine winter peak savings (kW). Verified Winter peak savings by measure type are shown in Table 5-12.

Table 5-12 C&I Winter Peak Savings Results by Measure

Measure	SBES (7-8 AM)	SBES (6-9 AM)	C&P (7-8 AM)	C&P (6-9 AM)
Door Heater Controls	0.97	0.97	0	0
HVAC Controls	2.96	2.96	0	0
LED Case Lights	0.60	0.60	0	0
LED Exterior Lights	2.71	5.90	0.14	0.30
LED Fixture	0.22	0.22	13.63	13.37
LED Linear	33.26	33.79	0	0
LED Screw-ins	1.15	1.16	0	0
Controls & Motors	5.19	4.82	0	0
Heat Pumps	0	0	4.37	3.94
Total	**47.06**	**50.44**	**18.15**	**17.61**

Results from the 29 projects show a reduction in winter peak savings from reported values. Reported winter peak savings were not provided in the same granularity, but a general comparison is shown in Table 5-16. Realization rates are based off the 7-8 AM winter peak savings.

Table 5-13 C&I Winter Peak Savings Comparison by Measure

Measure	Winter kW (7-8 AM)	Winter kW (6-9 AM)	Reported Winter kW	Realization Rate
Lighting	51.72	55.36	76.15	68%
Heat Pumps	4.37	3.94	6.53	67%
Refrigeration Controls and Motors	9.12	8.76	1.484	615%
Total	**65.21**	**68.05**	**84.16**	**77%**

Realization rates for these measures are driven by differences in the load shapes (developed through energy simulations) in which annual energy savings are applied. ADM used verified annual energy savings (kWh) to apply to load shapes. The verified annual energy savings were within a few percent of reported annual energy savings.

All Sectors

Evaluation results using winter peak savings algorithms based on evaluated energy savings applied to simulation developed load shapes are shown in Table 5-14. Realization rates are based off the 7-8 AM winter peak savings.

Table 5-14 C&I Verified Measure Energy Savings Results

Program	Winter kW (7-8 AM)	Winter kW (6-9 AM)	Reported Winter kW	Realization Rate
Weatherization	59.57	49.86	114.45	52%
Single Upgrades	90.35	72.08	75.98	119%
Small Business	47.06	50.44	68.03	69%
C&P	18.15	17.61	16.13	113%
Total	**215.13**	**190.00**	**274.59**	**78%**

Realization rates are driven by the following factors:

- Verified results used evaluated results from PSO’s 2020 and 2021 portfolio of energy-efficiency programs. This was analyzed through the application of energy savings ratios by measure or evaluation sample stratum realization rate.
- Verified Winter Peak Savings (kW) were derived from the application of energy simulation-based load shapes. ADM energy simulations were developed independently of implementation energy simulations.
    - Model parameters influenced the portion of energy consumption by measure and time of day. ADM developed models specific to facility types and end-use equipment associated with the energy efficiency measure implemented.

5.3.2.3 Circuit Level Analysis

Two approaches were considered when reviewing aggregated circuit-level consumption data; a binning approach based on HDD and a regression analysis. Electrical consumption during the winter of 2020/2021 was impacted by two major events, the COVID-19 pandemic, and a historic cold winter storm in February.

Bin Analysis

As described in the Methodology section, the bin analysis is based on binning hourly intervals into bins based on the quantity of total heating degree hours (HDD divided by 24) in each day. The development of bins allows for a pre-installation comparison to a post-installation comparison during similar temperatures. Reduction in consumption is the difference between the pre-installation bin and the post-installation bin weighted by the fraction of time intervals the winter peak period occurs. The results are normalized to TMY3 data for Paris, TX, and the average number of customers on the circuit in the post-installation condition. The analysis was performed for each sector. Residential results by HDD bin are shown in Table 5-15.

Table 5-15 Residential Circuit Bin Analysis Results

HDD Range	Percent of Intervals	Winter kW 6-9 AM	Winter kW 7-8 AM
0	6%	70.58	84.86
1 -3	6%	151.49	177.25
4 - 6	5%	96.49	104.93
7 - 9	8%	114.46	131.28
10 - 12	13%	13.60	4.99
13 - 15	5%	27.91	36.62
16 - 18	6%	19.60	18.01
19 - 21	13%	224.36	224.94
22 - 24	13%	147.70	143.37
25 - 27	5%	20.40	48.47
28 - 30	6%	435.21	498.70
31 - 33	5%	441.30	540.00
34 - 36	5%	(145.26)	(172.11)
37 - 39	3%	245.19	276.56
Total	**100%**	**131.90**	**144.92**

Commercial results by HDD bin are shown in Table 5-16.

Table 5-16 Commercial Circuit Bin Analysis Results

HDD Range	Percent of Intervals	Winter kW 6-9 AM	Winter kW 7-8 AM
0	6%	263.66	287.75
1 -3	6%	294.50	318.89
4 - 6	5%	105.38	113.94
7 - 9	8%	252.46	275.51
10 - 12	13%	183.62	196.97
13 - 15	5%	114.47	116.82
16 - 18	6%	50.60	56.59
19 - 21	13%	58.17	86.60
22 - 24	13%	165.32	184.37
25 - 27	5%	74.77	72.45
28 - 30	6%	9.38	36.62
31 - 33	5%	(83.24)	(90.65)
34 - 36	5%	72.31	90.17
37 - 39	3%	223.94	247.60
Total	**100%**	**133.72**	**150.38**

Combined winter peak reduction results using the HDD binning analysis are shown in Table 5-17.

Table 5-17 Total Circuit Bin Analysis Results

Sector	Winter kW 6-9 AM	Winter kW 7-8 AM
Residential	131.90	144.92
Commercial	133.72	150.38
Total	**265.62**	**295.30**

The bin analysis provides a normalization of changes on the circuit from the pre-installation condition to the post-installation condition taking ambient temperature into consideration. These results indicate that the circuit saw a reduction in expected energy consumption in the post-installation condition once normalized to TMY3 weather. While Industrial customers may have been aware of the implementation efforts and possibly received an energy audit, no energy efficiency measures were contributed to the program by industrial customers. Therefore, any reduction due to industrial customers is not considered. The potential winter peak savings (kW) using the bin analysis approach is 295.30 kW during the winter peak hours of 7-8 AM and 265.62 kW on average between 6 – 9 AM during the winter peak period.

Regression Analysis

Interval billing data by sector was provided to ADM for analysis from 2017 into 2022. ADM investigated linear regression analyses with a variety of factors built into the regression for the residential and commercial sectors. Parameters considered included:

- HDD
- CDD
- Pre/Post Condition (Binary)
- Occupancy (Binary)
- Weekday (Binary between weekday and weekend)
- Historic Winter Storm

Implementation of energy efficiency projects occurred from September 2020 into January 2021. Regression models were run accounting for this commissioning period with a binary cut off, a scaled transition, and removal of the period. In all instances, the Pre/Post Condition factoring demonstrated an underwhelming statistical significance (t-stat).

Iterations of regression attempts on the residential interval meter data resulted in the use independent curves generated for the pre-installation period and post-installation period. Using the statistical metric of R^2 and parameter relevance by t-stat, ADM determined the best possible fit with an R^2 value of 0.6669 for the pre-installation period and 0.8041 for the post-installation period.

Iterations of regression attempts on the commercial interval meter data also resulted in the use of independent curves generated for the pre-installation period and post-installation period. The most appropriate curve found resulted in an R^2 of 0.1529 for the pre-installation period and 0.6771 for the post-installation period. While neither the residential nor commercial regressions meet the requirements of ASHRAE, the results are presented as a means of representing consumption patterns on the circuit. Reduction in consumption for residential and commercial customers is shown in Table 5-18 and indicate an increase in consumption for commercial customers.

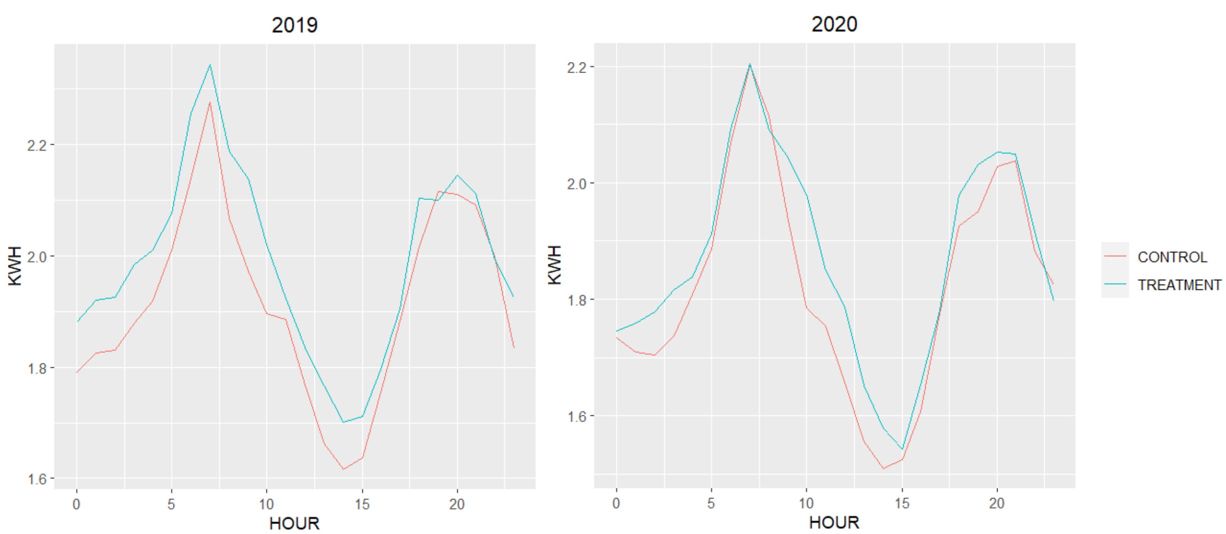
Table 5-18 Total Circuit Regression Analysis Results

Sector	Winter kW 6-9 AM	Winter kW 7-8 AM
Residential	154.33	155.53
Commercial	(370.53)	(373.31)
Total	**(216.20)**	**(217.78)**

5.3.2.4 Residential Treatment Group Billing Analysis

Attributing winter peak savings to program participants through a billing analysis requires the exploration of the difference in energy consumption to a control group. This analysis approach accounts for both the COVID-19 pandemic and the strong winter storm by matching a similar control group to the participants that would incur the same impacts from such events. As shown in Figure 5-12, the control group chosen was statistically representative of the participants in the pre-installation period of 2019 and installation period of 2020. Both the control group and the treatment group demonstrated a slight reduction in consumption in the post-installation period.

Figure 5-12: Control Group Matching



The difference-in-difference model, as described in the Evaluation Methodology section, consists of a mixed-effects regression. In this analysis, the installation date is identified for each project to determine the pre-installation period and the post-installation period. The analysis determined an average hourly winter peak savings (kW) from 7-8 AM of 0.088 kW. Aggregated across all participants results in a residential winter peak savings of 8.36 kW. Analysis statistics and results are shown in Table 5-19.

Table 5-19 Residential Difference-in-Difference Analysis Results

Coefficient of Interest	90% Confidence Lower Bound	90% Confidence Upper Bound	t-statistic	Estimated Hourly kW Reduction
-0.088	-0.050	-0.126	-3.80	8.36

5.3.3 Results Summary

Various analysis methods result in different impacts on the circuit and individual customers due to the energy efficiency measures implemented. Based on the statistical significance of methodologies, and knowing the complications with the pandemic, the engineering analysis is the most appropriate estimation of winter peak reduction. The bin analysis performed on the circuit indicates that consumption is reduced in the post-installation period (compared to a counterfactual baseline), thus justifying the engineering analysis.

A summary of evaluation results for the winter peak period reduction from 7-8 AM on non-holiday weekends in December and January, is shown in Table 5-20.

Table 5-20 NWS Evaluation Results Summary

Sector	Winter Peak Reduction (kW)
Residential	149.92
Commercial	65.21
Total	**215.13**

5.3.4 Evaluation Conclusions

Evaluation of the Non-Wires Solution Pilot Program quantified the energy impacts due to installation of energy efficiency measures at 93 residences and 29 businesses. Measures consisted of air infiltration, attic insulation, duct sealing, faucet aerators, LED lighting, low flow showerheads, water heater pipe insulation, air source heat pumps, heat pump tune-ups, mobile home duct sealing, refrigeration door heater controls, refrigeration evaporator/compressor controls, and EC motors. All measures installed were associated with the PSO portfolio of energy-efficiency programs with annual energy savings (kWh), and summer peak demand reduction (kW) included in the 2020 and 2021 portfolio evaluation results. This section has presented winter peak savings (kW) from the same installed energy efficient measures. The measures targeted for circuit 83831 enticed customers with additional incentives to support the non-wires approach of avoiding capital investment to increase capacity for customers on the circuit.

5.4 Research and Development Results

PSO completed three pilot programs under Research and Development during the portfolio cycle from 2019 – 2021. The pilot studies were not all evaluated with same metrics as goals. The Non-Wires Solution pilot was focused on generating a winter peak demand reduction. The Pool Pump Demand Response Program was focused on generating a summer peak demand reduction, and the Smart Street Lighting Program was focused on generating annual energy savings as well as operational improvements. A summary of results for all pilot studies is shown in

Table 5-21 R&D Evaluation Results Summary

Sector	Annual Energy Savings (kWh)	Peak Demand Reduction	Winter Peak Reduction (kW)
Non-Wires Solution	926,547*	204.00*	215.13
Smart Street Lighting	247,655	0	NA**
Pool Pump DR	0***	8.40	0
Total	**247,655**	**212.40**	**215.13**

*Annual Energy Savings and Peak Demand Reduction were claimed within PSO portfolio programs and thus are not claimed for Non-Wires Solution.

**While Smart Street Lighting may present winter peak demand reduction, the project did not take place on the NWS circuit in question and therefore was not calculated.

***Pool Pump DR will result in a small amount annual energy savings, but they were not calculated as part of the study.

Costs associated with each research and development pilot program across the portfolio cycle are shown in Table 5-22, Table 5-23, and Table 5-24.

Table 5-22 Smart Street Lighting Costs

	Budget			Actual		
Year	Cash Inducement ($)	Other Costs ($)	Total Pilot Cost ($)	Cash Inducement ($)	Other Costs ($)	Total Pilot Cost ($)
2019	$-	$39,000	$39,000	$-	$-	$-
2020	$-	$52,000	$52,000	$-	$70,101	$70,101
2021	$-	$57,200	$57,200	$-	$9,759	$9,759
Total	$-	$148,200	$148,200	$-	$79,860	$79,860

Table 5-23 Pool Pump Demand Response Costs

	Budget			Actual		
Year	Cash Inducement ($)	Other Costs ($)	Total Pilot Cost ($)	Cash Inducement ($)	Other Costs ($)	Total Pilot Cost ($)
2019	$20,625	$46,406	$67,031	$-	$-	$-
2020	$24,375	$54,844	$79,219	$1,100	$14,072	$15,172
2021	$26,875	$60,469	$87,344	$400	$11,832	$12,232
Total	**$71,875**	**$161,719**	**$233,594**	**$1,500**	**$25,903**	**$27,403**

Table 5-24 Non-Wires Solution Costs

	Budget			Actual		
Year	Cash Inducement ($)	Other Costs ($)	Total Pilot Cost ($)	Cash Inducement ($)	Other Costs ($)	Total Pilot Cost ($)
2019	$111,000	$89,000	$200,000	$-	$1,568	$1,568
2020	$111,000	$89,000	$200,000	$647,084	$175,598	$822,682
2021	$111,000	$89,000	$200,000	$-	$40,858	$40,858
Total	**$333,000**	**$267,000**	**$600,000**	**$647,084**	**$218,024**	**$865,108**

Appendix A. Glossary

Cash Inducement Costs: Refers to customer and service provider rebate/incentive costs incurred by PSO in the implementation of a program.

Coincidence Factor (CF): For energy efficiency measures, the CF represents the fraction of connected load reduction that occurs during the peak demand period.

Deemed Savings: A savings estimate for relatively homogeneous measures. Generally, an assumed average savings across many rebated units is applied to each individual unit installed.

Effective Useful Life (EUL): The number of years (or hours) that an energy-efficient technology is estimated to function. Also, referred to as “measure life.”

EM&V Administrative Costs: EM&V administrative costs include all costs associated with evaluation, measurement and verification of reported energy and demand impacts resulting from the implementation of a program.

Reported: Refers to estimates of energy savings and peak demand reduction developed before program evaluation. Equivalent to “reported impacts” or also “ex-ante.”

Verified: Refers to estimates of energy savings and peak demand reductions developed from program evaluation. Equivalent to “verified impacts” or also “ex-post.”

Free-ridership: Percentage of participants who would have implemented the same energy-efficiency measures in a similar timeframe even in the absence of the program.

Gross Impacts: Changes in energy consumption/demand that result directly from program-promoted actions regardless of the extent or nature of program influence on these actions.

Impact Evaluation: Impact evaluation is the verification and estimation of gross and net impacts resulting from the implementation of one or more energy-efficiency or demand response programs.

Measure: An energy-efficiency “measure” refers to any action taken to increase energy efficiency, whether through changes in equipment, control strategies, or behavior.

Net Savings: The portion of gross savings that is directly attributable to the actions of an energy-efficiency or demand response program.

Net-to-Gross Ratio (NTGR): A factor representing net program savings divided by gross program savings that is applied to gross program impacts to convert them into net program impacts. Generally calculated as 1 – (free-ridership %) + (Spillover %).

Non-Cash Inducement Costs: Non-cash inducement costs include third party implementation costs and advertising costs incurred by PSO in the implementation of a program. PSO earns no incentives on advertising costs.

Non-Energy Benefits: Non-energy benefits refer to any benefits PSO customers may experience due to their participation in PSO programs beyond energy savings. Examples include improved comfort, aesthetic enhancements, better indoor air quality, improved security, better employee productivity, etc.

Non-EM&V Administrative Costs: Non-EM&V administrative costs include PSO staff labor costs and overhead costs associated with implementing a program.

Oklahoma Deemed Savings Documents (OKDSD): Refers to the Oklahoma Deemed Savings, Installation & Efficiency Standards, and associated work papers for small commercial and residential energy efficiency measures. These documents were originally submitted to the OCC as part of Cause No. PUD 201800073. In 2013, the documents were updated to reflect more recent and applicable baseline conditions.

Participant Cost Test (PCT): The PCT examines the cost and benefits from the perspective of the customer installing the energy efficiency measure. Costs include incremental costs of purchasing and installing the efficient equipment, above the cost of standard equipment. Benefits include customer bill savings, incentives received from the utility, and any applicable tax credits.

Peak Demand: For the purposes of this report peak demand refers to the average metered demand during the peak period, defined as 2PM to 9 PM during the summer months, June through September, excluding weekends and holidays. Note that for the Peak Performers program, peak demand reduction is calculated as the average reduction during event hours.

Process Evaluation: A systematic assessment of an energy-efficiency program for documenting program operations at the time of examination and identifying potential improvements that can be made to increase the programs efficacy or effectiveness.

Projected, Reported, and Verified Savings: Projected impacts refer to the energy savings and peak demand reduction forecasts submitted to the OCC as part of PSO's 2019 – 2021 portfolio filing on June 29, 2018.[107] Reported impacts refer to energy savings and peak demand reduction estimates based on actual program participation in PY2020, before program evaluation activities. Finally, verified impacts refer to energy savings and demand reduction estimates for PY2020 developed through independent program evaluation, measurement, and verification (EM&V).

Ratepayer Impact Measure (RIM): The RIM examines the impact of energy-efficiency programs on utility rates. Reduced energy sales can lower revenues and put upward pressure on retail rates as the remaining fixed costs are spread over fewer kWh. Costs include overhead and incentive payments and the cost of lost revenue due to reduced

[107] Cause No. PUD 201800073.

sales. Benefits include cost savings associated with not delivering energy to customers. These “avoided costs” include generation, transmission, and distribution costs.

Realization Rate: The ratio of verified impacts to reported impacts.

Societal Cost Test (SCT): The SCT includes the same costs and benefits as the TRC but uses a lower discount rate to reflect the overall benefit to society over the long term.

Spillover: Energy and/or demand savings caused by a program, but for which the utility did not have to provide cash inducements.

Total Resource Cost Test (TRC): The TRC measures the net benefits of the energy-efficiency program for the region. Costs included in the TRC are incremental costs of purchasing and installing the efficient equipment, above the cost of standard equipment and overhead cost associated with implementing the program. Benefits include cost savings associated with not delivering energy to customers. These “avoided costs” include generation, transmission, and distribution costs.

Utility Cost Test (UCT): The UCT examines the costs and benefits of the energy-efficiency program from the perspective of the utility company. Costs include overhead (administration, marketing, EM&V) and incentive costs. Benefits include cost savings associated with not delivering energy to customers. These “avoided costs” include generation, transmission, and distribution costs. This test is also often referred to as the Program Administrator Cost Test (PACT).

Appendix B. Portfolio Cost-Effectiveness

This appendix provides an overview of each programs' participation, verified reduction in peak load, verified energy savings (kWh), annual admin costs, total program costs, as well as a summary of the cost effectiveness analysis.

B.1 Cost Effectiveness Summary

This appendix covers all verified electricity and peak demand savings, and associated program costs incurred in the implementation of PSO's 2021 energy efficiency and demand response portfolio from January 1, 2021, through December 31, 2021.

The cost-effectiveness of PSO's 2021 programs was calculated based on reported total spending, verified energy savings, and verified demand reduction for each of the energy efficiency and demand response programs. All spending estimates were provided by PSO. The methods used to calculate cost-effectiveness are informed by the California Standard Practice Manual. [108]

The demand reduction (kW) and energy savings (kWh) presented throughout this appendix represent net savings at the generator by applying program level net-to-gross (NTG) ratios and adjusting for line losses. Program level NTG ratios for the 2021 programs were estimated by ADM as part of the portfolio impact evaluation. Verified energy savings estimates at the meter were adjusted to account for line losses using a line loss adjustment factor of 1.0586 for energy savings and 1.0781 for peak reduction. For gas savings estimates, a 1.014 gas loss factor was included.

To calculate the cost-effectiveness of each program, measure lives were assigned on a measure-by-measure basis. Measure life values came from the Oklahoma Deemed Savings Documents (OKDSD) or the Arkansas TRM.[109] Additionally, assumptions regarding incremental/full measure costs were necessary. These costs were taken directly from the portfolio plan, California's Database for Energy Efficiency Resources (DEER) or project specific invoices. Avoided energy, capacity, transmission/distribution, and CO_2 costs used to calculate cost-effectiveness were provided by PSO and are found in Section B.4 of this appendix. Residential and commercial rates used to estimate certain cost-effectiveness tests were also provided by PSO.

Table B-1 lists each program included in this analysis, along with the projected savings estimates and projected budget. Impacts show in Table B-1 are net-at-generator, reflecting the NTG projections and line losses.

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[108] California Standard Practice Manuel: Economic Analysis of Demand Side Management Programs, October 2001. Available at:
http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/CPUC_STANDARD_PRACTICE_MANUAL.pdf
109 http://www.apscservices.info/EEInfo/TRM6.pdf

Table B-2 lists each program included in this analysis, along with the final verified savings estimates, total expenditures, Utility Cost Test (UCT)[110] results, and Total Resource Cost Test (TRC) results. Impacts shown in

Table B-2 presents values of net-at-generator, reflecting NTG assumptions and line losses as described above. Results from the UCT and TRC are focused on in this summary for the following reasons:

- The TRC and UCT results are a direct input to the shared savings component of the Demand Side Management Cost Recovery Rider (DSM Rider) as described in Oklahoma Administrative Code (OAC) 165:35-41-8(a).[111]
- Oklahoma Administrative Code (OAC) 165:35-41-2 lists the goals of energy efficiency and demand response programs as (1) minimize the long-term cost of utility service, and (2) avoid or delay the need for new generation, transmission, and distribution investment. The TRC test best reflects these goals, as it looks at benefits and costs from the perspective of all utility customers in the utility's service territory (participants and non-participants).

In addition to UCT and TRC results, results from the Ratepayer Impact Measure (RIM), Participant Cost Test (PCT) and Societal Cost Test (SCT) are included in the body of this appendix. Based on verified program impacts and spending during PY2021, PSO's overall portfolio is cost-effective based on both the UCT and TRC.

Table B-1: Projected by Program, 2021 (Impacts are Net, at Generator)

Program	Projected Peak Demand Reduction (kW)	Projected Annual Energy Savings (kWh)	Annual Gas Savings (Therms)	Total Program Expenditures
Business Rebates	7,375	40,236,713	(201,642)	$11,806,139
Multifamily	320	1,580,023	13,911	$958,169
Home Weatherization	1,234	2,535,252	175,836	$3,457,428
Energy Saving Products	1,935	15,654,121	(146,855)	$2,436,230
Home Rebates	2,519	6,521,368	285,365	$7,231,058
Education	392	3,276,011	(11,257)	$1,120,000
Behavioral	4,446	24,009,048	657,072	$1,273,750
Conservation Voltage Reduction	4,747	16,535,165	0	$1,026,114
Total – EE Programs	**22,968**	**110,347,701**	**772,430**	**$29,308,888**

110 The UCT is also referred to as the Program Administrator Cost Test (PACT).
111 http://www.occeweb.com/rules/CH35finalrules111819.pdf.

Program	Projected Peak Demand Reduction (kW)	Projected Annual Energy Savings (kWh)	Annual Gas Savings (Therms)	Total Program Expenditures
Power Hours	22,302	1,625,112	128,745	$2,367,669
Peak Performers	57,767	141,804	0	$3,401,479
Total – DR Programs	**80,069**	**1,766,916**	**128,745**	**$5,769,148.00**
Total – R&D Programs	**428**	**152,140**	**0**	**$344,544.00**
Total	**103,465**	**112,266,757**	**901,175**	**$35,422,580**

Table B-2: Cost-Effectiveness by Program, 2021 (Impacts are Verified Net)

Program	Peak Demand Reduction (kW at Meter)	Peak Demand Reduction (kW at Generator)	Energy Savings (kWh at Meter)	Energy Savings (kWh at Generator)	Total Program Expenditures	TRC (b/c ratio)	UCT (b/c ratio)
Business Rebates	7,515	8,151	39,816,029	42,294,486	$10,940,031	2.46	3.42
Multifamily	1,175	1,275	3,694,145	3,924,097	$1,559,715	3.62	2.58
Home Weatherization	2,412	2,616	4,227,635	4,490,795	$3,394,070	2.97	2.06
Energy Saving Products	3,754	4,072	23,470,632	24,931,625	$2,374,050	7.31	6.49
Home Rebates	2,640	2,864	6,961,029	7,394,337	$7,918,383	1.78	1.30
Education	637	691	3,185,305	3,383,583	$872,061	2.41	2.20
Behavioral	3,536	3,835	18,143,843	19,273,256	$1,095,354	1.28	1.22
Conservation Voltage Reduction	3,569	3,871	16,771,745	17,815,748	$1,485,248	1.47	1.34
Total – EE Programs	**25,237**	**27,375**	**116,270,363**	**123,507,927**	**$29,638,912**	**2.16**	**2.13**
Power Hours	16,103	17,468	1,441,896	1,531,651	$1,603,148	2.29	2.16
Peak Performers	45,564	49,424	1,360,734	1,476,010	$2,814,438	7.18	2.51
Total – DR Programs	**61,667**	**66,891**	**2,802,630**	**3,007,661**	**$4,417,586**	**4.23**	**2.39**
Total – R&D Programs	**8**	**9**	**247,655**	**268,635**	**$98,243**	**1.04**	**1.43**
Total	**86,904**	**94,275**	**119,320,648**	**126,784,224**	**$34,154,741**	**2.26**	**2.15**

B.2 Energy-Efficiency Programs

PSO's energy efficiency portfolio in 2021 consisted of eight programs with a verified net peak demand reduction of 27,375 kW and verified net annual energy savings of 123,507,927 kWh (including line-loss estimates of 5.86%). Total spending in 2021 equaled $29,638,912. Table B-3 provides a summary of program participation and verified net impacts for each of the energy-efficiency programs. *Participants represents a residence or business who participated as opposed to the number of measures or projects. For Energy Saving Products, the actual number of customers is unknown and instead this count is of unique customers that received rebates for qualifying downstream measures. ESP in total rebated 1,012,363 products.

Table B-4 provides a summary of program costs in 2021.

Table B-3: Energy-Efficiency Programs – Verified Impacts (Net, at Generator)

Program	Number of Participants in 2021*	Verified Peak Demand Reduction (kW)	Verified Annual Energy Savings (kWh)	Verified Gas Savings (Therms)
Business Rebates	1,414	8,151	42,294,486	0
Multifamily	3,063	1,275	3,924,097	59,727
Home Weatherization	2,214	2,616	4,490,795	452,736
Energy Saving Products	2,155	4,072	24,931,625	0
Home Rebates	3,715	2,864	7,394,337	769,019
Education	15,782	691	3,383,583	-4,512
Behavioral	174,380	3,835	19,273,256	0
Conservation Voltage Reduction	29,385	3,871	17,815,748	0
Total – EE Programs	**232,108**	**27,375**	**123,507,927**	**1,276,970**

*Participants represents a residence or business who participated as opposed to the number of measures or projects. For Energy Saving Products, the actual number of customers is unknown and instead this count is of unique customers that received rebates for qualifying downstream measures. ESP in total rebated 1,012,363 products.

Table B-4: Energy-Efficiency Programs – Reported Costs

Program	Annual Non-EM&V Admin Costs ($)[112]	Annual EM&V Admin Costs ($)	Annual Cash Inducement Costs ($)[113]	Annual Non-Cash Inducement Costs ($)[114]
Business Rebates	$338,948	$206,734	$6,735,346	$3,659,002
Multifamily	$20,302	$23,611	$1,248,172	$267,630
Home Weatherization	$101,657	$32,045	$3,092,637	$167,731
Energy Saving Products	$107,017	$74,554	$1,452,080	$740,399
Home Rebates	$184,721	$92,956	$5,505,219	$2,135,487
Education	$54,174	$20,159	$760,964	$36,765
Behavioral	$41,120	$40,459	$46,605	$967,171
Conservation Voltage Reduction	$15,719	$29,060	$0	$1,440,469
Total – EE Programs	**$863,658**	**$519,578**	**$18,841,023**	**$9,414,654**

Table B-5 shows the measures with measure life and associated programs. The measure life for Business Rebates measures is calculated as a weighted average based on kWh savings. The programs for Behavioral Modification, Peak Performers, and Conservation Voltage Reduction each have a Tier 1 EUL of one year.

112 Non-EM&V Admin Costs include PSO staff labor costs and overhead costs.
113 Cash inducement costs refer to customer rebate costs.
114 Non-cash inducement costs include third party implementation costs.

Table B-5: Measure Life

Measure	Measure life		Business Rebates	Multifamily	Home Weatherization	Energy Saving Products	Homes Rebates	Education	Power Hours	CVR
	Tier 1	Tier 2								
Commercial Lighting (DI)	9	0		x			x			
Duct Sealing	18	0		x	x		x			
Variable Speed Drive Pool Pump	10	0		x			x			
Air Sealing Package	11	0			x		x			
Air Source Heat Pumps	16	0					x			
Central AC	19	0					x			
Drop-Off Energy Kits	3	14					x			
Duct System Sealing	18	0			x		x			
Ground Source Heat Pumps	25	0					x			
HVAC Tune-Up	10	0					x			
Insulation - Attic	20	0		X	x		x			
Insulation - Exterior Wall	20	0					x			
Insulation - Floor over Open Crawlspace	20	0					x			
Insulation - Kneewalls/Vertical Attic Wall	20	0					x			
New Homes	20	0					x			
7-Plug Advanced Power Strip	10	0						x		
9-watt LED	3	0						x		
Advanced Power Strips	10	0				x		x		

Measure	Measure life		Business Rebates	Multifamily	Home Weatherization	Energy Saving Products	Homes Rebates	Education	Power Hours	CVR
	Tier 1	Tier 2								
FilterTone® Furnace Filter Alarm	14	0						x		
LED Night Light	8	0						x		
8760 Lighting	14	0	x							
Custom	17	0	x							
Exit Signs	13	0	x							
Exterior Lighting	14	0	x							
HVAC	17	0	x							
Interior Lighting	13	0	x							
Kitchen & Appliances	17	0	x							
Lighting	9	0	x							
NC Lighting	16	0	x							
Non-Lighting	13	0	x							
Oil & Gas	17	0	x							
Refrigeration	17	0	x							
Retrofit Lighting	14	0	x							
Air Conditioner	19	0		x						
Commercial Lighting (Non-DI)	9	0		x						
Dryer	14	0		x						
Faucet Aerator	10	0		x	x					
Heat Pump	16	0		x						
Lighting Controls	8	0		x						
Low Flow Shower Head	10	0		x						

Measure	Measure life		Business Rebates	Multifamily	Home Weatherization	Energy Saving Products	Homes Rebates	Education	Power Hours	CVR
	Tier 1	Tier 2								
NC Lighting	11	0		x						
Refrigerator	17	0		x						
Residential Lighting (DI)	2	18		x						
Washing Machine	14	0		x						
Water Heater	13	0		x						
Windows	20	0		x						
Air Filters	1	0				x				
Air Infiltration	11	0			x					
Air Infiltration - Mobile	11	0			x					
Bathroom Ventilation Fans	12	0				x				
Clothes Dryers	13	0				x				
Clothes Washers	14	0				x				
Conservation Voltage Reduction	25	0								x
DLC Events	1	0							x	
Electric Vehicle Chargers	10	0				x				
Faucet Aerators - Mobile	10	0			x					
Heat Pump Water Heaters	10	0				x				
LED-Mobile	2	18			x					
Lighting - Directional LED Retail	20	0				x				
Lighting - Omni-directional LED - DG	2	18				x				

Measure	Measure life		Business Rebates	Multifamily	Home Weatherization	Energy Saving Products	Homes Rebates	Education	Power Hours	CVR
	Tier 1	Tier 2								
Lighting - Omni-directional LED - FB	2	18				x				
Lighting - Omni-directional LED - Retail	2	18				x				
Refrigerators	17	0				x				
Room Air Conditioners	11	0				x				
Room Air Purifiers	9	0				x				
Showerheads - Mobile	10	0			x					
Smart Thermostat Incentive	11	0							x	
Water Dispensers	10	0				x				
Water Heater Jacket	7	0			x					
Water Heater Pipe Insulation	13	0			x					
Weatherization Measures	15	0				x				

In the tables that follow, total costs and benefits, and cost-effectiveness test results are provided for each energy-efficiency program in the program year.

B.2.1 Business Rebates Program

Table B-6: Business Rebates Benefit/Cost Tests

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost Test	Participant Cost Test
Benefit/Cost Ratio	**3.42**	**2.46**	**0.76**	**2.82**	**3.48**
Net Benefits ($000s)	20,562.93	19,102.96	(9,006.70)	23,789.29	22,848.71
Total Benefits ($000s)	29,051.41	32,176.00	29,051.41	36,862.33	32,060.61
Total Costs ($000s)	8,488.47	13,073.04	38,058.11	13,073.04	9,211.90

B.2.2 Multifamily Program

Table B-7: Multifamily Benefit/Cost Tests

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost Test	Participant Cost Test
Benefit/Cost Ratio	**2.58**	**3.62**	**0.67**	**4.23**	**5.38**
Net Benefits ($000s)	2,395.26	3,474.71	(1,884.92)	4,277.65	4,640.98
Total Benefits ($000s)	3,908.24	4,798.47	3,908.24	5,601.41	5,699.93
Total Costs ($000s)	1,512.98	1,323.76	5,793.17	1,323.76	1,058.95

B.2.3 Home Weatherization Program

Table B-8: Home Weatherization Benefit/Cost Tests

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost test	Participant Cost Test
Benefit/Cost Ratio	**2.06**	**2.97**	**0.79**	**3.57**	**3.91**
Net Benefits ($000s)	3,592.29	6,677.57	(1,908.10)	8,717.49	8,990.31
Total Benefits ($000s)	6,986.36	10,071.64	6,986.36	12,111.56	12,082.95
Total Costs ($000s)	3,394.07	3,394.07	8,894.46	3,394.07	3,092.64

B.2.4 Energy Saving Products Program

Table B-9: Energy Saving Products Benefit/Cost Tests

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost test	Participant Cost Test
Benefit/Cost Ratio	**6.49**	**7.31**	**0.60**	**11.95**	**24.37**
Net Benefits ($000s)	10,489.08	7,793.06	(8,389.62)	13,530.48	18,170.20
Total Benefits ($000s)	12,398.91	9,028.36	12,398.91	14,765.78	18,947.74
Total Costs ($000s)	1,909.83	1,235.29	20,788.54	1,235.29	777.54

B.2.5 Home Rebates Program

Table B-10: Home Rebates Benefit/Cost Test

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost test	Participant Cost Test
Benefit/Cost Ratio	**1.30**	**1.78**	**0.56**	**2.17**	**3.40**
Net Benefits ($000s)	2,189.39	6,647.20	(7,332.00)	10,029.81	14,717.07
Total Benefits ($000s)	9,512.97	15,217.19	9,512.97	18,599.81	20,837.59
Total Costs ($000s)	7,323.58	8,569.99	16,844.97	8,569.99	6,120.52

B.2.6 Education Program

Table B-11: Education Benefit/Cost Test

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost test	Participant Cost Test
Benefit/Cost Ratio	**2.20**	**2.41**	**0.58**	**2.70**	**4.07**
Net Benefits ($000s)	1,048.94	1,233.56	(1,393.94)	1,483.98	2,333.43
Total Benefits ($000s)	1,921.00	2,105.62	1,921.00	2,356.04	3,094.40
Total Costs ($000s)	872.06	872.06	3,314.94	872.06	760.96

B.2.7 Behavioral Program

Table B-12: Behavioral Benefit/Cost Test

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost test	Participant Cost Test
Benefit/Cost Ratio	**1.22**	**1.28**	**0.44**	**1.28**	**-**
Net Benefits ($000s)	244.34	290.94	(1,704.98)	290.94	2,117.27
Total Benefits ($000s)	1,339.69	1,339.69	1,339.69	1,339.69	2,117.27
Total Costs ($000s)	1,095.36	1,048.75	3,044.68	1,048.75	0.00

B.2.8 Conservation Voltage Reduction

Table B-13: CVR Benefit/Cost Test

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost test	Participant Cost Test
Benefit/Cost Ratio	**1.34**	**1.47**	**0.57**	**1.86**	**-**
Net Benefits ($000s)	5,410	7,585	(15,971)	13,727	18,079
Total Benefits ($000s)	21,425	23,600	21,425	29,742	18,079
Total Costs ($000s)	16,015	16,015	37,396	16,015	0

B.3 Demand Response Programs

PSO's demand response portfolio in 2021 consisted of two demand response programs with a verified net peak demand reduction of 66,891 kW[115] and a verified net energy savings of 3,007,661 kWh. Total spending in 2021 equaled $4,417,586. Table B-14 provides a summary of program participation and verified net impacts for the 2021 demand response portfolio. Table B-15 provides a summary of 2021 program costs.

Table B-14: Demand Response Programs – Verified Impacts (Net, at Generator)

Program	Number of Participants in 2021	Verified Peak Demand Reduction (kW)	Verified Annual Energy Savings (kWh)	Gas Savings (Therms)
Power Hours	23,891	17,468	1,531,651	0
Peak Performers	1,834	49,424	1,476,010	0
Total – DR Programs	**25,725**	**66,891**	**3,007,661**	**0**

115 The verified peak demand reduction shown here for the demand response programs includes an adjustment for line-losses (7.81%).

Table B-15: Demand Response Programs – Reported Costs

Program	Annual Non-EM&V Admin Costs ($)	Annual EM&V Admin Costs ($)	Annual Cash Inducement Costs ($)	Annual Non-Cash Inducement Costs ($)
Power Hours	$267,207	$31,420	$204,100	$1,100,421
Peak Performers	$153,206	$27,946	$2,439,049	$194,237
Total – DR Programs	**$420,413**	**$59,366**	**$2,643,149**	**$1,294,658**

In the table that follows, total costs and benefits, and full cost-effectiveness test results are provided for the Peak Performers program.

B.3.1 Power Hours Program

Table B-16: Power Hours Benefit/Cost Test

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost test	Participant Cost Test
Benefit/Cost Ratio	**2.16**	**2.29**	**1.22**	**2.36**	**8.66**
Net Benefits ($000s)	1,786.00	1,929.08	592.48	2,041.66	1,188.63
Total Benefits ($000s)	3,331.95	3,426.21	3,331.95	3,538.78	1,343.89
Total Costs ($000s)	1,545.96	1,497.12	2,739.47	1,497.12	155.27

B.3.2 Peak Performers Program

Table B-17: Peak Performers Benefit/Cost Test

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost test	Participant Cost Test
Benefit/Cost Ratio	**2.51**	**7.18**	**2.42**	**7.18**	**4.19**
Net Benefits ($000s)	4,256.41	6,085.70	4,145.54	6,085.70	1,947.06
Total Benefits ($000s)	7,070.85	7,070.85	7,070.85	7,070.85	2,556.82
Total Costs ($000s)	2,814.44	985.15	2,925.31	985.15	609.76

B.4 Research and Development

PSO's research and development portfolio in 2021 consisted of three research and development programs with a verified net peak demand reduction of 9 kW and a verified net energy savings of 268,635 kWh. Total spending in 2021 equaled $ 98,243. Table B-18 provides a summary of program participation and verified net impacts for the 2021 demand response portfolio. Table B-19 provides a summary of 2021 program costs.

Table B-18: Research and Development Programs - Verified Impacts (Net, at Generator)

Program	Number of Participants in 2021	Verified Peak Demand Reduction (kW)	Verified Annual Energy Savings (kWh)	Verified Gas Savings (Therms)
Research and Development	136	9	268,635	0
Total – R&D Programs	**136**	**9**	**268,635**	**0**

Table B-19: Research and Development Programs - Reported Costs

Program	Annual Non-EM&V Admin Costs	Annual EM&V Admin Costs	Annual Cash Inducement Costs	Annual Non-Cash Inducement Costs
Research and Development	$45,715	$40,555	$445	$11,528
Total – R&D Programs	**$45,715**	**$40,555**	**$445**	**$11,528**

Table B-20: Research and Development Programs Benefit/Cost Test

Metric	Utility Cost Test	Total Resource Cost Test	Ratepayer Impact Measure	Societal Cost Test	Participant Cost Test
Benefit/Cost Ratio	**1.43**	**1.04**	**0.44**	**1.22**	**3.47**
Net Benefits ($000s)	42.41	6.97	(182.69)	34.40	147.29
Total Benefits ($000s)	140.71	164.47	140.71	191.90	206.99
Total Costs ($000s)	98.30	157.50	323.40	157.50	59.70

B.5 Avoided Costs

The avoided costs in the Table B-21 were developed for energy, capacity, transmission and distribution (T&D), and CO2 during the portfolio design process (PUD 201800073) and utilized for the TRC, UCT SCT & PCT tests. The values used to calculate avoided costs for the RIM test values were scaled fuel cost factors + embedded cost rate (ECR).[116]

[116]https://psoklahoma.com/global/utilities/lib/docs/ratesandtariffs/Oklahoma/PSO%20Riders%20Jan%202019.pdf

Table B-21: Avoided Costs from PSO Portfolio Plan

Year	SPP - Energy	SPP Capacity		T&D Costs	CO2	Natural Gas
	$/MWh	$/MW-day	$/kW-yr	$/kW-yr	($/metric tonne)	($/Mcf)
2021	$54.12	$420.02	$153.31	$18.63	$1.26	$5.40
2022	$62.48	$429.68	$156.83	$18.91	$15.10	$5.43
2023	$64.07	$439.13	$160.28	$19.19	$15.29	$5.46
2024	$66.39	$448.79	$163.81	$19.48	$15.49	$5.49
2025	$68.59	$458.66	$167.41	$19.77	$15.69	$5.52
2026	$69.91	$468.75	$171.10	$20.07	$15.90	$5.69
2027	$72.18	$479.07	$174.86	$20.37	$16.10	$5.86
2028	$74.00	$489.13	$178.53	$20.67	$16.31	$6.03
2029	$75.92	$499.40	$182.28	$20.98	$16.52	$6.20
2030	$78.07	$509.89	$186.11	$21.30	$16.74	$6.37
2031	$80.38	$520.59	$190.02	$21.53	$16.96	$6.54
2032	$83.77	$531.53	$194.01	$21.82	$17.18	$6.71
2033	$85.54	$542.69	$198.08	$22.11	$17.40	$6.88
2034	$81.01	$554.08	$202.24	$22.39	$17.62	$7.05
2035	$83.93	$565.72	$206.49	$22.68	$17.86	$7.22
2036	$85.22	$578.11	$211.01	$22.97	$18.09	$7.40
2037	$86.54	$590.77	$215.63	$23.26	$18.33	$7.57
2038	$87.89	$603.71	$220.35	$23.55	$18.58	$7.74
2039	$89.26	$616.93	$225.18	$23.83	$18.83	$7.91
2040	$90.66	$630.44	$230.11	$24.12	$19.08	$8.08
2041	$92.09	$644.25	$235.15	$24.41	$19.33	$8.25
2042	$93.56	$658.36	$240.30	$24.70	$19.59	$8.44
2043	$95.05	$672.78	$245.56	$24.99	$19.83	$8.62
2044	$97.14	$687.58	$250.97	$25.54	$20.26	$8.81
2045	$99.28	$702.71	$256.49	$26.10	$20.71	$9.00

Appendix C. Summary of the 2019-2021 Demand Portfolio Energy Efficiency & Demand Response Programs

C.1 Introduction

Public Service Company of Oklahoma (PSO) received approval of the 2019 - 2021 Demand Portfolio, by the Oklahoma Corporation Commission on December 18, 2018, in Cause No. PUD201800073, Order No. 688452. The 3-year Demand Portfolio achieved GWh savings of 410.55 GWh or 122% of the energy savings goal and 277 MW savings or 94% of the demand saving goal while maintaining total spending under budget at $102,854,637 or 97% of the filed approved budget. Of the total spending, $64,415,972 or 63% was in the form of cash inducements (e.g., incentives and rebates) to participating customers. The total utility net benefit of the portfolio for 2021 was $97,086,955 with a Utility Cost Test of 2.15.

The following sections discuss the Demand Portfolio goals and actuals for energy savings (kWh), peak demand reduction (kW), program cost, cash inducements and cost effectiveness for each year.

C.1.1 Savings Summary

The savings summary of PSO's 2019-2021 Demand Portfolio is calculated based on verified energy savings and peak demand reduction for each of the energy efficiency and demand response programs. The cash inducements paid were reconciled and verified with VisionDSM. All spending values were provided by PSO. All energy savings and demand reduction values were taken directly from the portfolio tracking data provided by PSO. The verified energy savings and demand reductions reflect Evaluation, Measurement and Verification (EM&V) findings determined by ADM for each program year. Reported costs, verified annual energy savings, and verified peak demand reduction by program is shown in Table C-1. The peak demand reduction (kW) and annual energy savings (kWh) presented throughout this appendix represent net savings at the generator by applying program level net-to-gross (NTG) ratios and adjusting for line losses.

C.1.2 kWh Energy Savings

The annual energy savings (kWh) presented in Table C-1 represent net savings at the generator by applying program level net-to-gross (NTG) ratios and adjusting for line losses (a line loss adjustment factor of 5.86%).

Table C-1: Net kWh Savings by Program (Impacts are Net, at Generator)

Program	2019	2020	2021	2019-2021	3-Year Goal	% to Goal
Energy Efficiency Programs						
Business Rebates	65,983,221	47,159,612	42,294,486	155,437,319	120,463,678	129%
Multifamily	3,828,352	3,299,769	3,924,097	11,052,219	4,795,729	230%
Home Weatherization	3,976,252	4,503,536	4,490,795	12,970,583	7,565,228	171%
Energy Saving Products	38,696,169	35,326,015	24,931,625	98,953,809	58,627,370	169%
Home Rebates	4,645,422	5,643,628	7,394,337	17,683,387	19,632,607	90%
Education	3,725,951	3,819,817	3,383,583	10,929,352	10,297,430	106%
Behavioral	9,003,535	22,373,924	19,273,256	50,650,715	66,024,882	77%
Conservation Voltage Reduction	11,089,332	15,323,856	17,815,748	44,228,936	44,361,263	100%
Energy Efficiency Totals	**140,948,234**	**137,450,159**	**123,507,927**	**401,906,320**	**331,768,188**	**121%**
Demand Response Programs						
Power Hours	2,150,471	2,589,360	1,531,651	6,271,481	4,875,337	129%
Peak Performers	590,885	40,272	1,476,010	2,107,167	273,317	771%
Demand Response Totals	**2,741,356**	**2,629,632**	**3,007,661**	**8,378,649**	**5,148,654**	**163%**
Research and Development Programs						
Research and Development	**-***	**-***	**268,635****	**268,635****	**422,209**	**64%**
R&D Totals	**-***	**- ***	**268,635****	**268,635****	**422,209**	**64%**
Total	**143,689,589**	**140,079,790**	**126,784,224**	**410,553,604**	**337,339,051**	**122%**

*Savings and incentives related to R&D in 2019 and 2020 were combined into the associated programs of Home Weatherization, Home Rebates, and Business Rebates.

**R&D savings represent savings generated from the Smart Street Lighting Pilot and Pool Pump Demand Response Pilot. Savings generated from the Non-Wires Solution Pilot are represented within the programs Home Weatherization, Home Rebates, and Business Rebates

C.1.3 kW Demand Savings

The annual demand reduction (kW) presented in Table C-2 represents net savings at the generator by applying program level net-to-gross (NTG) ratios and adjusting for line losses (a line loss adjustment factor of 7.81%).

Table C-2: Net kW Savings by Program (Impacts are Net, at Generator)

Program	2019	2020	2021	2019-2021	3-Year Goal	% to Goal
Energy Efficiency Programs						
Business Rebates	10,791	8,011	8,151	26,953	22,126	122%
Multifamily	1,024	868	1,275	3,166	909	348%
Home Weatherization	2,201	2,385	2,616	7,202	3,689	195%
Energy Saving Products	6,168	6,303	4,072	16,543	7,249	228%
Home Rebates	2,604	2,355	2,864	7,823	7,570	103%
Education	717	783	691	2,191	1,233	178%
Behavioral	1,028	4,365	3,835	9,228	12,226	75%
Conservation Voltage Reduction	2,192	4,429	3,871	10,492	11,184	94%
Energy Efficiency Totals	**26,725**	**29,499**	**27,375**	**83,599**	**66,187**	**126%**
Demand Response Programs						
Power Hours	13,021	6,572	17,468	37,061	58,149	64%
Peak Performers	55,761	51,430	49,424	156,614	169,108	93%
Demand Response Totals	**68,782**	**58,001**	**66,891**	**193,675**	**227,257**	**85%**
Research and Development Programs						
Research and Development	**-***	**-***	**9****	**9****	**980**	**1%**
Research and Development Totals	**-***	**-***	**9****	**9****	**980**	**1%**
Portfolio Total	**95,507**	**87,500**	**94,275**	**277,283**	**294,424**	**94%**

*Savings and incentives related to R&D in 2019 and 2020 were combined into the associated programs of Home Weatherization, Home Rebates, and Business Rebates.

**R&D savings represent savings generated from the Smart Street Lighting Pilot and Pool Pump Demand Response Pilot. Savings generated from the Non-Wires Solution Pilot are represented within the programs Home Weatherization, Home Rebates, and Business Rebates

C.1.4 Program Costs

The program costs presented in Table C-3 represent total spending of the demand portfolio.

Table C-3: Total Program Cost by Program

Program	2019	2020	2021	2019-2021	3-Year Goal	% to Goal
Energy Efficiency Programs						
Business Rebates	$10,788,034	$10,952,859	$10,940,031	$32,680,925	$34,387,151	95%
Multifamily	$951,182	$1,497,183	$1,559,715	$4,008,080	$2,902,466	138%
Home Weatherization	$3,659,104	$3,316,716	$3,394,070	$10,369,890	$10,435,003	99%
Energy Saving Products	$3,613,293	$3,113,265	$2,374,050	$9,100,608	$8,563,652	106%
Home Rebates	$7,008,892	$8,269,131	$7,918,383	$23,196,406	$22,086,942	105%
Education	$873,910	$950,062	$872,061	$2,696,032	$3,384,000	80%
Behavioral	$1,116,829	$1,271,000	$1,095,354	$3,483,183	$3,836,250	91%
Conservation Voltage Reduction	$801,114	$1,126,666	$1,485,248	$3,413,028	$2,650,793	129%
Energy Efficiency Totals	**$28,812,360**	**$30,496,882**	**$29,638,912**	**$88,948,153**	**$88,246,257**	**101%**
Demand Response Programs						
Power Hours	$1,952,166	$1,910,328	$1,603,148	$5,465,642	$6,990,508	78%
Peak Performers	$2,721,470	$2,535,586	$2,814,438	$8,071,494	$9,957,570	81%
Demand Response Totals	**$4,673,636**	**$4,445,914**	**$4,417,586**	**$13,537,136**	**$16,948,078**	**80%**
Research and Development Programs						
Research and Development	**$1,568**	**$269,537**	**$98,243**	**$369,348**	**$981,794**	**38%**
Research and Development Totals	**$1,568**	**$269,537**	**$98,243**	**$369,348**	**$981,794**	**38%**
Total	**$33,487,563**	**$35,212,333**	**$34,154,741**	**$102,854,637**	**$106,176,129**	**97%**

C.1.5 Cash Inducements

Cash inducements are presented in Table C-4. Cash inducements are generally direct payments to customers or trade allies on behalf of customers, namely rebates and incentives.

Table C-4: Cash Inducements by Program

Program	2019	2020	2021	2019-2021	3-Year Goal	% to Goal
Energy Efficiency Programs						
Business Rebates	$6,527,767	$6,585,458	$6,735,346	$19,848,571	$19,892,072	100%
Multifamily	$703,272	$1,167,871	$1,248,172	$3,119,315	$1,878,733	166%
Home Weatherization	$3,260,805	$2,960,855	$3,092,637	$9,314,298	$9,209,432	101%
Energy Saving Products	$2,404,318	$2,019,881	$1,452,080	$5,876,279	$5,782,457	102%
Home Rebates	$4,475,056	$5,735,832	$5,505,219	$15,716,107	$14,123,067	111%
Education	$719,189	$774,520	$760,964	$2,254,673	$2,712,000	83%
Behavioral	$49,849	$74,435	$46,605	$170,889	$300,000	57%
Conservation Voltage Reduction	$0	$0	$0	$0	$0	0%
Energy Efficiency Totals	**18,140,257**	**19,318,851**	**18,841,023**	**$56,300,132**	**$53,897,761**	**104%**
Demand Response Programs						
Power Hours	$480,312	$483,723	$204,100	$1,168,135	$2,280,508	51%
Peak Performers	$2,333,926	$2,173,111	$2,439,049	$6,946,086	$7,842,844	89%
Demand Response Totals	**$2,814,238**	**$2,656,834**	**$2,643,149**	**$8,114,221**	**$10,123,352**	**80%**
Research and Development Programs						
Research and Development Totals	**$0**	**$1,175**	**$445**	**$1,620**	**$404,875**	**1%**
Total	**$20,954,495**	**$21,976,860**	**$21,622,047**	**$64,415,972**	**$64,425,988**	**100%**

C.1.6 Cost Effectiveness

Figure C-1 shows the Demand Portfolio's Total Resource Cost Test (TRC) results and Utility Cost Test (UCT)[117] results for each year. The reported impacts are net-at-generator, reflecting NTG assumptions and line losses as described in each year Annual Report. These results adhere to the stipulations set forth by the Oklahoma Corporate Commission for the Demand Side Management Cost Recovery Rider. Oklahoma Administrative Code (OAC) 165:35-41-2 lists the goals of energy efficiency and demand response programs as (1) minimize the long-term cost of utility service, and (2) avoid or delay the need for new generation, transmission, and distribution investment. The TRC test best reflects these goals, as it looks at benefits and costs from the perspective of all utility customers in the utility's service territory (participants and non-participants).

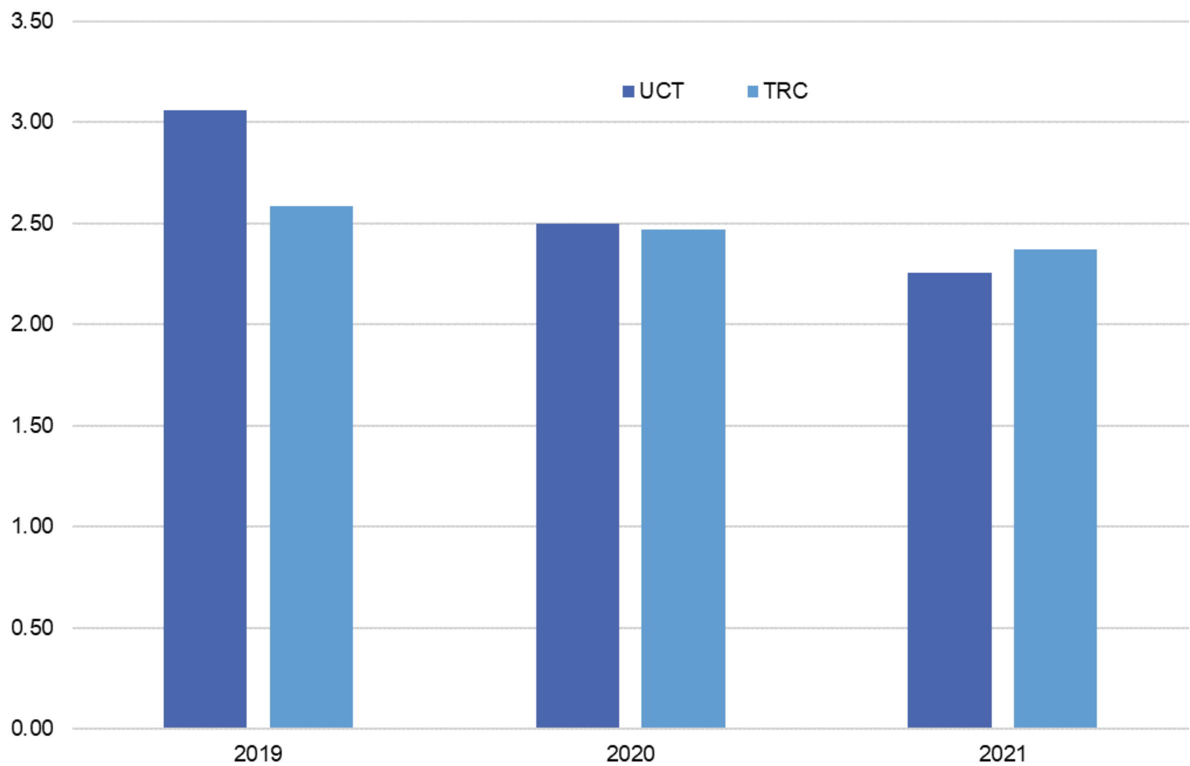
In addition to TRC and UCT results, results from the Ratepayer Impact Measure (RIM), Participant Cost Test (PCT) and Societal Cost Test (SCT) are included in each year's

[117] The UCT is also referred to as the Program Administrator Cost Test (PACT)

Annual Report. Based on reported program impacts and spending through December 31, 2021, PSO’s overall portfolio is cost-effective based on both the TRC and UCT.

Figure C-13 shows the changes in cost effectiveness ratios over the portfolio period. The ratios greater than one emphasizes the significant benefit provided customers over cost incurred.

Figure C-13: Demand Portfolio Cost Effectiveness by Year



C.2 Energy-Efficiency Programs

PSO's portfolio of energy efficiency portfolio offering consisted of eight programs.

C.2.1 Business Rebates Program

PSO's Business Rebates Program seeks to generate energy and demand savings for large and small commercial and industrial customers through promotion of high efficiency electric end use products including (but not limited to) lighting, HVAC, and motors. The program provides PSO's commercial and industrial customers with flexibility in choosing how to participate, by either self-sponsoring or by working through a third-party service provider to leverage technical expertise. The program included targeted subprograms in Small Business Energy Solutions, Midstream Rebates, Oil & Gas, Agriculture, and Custom and Prescriptive.

C.2.2 Multifamily

PSO's Multifamily Program seeks to generate energy savings for owners, operators, and service providers of Multifamily facilities through promotion of high efficiency electric end use products. The program seeks to combine provision of financial inducements with access to technical expertise to maximize program penetration across the range of potential Multifamily customers. Prescriptive rebate amounts are provided to participating customers for some measures including certain types of lighting, lighting controls, HVAC equipment, water-related equipment, and other equipment. Custom projects (i.e., chillers) that do not fall into prescriptive measure categories are rebated on a per kWh and kW impact basis.

C.2.3 Home Weatherization Program

PSO's Home Weatherization Program seeks to generate energy and demand savings for limited income residential customers through the installation of a wide range of cost-effective weatherization and other measures in eligible dwellings. The purpose of the Home Weatherization Program is to provide PSO's limited income residential customers the financial assistance they need to make their homes more energy efficient, increase comfort levels, and reduce their utility bills.

C.2.4 Energy Saving Products Program

PSO's Energy Saving Products Program seeks to generate energy and demand savings for residential customers through the promotion of energy saving LED light bulbs, air filters, weatherization measures, electric vehicle chargers, and EnergyStar® appliances. The purpose of this program is to provide PSO residential customers inducements for purchasing products that meet high efficiency standards. The program included three components:

1) downstream instant rebates for such measures as heat pump water heaters, clothes dryers, clothes washers, refrigerators, and level 2 electric vehicle chargers; 2) upstream discounts for LEDs, advanced power strips, and weatherization measures; and 3) LEDs distributed free-of-charge through community food banks.

C.2.5 Home Rebates Program

PSO's Home Rebates Program seeks to generate energy and demand savings for residential customers through the promotion of comprehensive efficiency upgrades to building envelope measures and HVAC equipment for both new homes and retrofits. The purpose of the Home Rebates Program is to provide PSO residential customers with inducements for increasing building envelope efficiencies and installing items such as high efficiency appliances and HVAC equipment.

C.2.6 Education Program

PSO's Education Program seeks to generate energy and demand savings for residential customers by providing elementary school students with easy self-install energy efficiency measures, such as LEDs and Advanced Power Strips. The purpose of the Education Program is to provide PSO residential customers with an educational experience on how to make their homes more efficient. A lesson plan is provided to the classroom teacher, which engages the students in learning about energy efficiency while also practicing mathematics and science. The students are then provided the take-home energy efficiency kit. Energy savings are achieved when these measures are installed in homes, however PSO does not claim any kW or kWh savings associated with these kits. Additionally, there may be energy savings and other benefits associated with behavioral changes the program induces with students, parents, and teachers.

C.2.7 Behavioral

The Behavioral Modification program provides monthly energy usage reports to residential customers. The program was designed to generate greater awareness of energy use and ways to manage energy use through energy efficiency education in the form of an emailed energy report. The energy report provides customers with energy conservation tips. It is expected that through this education, customers will adopt energy conservation tips that will lead to more efficient energy use in their homes.

C.2.8 Conservation Voltage Reduction

PSO's Conservation Voltage Reduction (CVR) Program seeks to generate energy and demand savings by using a system of devices, controls, software, and communications equipment to manage reactive power flow and lower voltage level for implemented distribution circuits at substations. The purpose of the CVR Program is to achieve energy efficiency savings by managing the voltage and power factor along the distribution circuit and lower the voltage profile within an acceptable bandwidth.

C.3 Demand Response Program

PSO's portfolio consisted of two demand response programs.

C.3.1 Peak Performers Program

The Peak Performers program is designed to incentivize commercial and industrial facilities for curtailing their energy usage during periods of high electrical demand. Nonresidential PSO customers enroll in the program and are notified when a load reduction event is initiated. Participants have the option of participating in each event individually and are paid incentives based on average reduction over the course of all events. Incentives are set at $32 per average kW reduction over all event hours, and participants receive a 5% payment bonus if they opt to participate in all reduction events throughout the year. There is no direct penalty for opting out of specific event days. The program is active during summer months when average demand typically approaches designated capacity thresholds.

C.3.2 Power Hours

The Power Hours Program provides ways to reduce energy usage of residential customers during peak demand periods by offering customers the option of participating in direct load control (DLC) events and providing full rebates for the purchase of a new smart thermostat. DLC events reduce energy usage when demand is highest by communicating with registered Wi-Fi enabled thermostats installed in the homes of participants. Smart thermostats help lower electricity usage by providing customers with improved real-time information about HVAC usage and cost, improved user interfaces, and algorithm optimization (such as occupancy detection and prediction).

Appendix D. Identification of Program Implementers

Table D-1 identifies program implementation contractors and associated contact information by 2021 program.

Table D-1: Program Implementer Identification

Program(s)	Implementation Contractor	Contact	Contact Title	Contact Address	Contact Phone	Contact Email
Business Rebates	ICF International	Janine Pittman	Program Manager	907 S. Detroit Ave. Suite 505 Tulsa, OK 74120	405-714-3437	Janine.Pittman@icfi.com
Multifamily	ICF International	Jason Fisher	Technical Specialist	907 S Detroit Ave. Suite 505, Tulsa, OK 74120	918-519-0214	Jason.Fisher@icf.com
Home Weatherization	Titan ES, LLC	Bradley Cockings	President	9700 S. Pole Road, Tulsa, OK 73160	405-632-1700	bcockings@titanes.us
	Revitalize T-Town	Jennifer Barcus - Schafer	Chief Executive Officer	14 E 7th St, Tulsa, OK 74119	918-742-6241	jennifer@revitalizettown.org
	Ki Bois Community Action Foundation	Michael Knapp	Weatherization Director	200 SE A Street Stigler, Oklahoma 74462	918-967-3325	michael.knapp@kibois.org
Energy Saving Products	CLEAResult	Karen Miller	Program Manager	146 Chestnut Street, Springfield, MA 01103	413-426-7888	karen.miller@clearesult.com
Home Rebates	ICF International	Andrea Palmer	Program Manager	907 S. Detroit Ave. Suite 505 Tulsa, OK 74120	918-348-0503	Andrea.palmer@icf.com
Education	AM Conservation Group	Lee Moran	Senior Program Manager	976 United Circle, Sparks, NV 89431	888-438-9473	LMoran@amconservationgroup.com

Program(s)	Implementation Contractor	Contact	Contact Title	Contact Address	Contact Phone	Contact Email
Power Hours	Honeywell	Amanda Richards	Program Manager	300 S Tryon St Suite 500, Charlotte, NC 28202	1-800-633-3991	amanda.richards@honeywell.com
Peak Performers	PSO	Nonette Surbaugh	EE & Consumer Program Coordinator	212 E. 6th St. Tulsa, OK 74119	918-599-2101	nonettes@aep.com
CVR	PSO	Tyler H Devereux	Customer Design Manager	212 E. 6th St. Tulsa, OK 74119	918-599-2488	thdevereux@aep.com

Appendix E. Training and Customer Outreach

During the program year, PSO conducted several service provider recruitment and training events. Additionally, PSO sponsored various customer outreach events and stakeholder presentations. Table E-1 summarizes the in-store retail lighting promotional events.

Date	Event Name	Location	Training/Education Type	Number of Attendees
01/03/2021	Lighting Event	Tulsa	Contractor	31-40
01/15/2021	Lighting Event	Lawton	Contractor	11-20
01/16/2021	Lighting Event	Lawton	Contractor	11-20
01/23/2021	Lighting Event	Owasso	Contractor	31-40
01/30/2021	Lighting Event	Lawton	Contractor	11-20
02/06/2021	Lighting Event	McAlester	Contractor	11-20
02/13/2021	Lighting Event	Lawton	Contractor	11-20
02/20/2021	Lighting Event	Tulsa	Contractor	21-30
02/21/2021	Lighting Event	Tulsa	Contractor	31-40
03/06/2021	Lighting Event	Tulsa	Contractor	31-40
03/06/2021	Lighting Event	Elk City	Contractor	11-20
03/07/2021	Lighting Event	Tulsa	Contractor	41-50
03/13/2021	Lighting Event	Lawton	Contractor	11-20
04/10/2021	Lighting Event	Lawton	Contractor	11-20
04/17/2021	Lighting Event	Lawton	Contractor	11-20
04/17/2021	Lighting Event	Tulsa	Contractor	31-40
04/18/2021	Lighting Event	Owasso	Contractor	31-40
05/08/2021	Lighting Event	McAlester	Contractor	21-30
05/15/2021	Lighting Event	Tulsa	Contractor	31-40
05/16/2021	Lighting Event	Tulsa	Contractor	31-40
05/22/2021	Lighting Event	Hobart	Contractor	11-20
06/05/2021	Lighting Event	Grove	Contractor	21-30
06/12/2021	Lighting Event	Lawton	Contractor	11-20
06/19/2021	Lighting Event	Bartlesville	Contractor	41-50
06/26/2021	Lighting Event	Lawton	Contractor	11-20
07/17/2021	Lighting Event	Lawton	Contractor	11-20
07/24/2021	Lighting Event	Lawton	Contractor	11-20
07/24/2021	Lighting Event	Tulsa	Contractor	31-40
07/31/2021	Lighting Event	Tulsa	Contractor	21-30

Date	Event Name	Location	Training/Education Type	Number of Attendees
08/01/2021	Lighting Event	Owasso	Contractor	41-50
08/14/2021	Lighting Event	Lawton	Contractor	11-20
08/28/2021	Lighting Event	Broken Arrow	Contractor	31-40
08/28/2021	Lighting Event	McAlester	Contractor	11-20
09/18/2021	Lighting Event	Hobart	Contractor	11-20
09/25/2021	Lighting Event	Owasso	Contractor	41-50
09/25/2021	Lighting Event	Lawton	Contractor	11-20
09/26/2021	Lighting Event	Tulsa	Contractor	41-50
10/02/2021	Lighting Event	Tulsa	Contractor	41-50
10/03/2021	Lighting Event	Tulsa	Contractor	41-50
10/16/2021	Lighting Event	Lawton	Contractor	11-20
10/30/2021	Lighting Event	McAlester	Contractor	11-20
11/06/2021	Lighting Event	Hobart	Contractor	11-20
11/13/2021	Lighting Event	Lawton	Contractor	11-20
11/20/2021	Lighting Event	Tulsa	Contractor	41-50
11/21/2021	Lighting Event	Tulsa	Contractor	31-40

Table E-2 summarizes service provider recruitment and training events, customer outreach events, and other non-lighting promotion events throughout the program year.

Table E-1: Summary of In-Store Retail Lighting Promotional Events

Date	Event Name	Location	Training/Education Type	Number of Attendees
01/03/2021	Lighting Event	Tulsa	Contractor	31-40
01/15/2021	Lighting Event	Lawton	Contractor	11-20
01/16/2021	Lighting Event	Lawton	Contractor	11-20
01/23/2021	Lighting Event	Owasso	Contractor	31-40
01/30/2021	Lighting Event	Lawton	Contractor	11-20
02/06/2021	Lighting Event	McAlester	Contractor	11-20
02/13/2021	Lighting Event	Lawton	Contractor	11-20
02/20/2021	Lighting Event	Tulsa	Contractor	21-30
02/21/2021	Lighting Event	Tulsa	Contractor	31-40
03/06/2021	Lighting Event	Tulsa	Contractor	31-40
03/06/2021	Lighting Event	Elk City	Contractor	11-20
03/07/2021	Lighting Event	Tulsa	Contractor	41-50
03/13/2021	Lighting Event	Lawton	Contractor	11-20

Date	Event Name	Location	Training/Education Type	Number of Attendees
04/10/2021	Lighting Event	Lawton	Contractor	11-20
04/17/2021	Lighting Event	Lawton	Contractor	11-20
04/17/2021	Lighting Event	Tulsa	Contractor	31-40
04/18/2021	Lighting Event	Owasso	Contractor	31-40
05/08/2021	Lighting Event	McAlester	Contractor	21-30
05/15/2021	Lighting Event	Tulsa	Contractor	31-40
05/16/2021	Lighting Event	Tulsa	Contractor	31-40
05/22/2021	Lighting Event	Hobart	Contractor	11-20
06/05/2021	Lighting Event	Grove	Contractor	21-30
06/12/2021	Lighting Event	Lawton	Contractor	11-20
06/19/2021	Lighting Event	Bartlesville	Contractor	41-50
06/26/2021	Lighting Event	Lawton	Contractor	11-20
07/17/2021	Lighting Event	Lawton	Contractor	11-20
07/24/2021	Lighting Event	Lawton	Contractor	11-20
07/24/2021	Lighting Event	Tulsa	Contractor	31-40
07/31/2021	Lighting Event	Tulsa	Contractor	21-30
08/01/2021	Lighting Event	Owasso	Contractor	41-50
08/14/2021	Lighting Event	Lawton	Contractor	11-20
08/28/2021	Lighting Event	Broken Arrow	Contractor	31-40
08/28/2021	Lighting Event	McAlester	Contractor	11-20
09/18/2021	Lighting Event	Hobart	Contractor	11-20
09/25/2021	Lighting Event	Owasso	Contractor	41-50
09/25/2021	Lighting Event	Lawton	Contractor	11-20
09/26/2021	Lighting Event	Tulsa	Contractor	41-50
10/02/2021	Lighting Event	Tulsa	Contractor	41-50
10/03/2021	Lighting Event	Tulsa	Contractor	41-50
10/16/2021	Lighting Event	Lawton	Contractor	11-20
10/30/2021	Lighting Event	McAlester	Contractor	11-20
11/06/2021	Lighting Event	Hobart	Contractor	11-20
11/13/2021	Lighting Event	Lawton	Contractor	11-20
11/20/2021	Lighting Event	Tulsa	Contractor	41-50
11/21/2021	Lighting Event	Tulsa	Contractor	31-40

Table E-2: Service Provider Recruitment & Training Events, Customer Outreach Events, and Other Non-Lighting Promotional Events

Date	Event Name	Location	Training/Education Type	Number of Attendees
01/07/2021	HPH Service Provider Training	McAlester	Contractor	11-20
01/07/2021	HPH Service Provider Training	McAlester	Contractor	11-20
01/30/2021	HPH Service Provider Training	Other	Contractor	21-30
04/07/2021	HPH Builder/Rater Training	Oklahoma City	Contractor	0-10
04/26/2021	HPH Builder/Rater Training	Tulsa	Contractor	0-10
05/18/2021	HPH Builder/Rater Training	Tulsa	Contractor	0-10
06/24/2021	HPH Service Provider Training	Grove	Contractor	0-10
08/10/2021	HPH Builder/Rater Training	Tulsa	Contractor	0-10
08/12/2021	HPH Service Provider Training	Tulsa	Contractor	0-10
08/16/2021	PowerForward Overview	Tulsa	Other	21-30
08/17/2021	PowerForward Overview	Tulsa	Other	21-30
08/19/2021	PowerForward Overview	Tulsa	Other	21-30
08/20/2021	PowerForward Overview	Tulsa	Other	21-30
09/27/2021	HPH Service Provider Training	Chickasha	Contractor	0-10
10/21/2021	PowerForward Overview	Oologah	Other	0-10
10/25/2021	HPH Service Provider Training	Broken Arrow	Contractor	0-10
10/27/2021	HPH Program Updates	Tulsa	Contractor	0-10
11/02/2021	HPH Service Provider Training	Duncan	Contractor	0-10
11/11/2021	HPH Service Provider Training	Tulsa	Contractor	0-10
11/19/2021	PowerForward Overview	Tulsa	Other	11-20
12/14/2021	HPH Service Provider Training	Virtual	Contractor, Other	100+
12/15/2021	PowerForward Overview	McAlester	Other	0-10

Appendix F. Marketing Synopsis – Customer Engagement

The following pages of this appendix provide examples of materials used to promote, engage, and educate customers on PSO's Demand Portfolio in the 2021 program year.

PSO's strategies for Power Forward with PSO continue to evolve in attracting, engaging, and educating customers on energy efficiency. Multichannel marketing strategies are utilized to increase opportunities for customer awareness and engagement. PSO's ensures strategic planning and execution across all energy-efficiency programs, delivering a consistent message and experience for customers regardless of program.

F.1 2021 Goals

This section presents the methods used to meet PSO's portfolio engagement goals.

F.1.1 Strategies and Tactics

- Harness feedback from customers, industry experts and partners to improve the clarity, effectiveness, and follow-up efforts of PSO's energy-efficiency program marketing
- Utilize audience intelligence data from PowerForwardWithPSO.com to further refine our audience personas
- Utilize paid media to deliver targeted messages to customers
- AIB Message Testing
- Develop content to support paid media and digital channels
- Utilize eblasts to promote program participation
- Website Assessment for Redesign
- Create opportunities for innovation and customer engagement
- Continue to identify opportunities for customer education

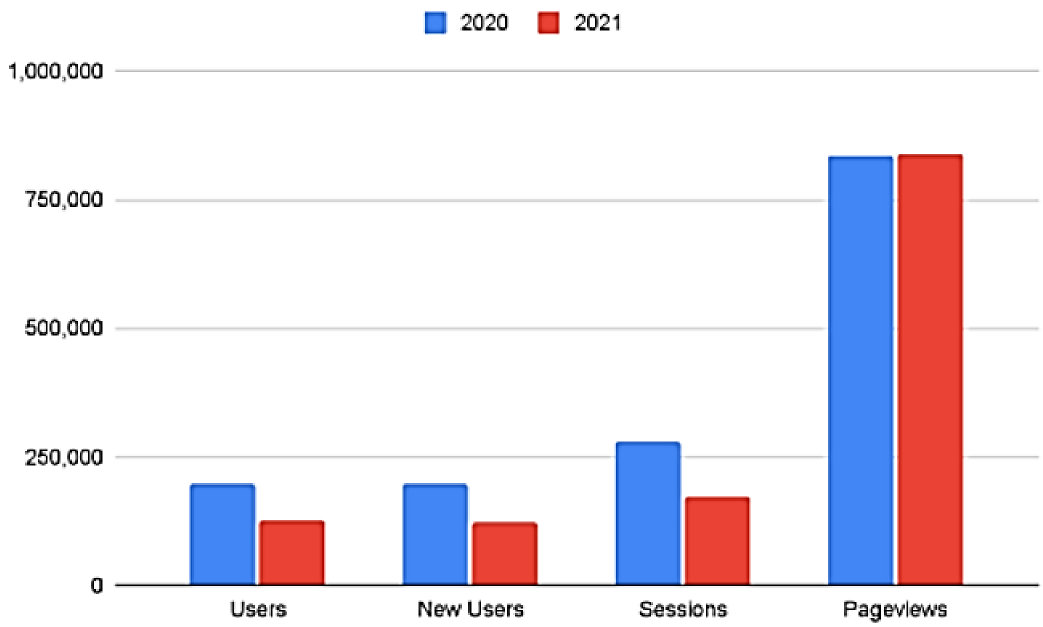
F.1.2 PSO Website

In 2021, PSO began the process of updating their website to a new design and overall site experience. Phases to this project have included Information Architecture, Mood Boards, Wireframes, Prototyping, User Testing and Copy Updates. As we finalize the work in early 2022, we're focusing on the Staging Site and QA, before turning the site live. Learnings and findings will continue to influence future site updates, to ensure we're building and creating the best site and experience possible for customers

F.2 Overall Website Performance

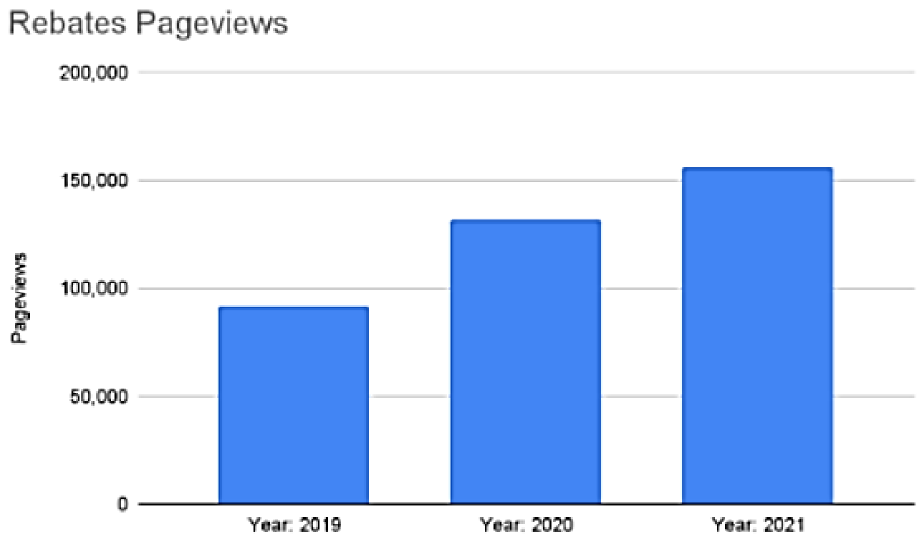
Compared to 2020, PSO saw Users, New Users and Sessions soften year over year. Page views saw a minimal increase compared to 2020.

Table F-1: Website Comparison from 2019 to 2020



124,803 **Users** -37.05%	123,297 **New Users** -37.19%	174,021 **Sessions** -37.38%	838,086 **Pageviews** 0.17%

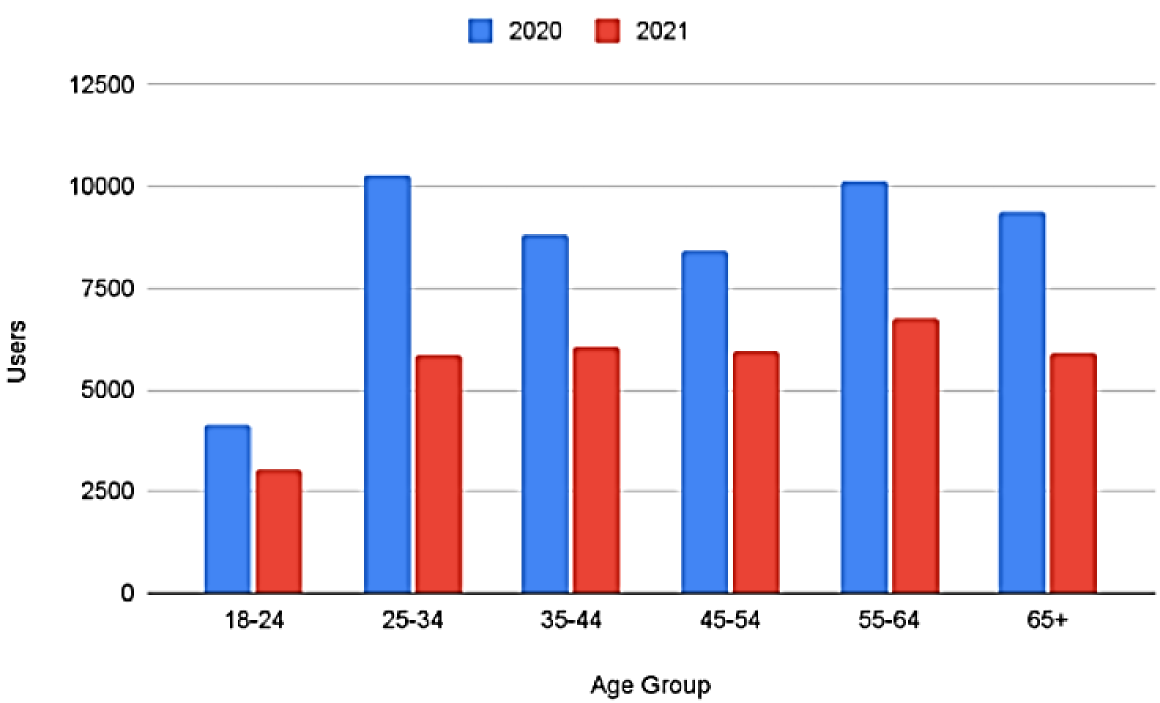
Table F-2: Rebates Page Views 2019 - 2021



F.2.1 Site Visitors: By Age

Website visitors declined across all age groups, when comparing 2020 to 2021.

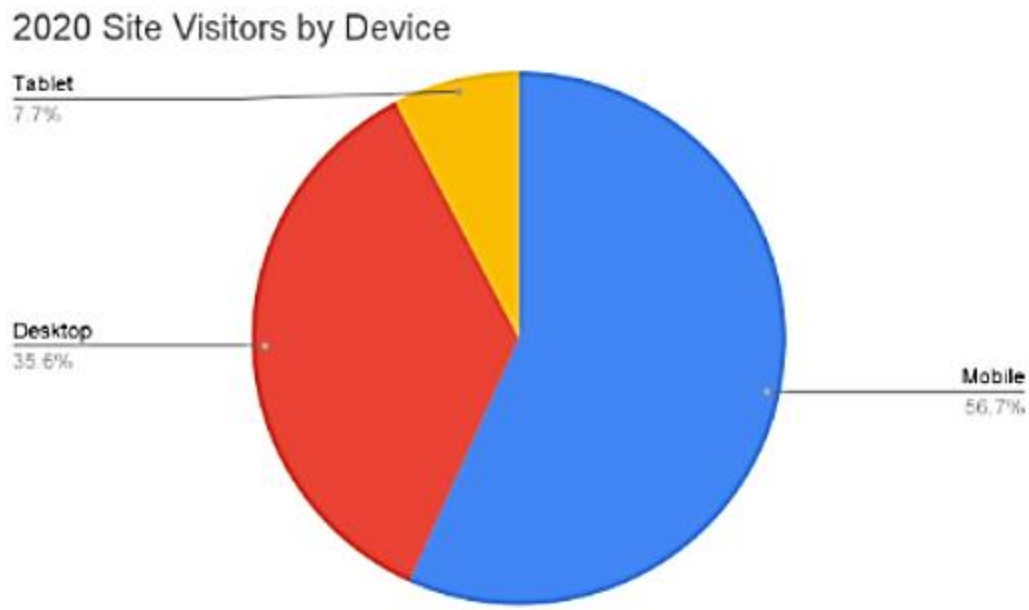
Table F-3: Age Group Comparison 2020 - 2021

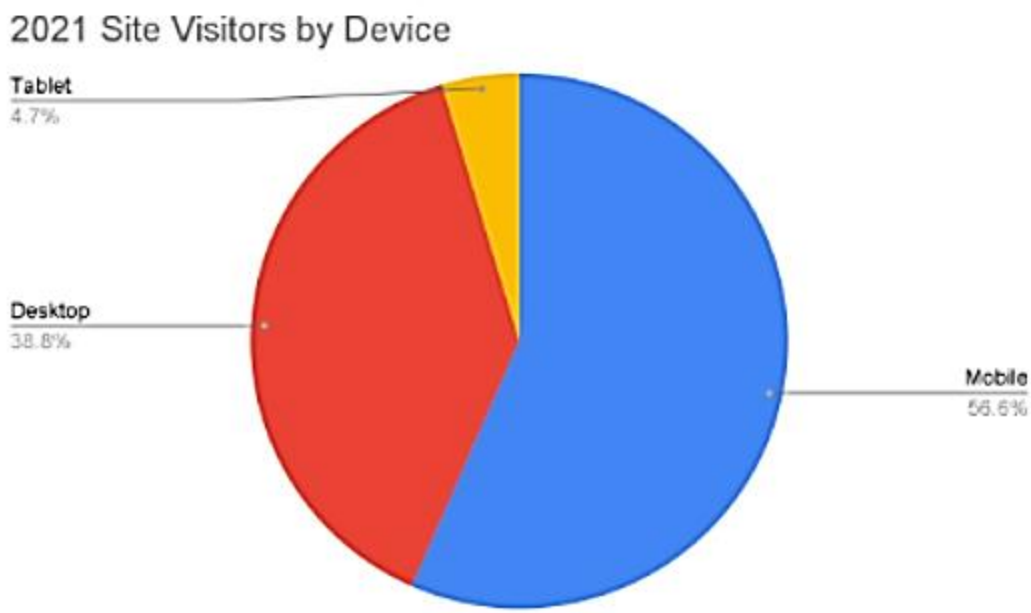


F.2.2 Site Visitors: By Device

Over the years there has been a shift from the devices that are being used. With most users being mobile-first, we've seen mobile performance metrics remain steady over the last two years. Tablet usage has softened, with more users defaulting to desktop use, especially with the pandemic increasing the amount of desktop usage, and users checking email and visiting sites alongside their daily work.

Table F-4: Site Visitors by Device





F.2.3 Website Events

The data below represents the top events by number of events during 2021.

Table F-5:Website Events 2021

EVENT TYPE	#OF EVENTS
Find a Retailer/Provider Home Rebates	9,445
My PSO Account - Footer	3,721
Power Hours Sign Up	3,629
Weatherization Form	2,276
Submit an Application	1,405
Schedule a Consultation Business	1,245
Peak Performers	669
My Energy Advisor - Create Your Energy Profile	630
Small Business Energy Audit - Button	295

F.2.4 Website Engagement

The following pages have the most engagement determined by total pageviews.

Table F-6:Website Engagement 2021

PAGE DESCRIPTION	PAGEVIEWS
Rebates – Residential	156,619
Homepage – Residential	136,670
Tips & Tools	50,883
Weatherization Assistance	48,400
Tune Up	46,227
Homepage - My Business	28,676

F.2.5 Paid Search Results

Paid search is being utilized to capture customers at the bottom of the sales funnel. In 2021, we consistently refined search keywords to increase media effectiveness and reduce spend to support additional upper funnel marketing tactics, which focus on moving customers from awareness to consideration.

Table F-7: Paid Search Results

PAID SEARCH IMPRESSIONS	
Residential	152,467
Commercial	48,725

Top Search Terms: "IO ways to save energy" (phrase match), "+new +home +builders+near +me" (phrase match), "new home weatherization" (phrase match), "Small Business Rebates" (phrase match), "refrigeration rebate" (phrase match), "business rebates" (phrase match)

F.2.6 Web Traffic - Social

Social continues to be a strong driver of traffic to the website. In 2021, we continued placements on NextDoor and Reddit into the media mix to diversify and reach customers across a variety of platforms where content is consumed.

Table F-8: Social Web Referrals

SOCIAL WEB REFERRALS	
Sessions	5,260

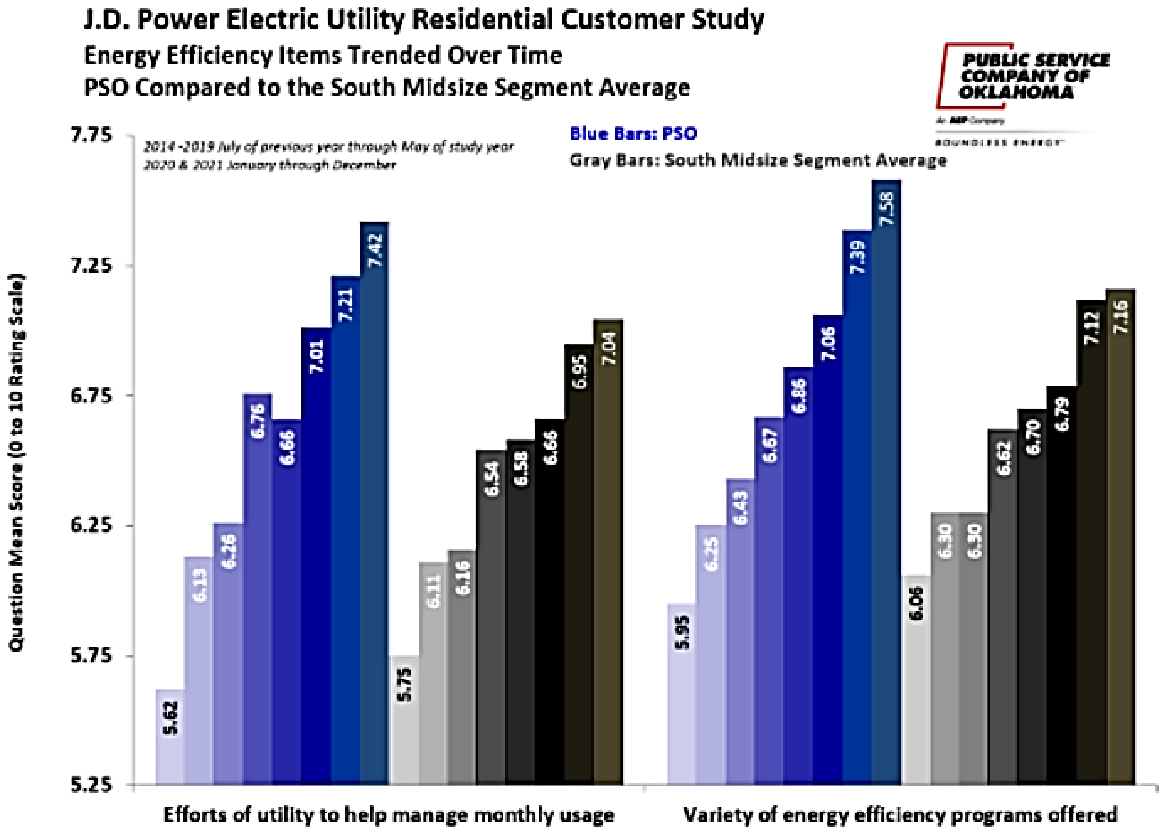
Table F-9: Top Referral Channels

TOP REFERRAL CHANNELS	SESSIONS
Facebook	4,529
Pinterest	361
Reddit	216
LinkedIn	126

F.3 J.D. Power Scores

J.D. Power provides electric utility customer satisfaction scores that PSO uses for measurement comparison purposes. The figure below shows satisfaction scores from residential customers.

Table F-10:PSO's J.D. Power Scores



F.4 Videos

In 2021, we continued our video marketing strategy that leveraged the specific platform of YouTube as well as multiple platforms via programmatic to reach a wider customer base. Optimizations focused on fine tuning audience targeting on these platforms to maximize KPIs.

Table F-11: YouTube Channel Performance

VIDEO PERFORMANCE			
Video Type	**Impressions**	**Clicks**	**CTR**
Residential	3,017,052	8,846	0.38%
Commercial	1,933,294	6,847	0.31%

F.4.1 Video Performance by Campaign

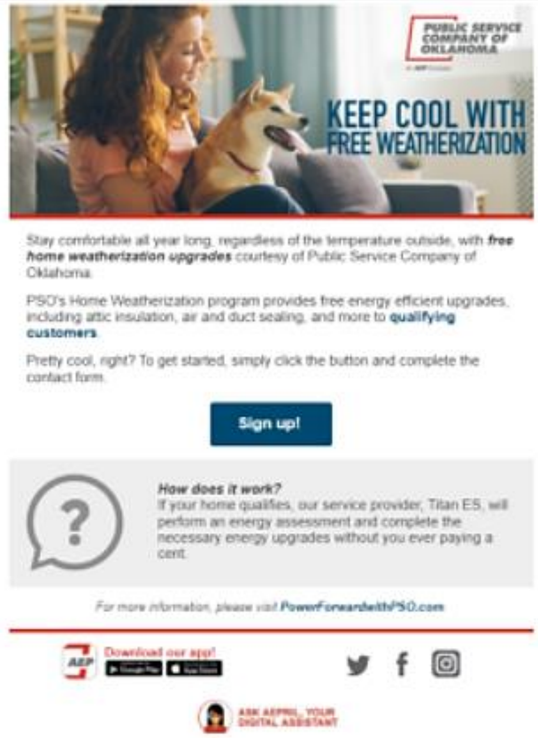
Table F-12:2021 Video Performance

VIDEO PERFORMANCE			
Creative	**Impressions**	**Clicks**	**CTR**
Ag / Oil & Gas	256,411	494	0.21%
Business Rebates	582,763	1,071	0.16%
HPWH	95,702	232	0.24%
HVAC Tuneup	566,406	1,251	0.20%
M.U.S.H.	263,852	721	0.30%
New Movers	791,156	1,646	0.21%
Peak Performers	361,997	2,739	0.76%
Seasonal Tips	853,885	4,303	0.70%
Small Business	468,271	1,822	0.39%
Weatherization	709,903	1,414	0.20%

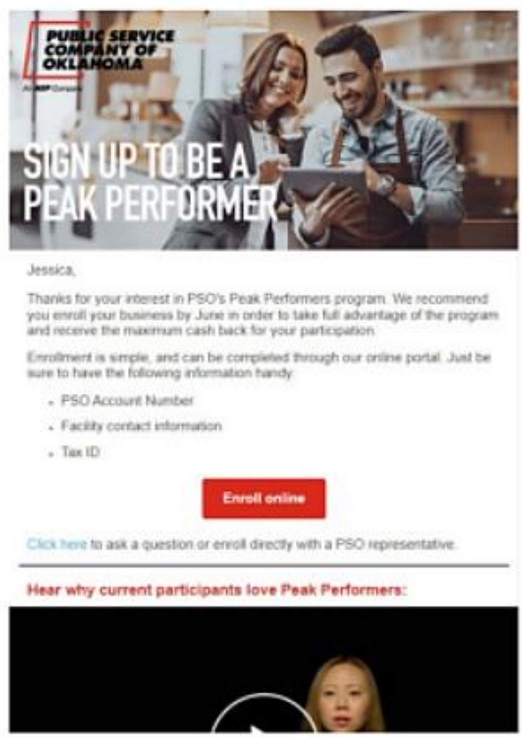
F.5 Email Marketing

PSO utilized email marketing to send communications regarding rebates and programs to various customer segments. Program participation data was utilized to ensure the right customers were targeted with relevant messaging. Emails included clear call to action buttons to improve customer engagement.


GIVE YOUR HVAC SOME TLC.
Save Up to $150 on Your Next HVAC Tune-Up
Your summer just got a little brighter — PSO is now offering rebates up to $150 on HVAC tune-ups!
We've partnered with select service providers in your area to deliver this valuable service. A well-maintained air conditioner works better, lasts longer and can reduce your cooling costs.
SPECIAL OFFER
View details
Funds are limited, so don't wait. Request a tune-up today!
Request a Tune-Up
Download our app!
ASK AEPRIL, YOUR DIGITAL ASSISTANT


PUBLIC SERVICE COMPANY OF OKLAHOMA
KEEP COOL WITH FREE WEATHERIZATION
Stay comfortable all year long, regardless of the temperature outside, with free home weatherization upgrades courtesy of Public Service Company of Oklahoma.
PSO's Home Weatherization program provides free energy efficient upgrades, including attic insulation, air and duct sealing, and more to qualifying customers.
Pretty cool, right? To get started, simply click the button and complete the contact form.
Sign up!
How does it work?
If your home qualifies, our service provider, Titan ES, will perform an energy assessment and complete the necessary energy upgrades without you ever paying a cent.
For more information, please visit PowerForwardwithPSO.com
Download our app!
ASK AEPRIL, YOUR DIGITAL ASSISTANT


PUBLIC SERVICE COMPANY OF OKLAHOMA
BIG SAVINGS FOR SMALL BUSINESSES!
Set your business up for success with PSO rebates. Our small business rebates help you save up to 70% of the cost of upgrading to efficient LED lighting and refrigeration equipment — reducing your business's overhead and helping you save year-round.
On average, businesses receive $15,202 in rebates, plus $2,566 in annual bill savings!
See How Much You Could Save
Getting easy is started — simply request a free energy audit below!
Request Your Free Audit
Download our app!
ASK AEPRIL, YOUR DIGITAL ASSISTANT


PUBLIC SERVICE COMPANY OF OKLAHOMA
SIGN UP TO BE A PEAK PERFORMER
Jessica,
Thanks for your interest in PSO's Peak Performers program. We recommend you enroll your business by June in order to take full advantage of the program and receive the maximum cash back for your participation.
Enrollment is simple, and can be completed through our online portal. Just be sure to have the following information handy:
PSO Account Number
Facility contact information
Tax ID
Enroll online
Click here to ask a question or enroll directly with a PSO representative.
Hear why current participants love Peak Performers:

F.5.1 Creative Examples – Residential

Sent to approximately 320,000 customers monthly. Content highlights energy-saving blog content, tips, and available rebates. Customers are encouraged to visit the Power Forward with PSO website.

April E-Newsletter

May E-Newsletter

June E-Newsletter

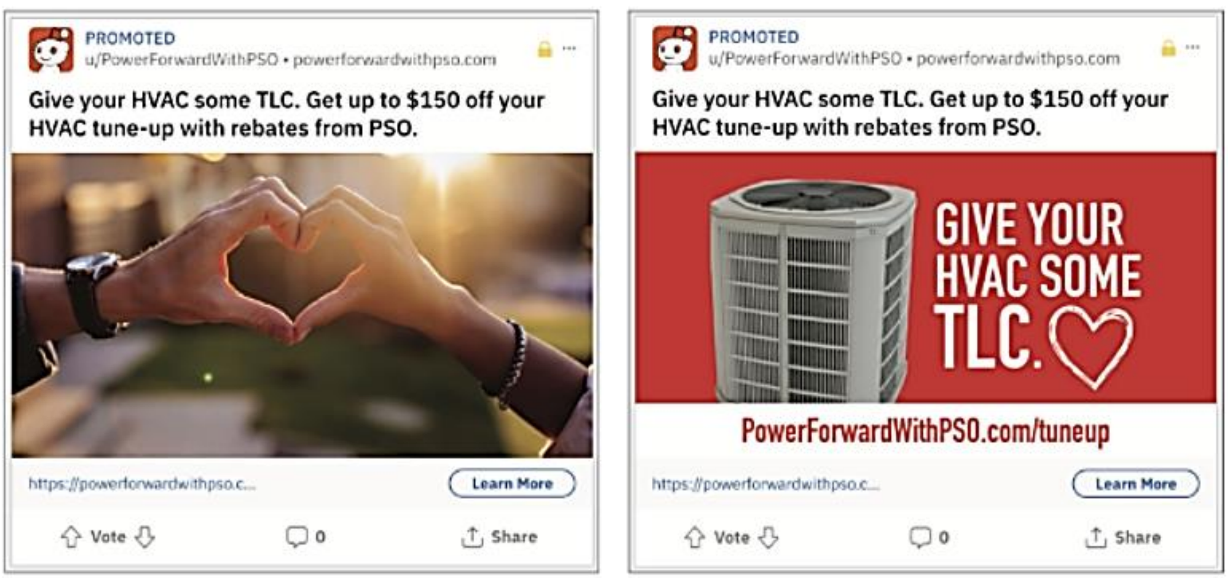
ENERGY STAR®

July Bill Insert

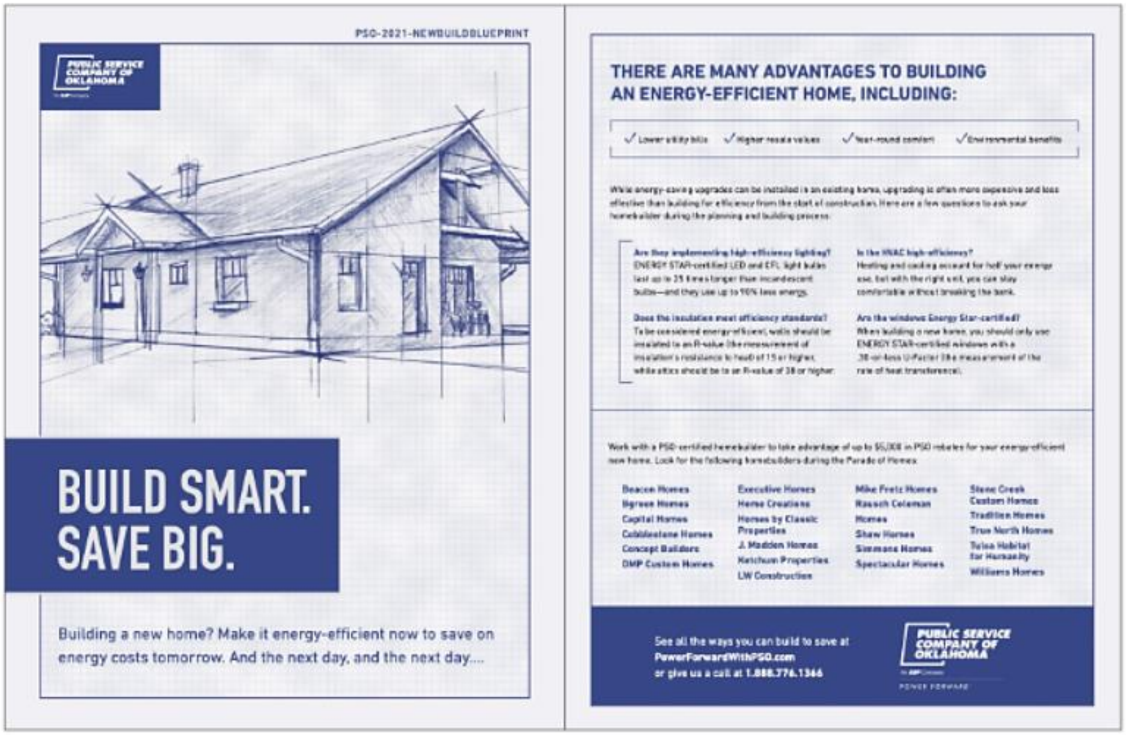
Heat Pump Water Heaters

RESIDENTIAL PROGRAMS

Centro - Weatherization Assistance



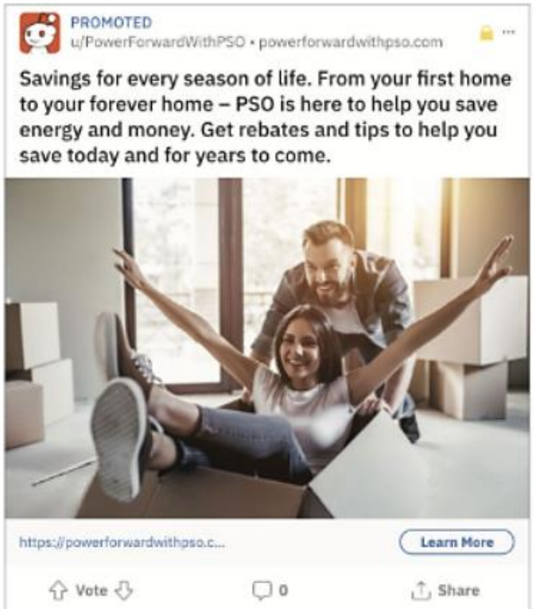
Reddit - HVAC Tune-Up



Parade of Homes Print Advertisement (Update)

Broken Arrow Chamber Print Advertisement

RESIDENTIAL PROGRAMS



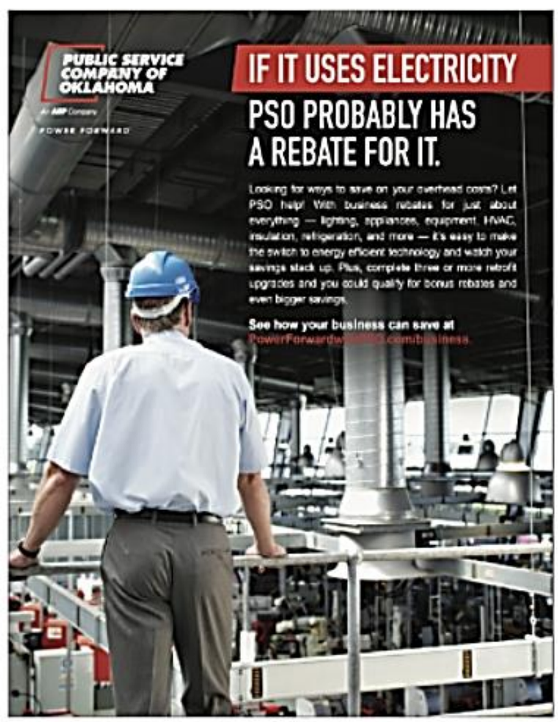
Reddit - Rebates

NextDoor - Rebates

F.5.2 Creative Examples – Commercial

PRINT

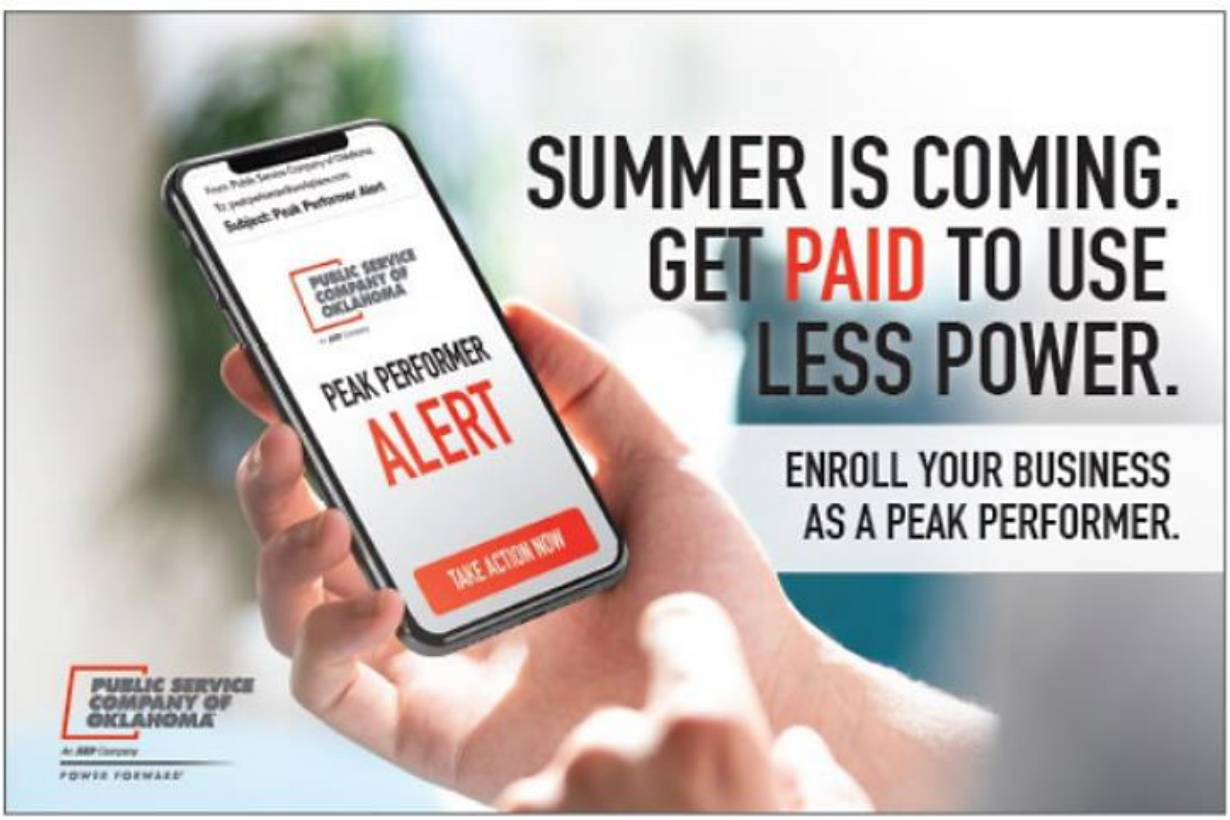
Tulsa People - Peak Performers



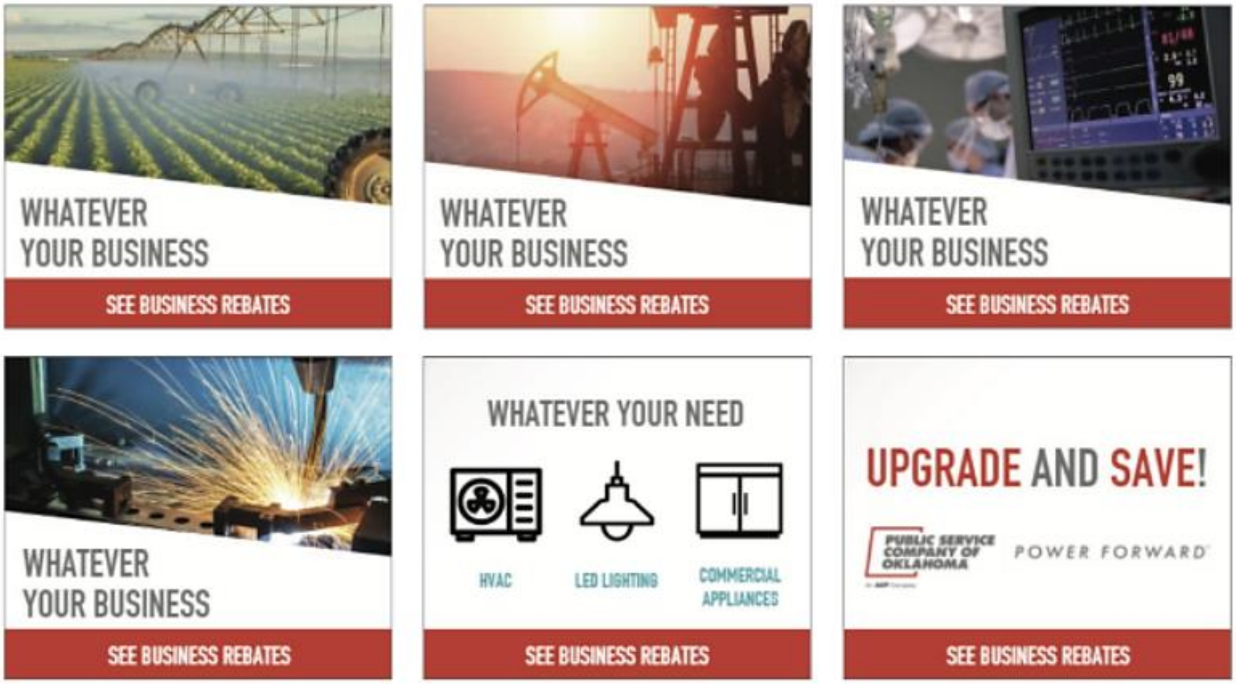
Tulsa People - Commercial Rebates

DIRECT MAIL


BIG SAVINGS FOR SMALL BUSINESSES!
PUBLIC SERVICE COMPANY OF OKLAHOMA
ON AVERAGE, BUSINESSES RECEIVE $15,202 IN REBATES, PLUS $2,566 IN ANNUAL BILL SAVINGS.*
*Average savings based on projects completed from 2019-2021


SUMMER IS COMING. GET PAID TO USE LESS POWER.
ENROLL YOUR BUSINESS AS A PEAK PERFORMER.
PEAK PERFORMER
ALERT
TAKE ACTION NOW
PUBLIC SERVICE COMPANY OF OKLAHOMA

DISPLAY



Programmatic - M.U.S.H.

Centro - Peak Performers

BRAND WINDOWS

Agriculatural Rebates Brand Widow

Peak Performers Brand Window

PREROLL

Programmatic Video Ad - Small Business

F.6 Community Engagement

PSO participates in a variety of community events, including tradeshows, lighting demonstrations, program presentations, seminars and more. Community events are used to help educate customers on rebate and program offerings.

- 67 Training Events, including 45 retailer lighting promotions
- 20+ local promotional events

Appendix G. OKDSD, AR, & IL TRM Deemed Savings and Algorithms

G.1 Energy-Efficiency Programs

G.1.1 Business Rebates Program

ADM's approach to project level savings analysis depends largely on the types of measures installed. Whenever possible, deemed savings and prescribed algorithms from the Arkansas Technical Reference Manual v7.0[118] (AR TRM) will be used to determine verified gross savings. Care will be taken to assure any assumptions are reasonable and current, and that there are no errors in the algorithms. Additionally, where engineering calculations from the AR TRM are applicable to measures installed through the Business Rebates Program, those algorithms may also be used. Care will be taken to ensure that weather conditions and other factors that may vary from Arkansas to Oklahoma will be considered when applying these algorithms. The following discussion describes, in general, ADM's plan for analyzing savings from different measure types:

G.1.1.1 ADM Baseline Methodology

Lighting measures may include retrofits of existing fixtures, lamps and/or ballasts with energy efficient fixtures, lamps and/or ballasts. These types of measures reduce demand, but operating hours for fixtures are generally the same pre- and post-retrofit. Also examined are any proposed lighting control strategies that might include the addition of energy conserving control technologies, such as motion sensors or day-lighting controls. These measures typically involve a reduction in hours of operation and/or lower current passing through the fixtures. New construction lighting projects are also included in the Business Rebates Program, which requires calculating savings in comparison to applicable building codes instead of pre-retrofit conditions.

ADM analyzes the savings from lighting measures using data for new/retrofitted fixtures on (1) wattages before and after retrofit and (2) hours of operation before and after the retrofit. Fixture wattages are generally determined through M&V practices but may be taken from a table of standard wattages or cut sheets when feasible, with corrections made for non-operating fixtures. Prescriptive algorithms for calculating energy savings and demand reductions from the AR TRM or other relevant program sources will be used. Additionally, HVAC interactive effects will be accounted for using partially deemed algorithms from the AR TRM dependent upon heating and cooling systems serving areas where lighting systems are installed.

[118] Arkansas Technical Reference Manual, version 7.0 volume 1: EM&V Protocols, *prepared by* The Independent Evaluation Monitor, *approved in Docket* 10-100-R, August 31, 2017.

G.1.1.2 Analyzing Savings from HVAC Measures

For the analysis of non-prescriptive HVAC and control measures, ADM developed estimates of the savings through simulations with energy analysis models (e.g., DOE-2, eQuest). Before making the analytical runs for each sample site with these measures, a Model Calibration Run is prepared. Calibration is based on actual billed usage during actual weather conditions. Once the analysis model has been calibrated for a particular facility, there are three steps in the procedure for calculating estimates of energy savings for HVAC measures installed or to be installed at the facility. First, an analysis of energy use was performed at a facility under the assumption that the energy efficiency measures were not installed. Second, energy use is analyzed at the facility with all conditions the same but with the energy efficiency measures now installed. Third, the results are compared of the analyses from the preceding steps to determine the energy savings attributable to the energy efficiency measure. The compared analysis runs were normalized to a typical meteorological weather year (TMY3). ADM used monitoring data to verify set points and operating characters and to calibrate the simulations, as necessary.

G.1.1.3 Analyzing Savings from Motor and VFDs

Estimates of energy savings from the use of non-prescriptive high efficiency motors or VFDs are derived through an "after-only" analysis. With this method, energy use is measured for the high efficiency motor or VFD and after it has been installed. ADM (1) makes one-time measurements of voltage, current, and power factor of the VFD/motor and (2) use ACR loggers to conduct continuous measurements of amps or watts over a period to obtain the data needed on operating schedules. The data thus collected is then used in estimating what energy use would have been for the motor application if the high efficiency motor or VFD had not been installed. ADM field staff participate in annual safety training to ensure that safety best practices are used.

G.1.1.4 Analyzing Savings from Process Improvements

Analysis of savings from process improvements (including air compressors, process machines, etc.) is inherently project specific. Because of the specificity of such processes, analyzing the processes through simulations is generally not feasible. Rather, engineering analysis of the process affected by the improvements is relied on. Major factors in the engineering analysis of process savings are operating schedules and load factors. ADM developed the information on these factors through energy management system data collection or short-term monitoring of the affected equipment, be it pumps, heaters, compressors, etc. The monitoring was done after the process change, and the data gathered on operating hours and load factors were used in the engineering analysis to define “before” conditions for the analysis of savings.

For large projects, a billing regression analysis is often the most accurate representation of consumption changes due to energy efficiency measures. ADM adheres to ASHRAE Guide 14 to ensure the results are statistically representative. In addition, ADM will interview the site contact to ensure that no other operational changes or other energy efficiency measures are impacting consumption.

G.1.1.5 Retro-commissioning and Enhanced O&M

As is the case for custom measures, the methods used to verify project gross energy impacts were dependent on the specifics of each site and the availability of data. However, the gross savings analysis for each site are more involved based on the additional data and documentation that is included in the savings calculations.

Methods include the range of International Performance Measurement & Verification Protocols, as shown in Table G-1 below. An emphasis is placed on Option D (Building simulation) for commercial facilities and Options B (pre/post monitoring) & C (Billing analysis) for industrial facilities. Often, multiple approaches are used to minimize uncertainty in the verified energy savings estimates. The preceding descriptions of typical gross savings estimation methods by measure type are used for retro-commissioning projects as well.

Table G-1: International Performance Measurement & Verification Protocols – M&V Options

M&V Option	How Savings Are Calculated
Partially Measure Retrofit Isolation	Engineering calculations using short term or continuous post-retrofit measurements and stipulations.
Retrofit Isolation	Engineering calculations using short term or continuous measurements.
Whole Facility	Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.
Calibrated Simulation	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering.

G.1.2 Home Weatherization Program

This section includes the measure level algorithms and deemed savings values utilized for the verified kWh and kW savings calculations.

G.1.2.1 Infiltration Reduction

ADM utilized the AR TRM for the savings algorithms. Savings were calculated by multiplying the air infiltration reduction (CFM) with the energy savings factor corresponding to the climate zone / HVAC type. The air infiltration reduction estimate in CFM was obtained through blower door testing performed by the program contractor for each home serviced. Only homes with electric cooling systems are eligible for the measure (central AC or room AC). The algorithms for energy savings listed in the AR TRM are:

Equation G-15: Annual Energy Savings

$$kWh_{Savings} = CFM\ X\ ESF$$

Equation G-16: Peak Demand Savings

$$kW_{Savings} = CFM\ X\ DSF$$

Where:

CFM = Air infiltration reduction in Cubic Feet per Minute at 50 Pascal

ESF = The energy savings value corresponding to the climate zone and heating and cooling type in the following table

DSF = The demand savings value corresponding to the climate zone and heating and cooling type in the following table:

Table G-2: Infiltration Control Deemed Savings Values

Infiltration Control Deemed Savings				
Impact per CFM50 Reduction				
Equipment Type	kWh Savings (ESF)	kW Savings (DSF)	Therm Savings (GSF)	Peak Therms (GPSF)
Zone 9				
Electric AC with Gas Heat	0.166	0.000098	0.095	0.002529
Gas Heat Only (no AC)	0.073	NA	0.099	0.002529
Elec. AC with Resistance Heat	2.344	0.000098	NA	NA
Heat Pump	1.099	0.000098	NA	NA
Zone 8				
Electric AC with Gas Heat	0.188	0.00014	0.0825	0.002325
Gas Heat Only (no AC)	0.062	NA	0.0863	0.002325
Elec. AC with Resistance Heat	2.079	0.00014	NA	NA
Heat Pump	0.942	0.00014	NA	NA

Infiltration Control Deemed Savings				
Impact per CFM50 Reduction				
Zone 7				
Electric AC with Gas Heat	0.19	0.00016	0.0707	0.002181
Gas Heat Only (no AC)	0.053	NA	0.0747	0.002181
Elec. AC with Resistance Heat	1.812	0.00016	NA	NA
Heat Pump	0.818	0.00016	NA	NA
Zone 6				
Electric AC with Gas Heat	0.255	0.00017	0.0604	0.001812
Gas Heat Only (no AC)	0.046	NA	0.0639	0.001812
Elec. AC with Resistance Heat	1.641	0.00017	NA	NA
Heat Pump	0.756	0.00017	NA	NA

G.1.2.2 Duct Sealing

ADM utilized the Oklahoma Deemed Savings Document (OKDSD) in conjunction with the duct leakage reduction results to calculate measure savings. ADM modified to the default SEER value used in the algorithm. The default SEER value is 13, but ADM utilized a value of 11.5 SEER because the measure is being implemented in qualified income homes which tend to be older. The 11.5 SEER value is the average of U.S. DOE minimum allowed SEER for air conditioners from 1992-2006 (10 SEER) and after January 23, 2006 (13 SEER). The algorithms for cooling and energy saving listed in the OKDSD for duct sealing are as follows:

Equation G-17: Cooling Savings

$$kWH_{savings,C} = \frac{(DL_{pre} - DL_{\boldsymbol{post}})X\ EFLH_C\ X\ (h_{out}\rho_{out} - h_{in}\rho_{in})\ X\ 60}{1000\ X\ SEER}$$

Where:

DL_{pre} = Pre-improvement duct leakage at 25 Pa (ft3/min)

DL_{post} = Post-improvement duct leakage at 25 Pa (ft3/min)

$EFLH_c$ = Equivalent full load cooling hours, from Table G-3

h = Outdoor/Indoor seasonal specific enthalpy (Btu/lb), from Table G-4

ρ_{out} = Density of outdoor air (lb/ft3) from Table G-5

ρ_{in} = Density of conditioned air at 75°F (lb/ft3)

= 0.0756

60 = Constant to convert from minutes to hours

1,000 = Constant to convert from W to kW

SEER = Seasonal Energy Efficiency Ratio of existing system (Btu/W·hr)

= 11.5[119]

Table G-3: Equivalent Full-Load Hours for Cooling by Weather Zone for Duct Sealing

Weather Zone	$EFLH_c$
Zone 6: El Dorado, AR [11]	1,738
Zone 7: Lawton, OK [12]	1,681
Zone 8a: Oklahoma City, OK	1,436
Zone 8b: Tulsa, OK	1,486
Zone 9: Fayetteville, AR [13]	1,305

Table G-4: Seasonal Specific Enthalpy by Weather Zone for Duct Sealing

Weather Zone	h_{out} (BTU/lb)	h_{in} (BTU/lb)
Zone 6: El Dorado, AR 11	40	30
Zone 7: Lawton, OK 12	39	29
Zone 8a: Oklahoma City, OK	39	29
Zone 8b: Tulsa, OK	39	29
Zone 9: Fayetteville, AR 13	39	30

Table G-5: Outdoor Air Density by Weather Zone for Duct Sealing

Weather Zone	Temp. (°F) 16	ρout (lb/ft3)
Zone 6: El Dorado, AR	96	0.0739
Zone 7: Lawton, OK	99	0.0738
Zone 8a: Oklahoma City, OK	97	0.0739
Zone 8b: Tulsa, OK	98	0.0738
Zone 9: Fayetteville, AR	94	0.0741

The algorithms for heating (heat pump) and energy saving listed in the OKDSD for duct sealing are as follows:

Equation G-18: Heating Savings (Heat Pump)

$$kWH_{savings,C} = \frac{\left(DL_{pre} - DL_{\boldsymbol{post}}\right) X\ 60\ X\ 0.77\ X\ HDD\ X\ 24\ X\ .018}{1000\ X\ HSPF}$$

[119] Average of US DOE minimum allowed SEER for new air conditioners from 1992-2006 (10 SEER) and after January 23,2006 (13 SEER).

Where:

DL_{pre} = Pre-improvement duct leakage at 25 Pa (ft3/min

DL_{post} = Post-improvement duct leakage at 25 Pa (ft3/min)

60 = Constant to convert from minutes to hours

0.77 = Factor to correlated design load hours to EFLH under actual working conditions (to account for the fact that people do not always operate their heating system when the outside temperature is less than 65°F)

HDD = Heating Degree Day from Table G-6

24 = Constant to convert from days to hours

0.018 = Volumetric heat capacity of air (Btu/ft3°F)

1,000 = Constant to convert from W to kW

HSPF = Heating Seasonal Performance Factor of existing system (Btu/W·hr)

= 7.7 (default)

Table G-6: Heating Degree Days by Weather Zone for Duct Sealing

Weather Zone	HDD
Zone 6: El Dorado, AR 11	2,673
Zone 7: Lawton, OK 12	3,017
Zone 8a: Oklahoma City, OK	3,663
Zone 8b: Tulsa, OK	3,641
Zone 9: Fayetteville, AR 13	4,027

Equation G-19: Heating Savings (Electric Resistance)

$$kWH_{savings,C} = \frac{\left(DL_{pre} - DL_{\boldsymbol{post}}\right) X\ 60\ X\ 0.77\ X\ HDD\ X\ 24\ X\ .018}{3{,}412}$$

Where:

DL_{pre} = Pre-improvement duct leakage at 25 Pa (ft3/min

DL_{post} = Post-improvement duct leakage at 25 Pa (ft3/min)

60 = Constant to convert from minutes to hours

0.77 = Factor to correlated design load hours to EFLH under actual working conditions (to account for the fact that people do not always operated their heating system when the outside temperature is less than 65°F)

HDD = Heating Degree Day from Table G-6

0.018 = Volumetric heat capacity of air (Btu/ft3°F)

3,412 = Constant to convert from Btu to kWh

G.1.2.3 Ceiling Insulation

ADM utilized the AR TRM for the savings algorithms and scaled deemed savings values. Deemed savings provided in the AR TRM are based on the R-value of the baseline insulation. Savings are calculated by multiplying the applicable savings value by the square footage insulated. The savings algorithms require new insulation to meet a minimum R-value of R-38.

Table G-7: Deemed Savings for R-38 Ceiling Insulation

Ceiling Insulation R-38							
Impact per sq. ft.							
Baseline Insulation R-Value	**AC/Gas Heat kWh**	**Gas Heat (No AC) kWh**	**Gas Heat Therms**	**AC/Electric Resistance kWh**	**Heat Pump kWh**	**AC Peak Savings kW**	**Peak Gas Savings Therms**
Zone 9							
0 to 1	1.716	0.254	0.342	9.366	5.071	0.0014	0.00541
2 to 4	0.969	0.141	0.189	5.212	2.764	0.0008	0.00283
5 to 8	0.586	0.084	0.114	3.136	1.653	0.0005	0.00164
9 to 14	0.364	0.052	0.07	1.926	1.013	0.00032	0.001
15 to 22	0.172	0.025	0.034	0.931	0.486	0.00014	0.00047
Zone 8							
0 to 1	1.948	0.227	0.312	9.334	4.669	0.003	0.00539
2 to 4	1.097	0.125	0.172	5.179	2.548	0.002	0.00284
5 to 8	0.642	0.074	0.102	3.145	1.503	0.001	0.00165
9 to 14	0.402	0.044	0.063	1.933	0.933	0.001	0.00099
15 to 22	0.191	0.022	0.031	0.093	0.450	0.000	0.00048
Zone 7							
0 to 1	1.841	0.164	0.233	7.424	3.815	0.002	0.00482
2 to 4	1.027	0.091	0.129	4.117	2.112	0.001	0.00254
5 to 8	0.595	0.053	0.078	2.489	1.245	0.000	0.00149
9 to 14	0.371	0.033	0.047	1.519	0.764	0.000	0.0009
15 to 22	0.178	0.016	0.022	0.728	0.363	0.000	0.00043

Ceiling Insulation R-38							
Impact per sq. ft.							
Baseline Insulation R-Value	AC/Gas Heat kWh	Gas Heat (No AC) kWh	Gas Heat Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW	Peak Gas Savings Therms
Zone 6							
0 to 1	2.213	0.132	0.191	6.761	3.537	0.001	0.0044
2 to 4	1.248	0.074	0.107	3.795	1.991	0.001	0.00235
5 to 8	0.720	0.045	0.065	2.319	1.266	0.000	0.00137
9 to 14	0.448	0.028	0.039	1.427	0.787	0.000	0.00082
15 to 22	0.080	0.004	0.005	0.020	0.121	0.000	0.0004

G.1.2.4 Water Heater Jackets

For water heater jackets, a review of the tracking system showed that conservative assumptions were used to inform the use of the deemed savings. Savings values corresponding to 2" thick jackets on 40-gallon tanks were used for all sites. The deemed savings for this measure depend on 1) insulation thickness and 2) water heater tank size. The table below shows the deemed savings for water heater jackets installed on electric water heaters.

Table G-8: Deemed Savings – Electric Water Heater Jacket

Approximate Tank Size	Electric					
	Energy Savings (kWh)			Peak Savings (kW)		
	40	52	80	40	52	80
2" WHJ savings kWh	68	76	101	0.005	0.006	0.008
3" WHJ savings kWh	94	104	139	0.007	0.008	0.011

G.1.2.5 Water Heater Pipe Insulation

Water heater pipe insulation involves insulating of all hot and cold vertical lengths of pipe, plus the initial length of horizontal hot and cold-water pipe, up to three feet from the transition, or until wall penetration, whichever is less. The OKDSD specifies deemed values below for energy and demand impacts of water heater pipe insulation measures.

Table G-9: Deemed Savings – Electric Water Heater Pipe Insulation

Elec. Water Heater Pipe Insulation		Gas Water Heater Pipe Insulation	
Annual kWh Savings Per home	**Peak kW Savings Per Home**	**Therm Savings Per home**	**Peak Therm Savings Per Home**
44	0.014	4.4	0.00420

G.1.2.6 Low Flow Showerheads

This measure consists of removing existing showerheads and installing low flow showerheads in homes with electric water heating. The deemed savings are per low flow showerhead installed. The newly installed showerheads should not be easily modified to increase the flow rate for the unit to be eligible. The baseline flow rate is 2.5 gallons per minute (gpm) and the efficient showerhead is 1.5 gpm which saves 3,246 gallons of water per year and has a ratio of 0.000104 peak kW demand reduction to annual kWh savings.

ADM used AR TRM 7.0 to determine savings for four weather zones (see Table G-10).

Table G-10: Savings for Low Flow Showerheads (1.5 gpm)[120]

Weather Zone	Average water main temperature (°F)	Mixed water temperature (°F)	Gross kWh savings	Gross Peak kW Demand Savings
9	65.6	103.7	308	0.032
8	66.1	103.9	306	0.032
7	67.8	104.4	296	0.031
6	70.1	105.1	283	0.029

G.1.2.7 Faucet Aerators

This measure involves the retrofit of aerators on kitchen and bathroom water faucets. The deemed savings are per faucet aerator installed. The baseline faucet flow rate is 2.2 gallons per minute (gpm) and the efficient faucet aerators is 1.5 gpm.

The AR TRM 7.0 provides deemed savings for four weather zones (see Table G-11).

[120] AR TRM 7.0 Table 160 and Table 162.

Table G-11: Savings for Faucet Aerators (1.5 gpm)[121]

Weather Zone	Average water main temperature (°F)	Mixed water temperature (°F)	Gross kWh savings	Gross Peak kW Demand Savings
9	65.6	102.0	35	0.004
8	66.1	102.2	34	0.004
7	67.8	102.7	33	0.003
6	70.1	103.5	32	0.003

G.1.2.8 Advanced Power Strips

This measure involves the installation of a 5-plug Advanced Power Strip (APS) that can automatically disconnect related equipment loads (i.e., speakers, video games, Blu-ray, etc.) depending on when the “master” device (i.e., television) is turned off. The baseline condition for this measure is the absence of an APS, where the devices are connected to a traditional power strip or wall outlet.

The AR TRM provides average whole system deemed savings for home office and home entertainment systems. It is most likely that APS will be installed for home entertainment purposes; therefore, ADM will apply the following deemed savings equation that pertains to home entertainment systems using APS. These systems can typically include a television, media player (DVD, Blu-Ray), gaming console (Xbox, PlayStation, Nintendo), and audio equipment. The APS deemed savings are as follows:

$$kWh = 252.2\ kWh$$

$$kW = 0.030\ kW$$

G.1.2.9 ENERGY® STAR Omni-Directional LEDs

ADM will use AR TRM 7.0 to assess savings and demand reduction for the installation of ENERGY STAR® Omni-Directional LEDs (9.5W). The AR TRM v7.0 specifies the following formula for use in calculating energy and demand impacts of ENERGY STAR® Omni-Directional LEDs measures.

Equation G-20: ENERGY® STAR Omni-Directional LED Energy Savings

$$LED\ kWh\ savings\ = \left(\frac{\Delta Watts}{1000}\right) * ISR * Hours * IEF_E$$

[121] AR TRM 7.0 Table 155 and Table 157.

Where:

∆Watts	= Average delta watts for specified measure. The baseline wattage for PY2021 is 43W according to EISA 2007 Baselines. The installed LED lightbulb wattage for PY2021 is 9.5W.
ISR	= In-Service Rate. The percentage of LEDs distributed that are installed within one year of purchase.
	= 0.97 (Table 219 in AR TRM 7.0)
Hours	= Average hours of use per year
	= 365 days in year * Daily usage (hours/day) for residential lamps. ADM has reviewed all well-regarded and recent metering studies and calculated an unweighted average across HOU per lamp across all studies to reduce the possibility of bias. ADM will use a value of 2.63 hours * 365.25 days in year.
	= 960.61 hours
IEFE	= Interactive Effects Factor to account for cooling energy savings and heating energy penalties (Table 220 in AR TRM 7.0).

Equation G-21: ENERGY® STAR Omni-Directional LED Summer Peak Demand Savings

$$LED\ kW_{savings} = \left(\frac{\Delta Watts}{1000}\right) \times CF \times ISR \times IEF_D$$

Where:

CF	= Summer peak coincidence factor for measure, 10% indoor and 0% outdoor (Table 221 in AR TRM v7.0)
IEFD	= Interactive Effects Factor to account for cooling demand savings and heating demand penalties; this factor also applies to outdoor and unconditioned spaces (Table 222 in AR TRM v7.0).

Table G-12: ENERGY STAR® Omni-Directional LED – Interactive Effects Factor, Gross kWh Savings, and Peak kW Demand Reduction[122]

Heating Type	IEF_E	IEF_D	Gross kWh savings	Gross Peak kW Demand Savings
Gas Heat with AC	1.10	1.29	34	0.0042
Gas Heat with no AC	1.00	1.00	31	0.0032
Electric Resistance Heat with AC	0.83	1.29	26	0.0042
Electric Resistance Heat with no AC	0.73	1.00	23	0.0032
Heat Pump	0.96	1.29	30	0.0042
Heating/Cooling Unknown	0.97	1.25	30	0.0041

G.1.2.10 Mobile Home Air Infiltration

The prescriptive like savings were calculated using the AR TRM 7.0. The savings are typically calculated by multiplying the leakage improvement (CFM) by the deemed kWh savings. The deemed kWh savings are dependent on heating and cooling type along with the weather zone.

ADM calculated average savings per square feet (kWh/sq.ft.) to adjust savings for each mobile home while minimizing inputs needed (heat/cool type, weather zone, etc). This allows for the implementer to calculate air infiltration savings by simply gathering the homes' square footage.

The proposed air infiltration algorithms are as follows.

$$kWh = 0.416 \frac{kWh}{sq.ft} \, x \; Homes \; sq.ft.$$

$$kW = 0.00014 \frac{kW}{sq.ft} \, x \; Homes \; sq.ft.$$

Where:

$$0.416 \frac{kWh}{sq.ft} = Average \; savings \; per \; sq.ft., calculated \; as \; follows;$$

$$0.416 \frac{kWh}{sq.ft.} = \frac{Average \; Air \; Infiltration \; Savings}{Average \; Home \; Sq.ft.}$$

$$0.416 \frac{kWh}{sq.ft} = \frac{544 \; kWh}{1{,}307 \; sq.ft.}$$

$$Homes \; sq.ft. = Square \; footage \; of \; home \; being \; serviced \; by \; non \; profit$$

[122] AR TRM 7.0 Table 220 and Table 222.

G.1.3 Energy Saving Products Program

This section includes the measure level algorithms and deemed savings values utilized for the verified gross kWh and kW savings calculations. Deemed savings values and guidelines from the OKDSD were used whenever applicable.[123] When deemed savings calculations were not available in the OKDSD, ADM relied on one of the following other technical reference manuals (TRMs): AR TRM, the Illinois TRM v7.0 (IL TRM)[124], the Texas TRM v6.0 (TX TRM)[125], or the 2016 Pennsylvania TRM (PA TRM).[126]

G.1.3.1 ENERGY STAR® LEDs

ADM checked LED model numbers listed in the program tracking system against ENERGY STAR® databases (www.energystar.gov) to verify that each LED distributed during each program year was (1) ENERGY STAR® certified and (2) assigned the correct Watts per lamp.

Deemed kWh savings values for LEDs are unavailable in the OKDSD. However, the baseline wattages from the OKDSD account for Energy Independence and Security Act (EISA) requirements that took effect in 2012, 2013, and 2014. Thus, kWh savings for LEDs were calculated via Equation G-20 above.

Peak demand savings for LEDs discounted through the program were also calculated using the algorithm from the OKDSD, shown in Equation G-21 above.

Point-of-Sale Measure Leakage

Programs that provide incentives at the point-of-sale can result in installations outside of the territory of the sponsoring utility. This effect, referred to as “leakage”, can be particularly prominent when a service territory is not geographically contiguous, or when a major retailer is located near the border of a service territory. When leakage takes place, bulbs that have been discounted through a utility’s program are installed outside of its service territory and therefore the energy and demand impacts from the discounted bulbs are not realized within the territory of the utility that financially supported and claimed the savings.

For PY2019-2021, ADM utilized the AR TRM Protocol K: Leakage guidelines for assessing the impact of leakage on the Energy Saving Products program’s savings. This protocol was developed based on Arkansas Public Service Commission guidance as to how to quantify and apply the effects of leakage. Estimates of leakage were assessed

[123] Residential Oklahoma Deemed Savings, Installation & Efficiency Standards, *prepared by* Frontier Associates, LLC; November 27, 2013.
[124] Illinois Statewide Technical Reference Manual for Energy Efficiency, version 7.0 volume 3: Residential Measures, September 28, 2018.
[125] Texas Technical Reference Manual, version 6.0 volume 2: Residential Measures, November 7, 2018.
[126] Pennsylvania Technical Reference Manual, June 2016.

using an approach that combines general population survey responses with geo-spatial mapping. Overall, the analysis was built around the following steps:

- First, ADM developed a map of concentric circles surrounding the participating retailers. The initial modeling assumed the “reach” of a retailer is a 60-minute drive, which is then modified by the presence of an alternative sponsoring retailer (i.e., if a customer is within a 60-minute drive of two sponsoring retailers, it is assume they will purchase from the closest one). This allowed for an initial leakage score to be applied to each participating retail location based upon the percent of customers within the concentric circle that are served by the sponsoring utility.
- Second, several relevant questions were integrated into the general population survey to assess the shopping habits of customers within the radius of participating retailers. This was used to assess the total and maximum drive time that Oklahoma consumers would accept when shopping for products incentivized by the Program. Additionally, the survey was used to modify the initial 60-minute drive assumption established in Step 1.
- Finally, the percentage of LEDs that “leaked” out of the PSO territory and were installed out of state was calculated.

Ultimately, ADM estimated that out-of-state leakage of LEDs is approximately 0.2%. The complete findings can be found in a separate report entitled “*2019 Lighting Sales Leakage Memo*”. The leakage estimate developed during PY2019 will be used throughout the PY2019-PY2021 program evaluation cycle. The decision to use the leakage estimate from PY2019 throughout the portfolio cycle is reliable since the lighting program is unlikely to change significantly over that time frame. Any substantial changes to the program will be reviewed on an annual basis.

Cross Sector Sales Adjustments

ADM used an estimated HOU equal to 960.61 based on a meta-analysis completed in PY2016. This reflects an average daily HOU of 2.63 blended hours for indoor/outdoor applications and applies a 0.688 degradation factor to indoor bulbs times 365.25 days per year. While this is within the range of HOU estimates from previous studies of residential lighting use, it likely underestimates HOU for bulbs that are installed in non-residential buildings. In non-residential settings, annual HOU is higher and implies a shorter expected useful life for the bulbs (in years). The period in which the savings occur affects the applicable baseline wattage and discount factor for cost effectiveness savings. ADM calculated a peak coincidence factor (CF) and HOU for bulbs installed in non-residential settings based on the type of businesses where LEDs were installed from the Business Rebates Program during each program year. A weighted average for CF and HOU was calculated. Responses from the general population surveys were used to estimate the percentage of purchased bulbs that were installed in non-residential settings. This has the effect of increasing annual energy savings and peak demand reduction for the percentage of bulbs estimated to be installed in non-residential settings. Lifetime energy savings for these bulbs also increases to the extent that the savings occur sooner, before EISA Tier 2 baselines become effective.

G.1.3.2 Room Air Purifiers (RAP)

ADM checked room air purifier (RAP) model numbers listed in the program tracking system against ENERGY STAR® databases to verify that each RAP distributed through the program each year was ENERGY STAR® certified and assigned the correct capacity and efficiency ratings.

Deemed kWh savings values for RAPs are unavailable in the OKDSD; however, the IL TRM has established deemed kWh savings and peak kW demand values that were used for this analysis.[127] Thus, kWh energy savings for RAPs were calculated via Equation G-22, below.

Equation G-22: Energy Savings (Room Air Purifiers)

$$Room\ Air\ Purifier\ kWh\ savings\ = kWh_{Base} - kWh_{ESTAR}$$

Where:

kWh_{Base} = Baseline kWh consumption per year; based on Table G-13 below

kWh_{ESTAR} = ENERGY STAR® kWh consumption per year; based on Table G-13 below

Table G-13: kWh per Year Usage Based on Clear Air Delivery Rate[128]

Clean Air Delivery Rate (CADR)	CADR used in calculation	Baseline Unit Energy Consumption (kWh/year)	ENERGY STAR® Unit Energy Consumption (kWh/year)	ΔkWH
CADR 51-100	75	441	148	293
CADR 101-150	125	733	245	488
CADR 151-200	175	1,025	342	683
CADR 201-250	225	1,317	440	877
CADR Over 250	300	1,755	586	1,169

The peak demand (kW) savings for RAPs was calculated via Equation G-23, shown below:

[127] Calculation for kWh savings and peak kW demand are based on the Mid-Atlantic TRM version 4.0. This specifies baseline kWh/year consumption and ENERGY STAR® kWh/year consumption based on the Clean Air Delivery Rate (CADR) for ENERGY STAR® room air purifier.
[128] Reproduced after lookup table on pg. 7 of the IL TRM.

Equation G-23: Peak Demand Savings (Room Air Purifiers)

$$Room\ Air\ Purifier\ peak\ kW\ demand = \frac{\Delta kWh}{Hours} * CF$$

Where:

ΔkWh =Gross customer annual kWh savings for the measure

$Hours$ = Average hours of use per year

= 5844[129]

CF = Summer Peak Coincidence Factor for measure

= 0.667[130]

Table G-14: Peak kW Demand Based on Clear Air Delivery Rate

Clean Air Delivery Rate	ΔkW
CADR 51-100	0.034
CADR 101-150	0.056
CADR 151-200	0.078
CADR 201-250	0.100
CADR Over 250	0.133

G.1.3.3 Advanced Power Strips (APS)

ADM verified that each advanced power strip (APS) distributed each year was correctly assigned to the appropriate tier in the tracking system.

Energy savings (kWh) values for APS are not available in the OKDSD; however, deemed savings are described in the AR TRM. APSs are separated into two classifications: Tier 1 and Tier 2; only Tier 1 APSs are discounted through the ESP Program. Tier 1 APS are controlled by a load sensor in the strip, which disconnects power from the control outlets when the master power draw is below a certain threshold. The load sensor feature allows for a reduction of power from peripheral consumer electronics that maintain some load even when off or in the standby position. Deemed savings were calculated for Tier 1 by average complete system as the type of installation was unknown. Additionally, an ISR adjustment was applied to the deemed APS gross savings. The reason for the adjustment is that most people do not install and utilize APS correctly, particularly as an upstream measure. Therefore, ADM relied on an estimated ISR of 50%.

[129] Consistent with ENERGY STAR® Qualified Room Air Clean Calculator; 16 hours a day, 365.25 days a year. As stipulated in the IL TRM, see footnote 7 on pg. 7 of the TRM.
[130] Assumes appliance use is evenly spread throughout the year. As stipulated in the IL TRM, see footnote 8 on pg. 7 of the TRM.

Table G-15: Advanced Power Strip – Deemed Savings in Residential Applications

APS Type	System Type	Peripheral Device	kW Savings	kWh Savings
Tier 1	Average	Whole System Average	0.019	167.40

G.1.3.4 Bathroom Ventilation Fans (BVF)

ADM checked bathroom ventilation fan (BVF) model numbers listed in the program tracking system against the ENERGY STAR® databases to verify that each BVF distributed via the program each year was ENERGY STAR® certified.

Since deemed energy savings (kWh) values for BVFs are unavailable in the OKDSD, ADM referred to equations provided by the IL TRM. The energy (kWh) savings for BVFs was calculated via the following formula and is set at 27.4 kWh:

Equation G-24: Energy Savings (BVF)

$$BVF\ kWhsavings = CFM\ \times \frac{\frac{1}{\eta_{Baseline}} - \frac{1}{\eta_{Efficient}}}{1000} \times\ Hours = 27.4\ kWh$$

Where:

CFM = Nominal Capacity of the exhaust fan

= 92.4[131]

$\eta_{Baseline}$ = Average efficacy for baseline fan

= 2.2[132]

$\eta_{Efficient}$ = Average efficacy for efficient fan

= 5.3[133]

$Hours$ = Assumed annual run hours for continuous ventilation

= 1,089[134]

Demand savings (kW) were calculated via the following formula, and is set at 0.0034 kW:

[131] As stipulated by the IL TRM for standard usage with an unknown minimum and maximum CFM, see pg. 125 of the TRM.
[132] As stipulated by the IL TRM for standard usage with an unknown minimum and maximum CFM, see pg. 125 of the TRM.
[133] As stipulated by the IL TRM for standard usage with an unknown minimum and maximum CFM, see pg. 125 of the TRM.
[134] As stipulated by the IL TRM for standard usage with an unknown minimum and maximum CFM, see pg. 125 of the TRM.

Equation G-25: Peak Demand Savings (Ventilation Fan)

$$BVF\ kWsavings = CFM\ \times \frac{\frac{1}{\eta_{Baseline}} - \frac{1}{\eta_{Efficient}}}{1000} \times CF = \ 0.0034\ \mathrm{kW}$$

Where:

CFM = Nominal Capacity of the exhaust fan

= 92.4[135]

$\eta_{Baseline}$ = Average efficacy for baseline fan

= 2.2[136]

$\eta_{Efficient}$ = Average efficacy for efficient

= 5.3[137]

CF = Summer peak coincidence factor for standard usage

= 0.135[138]

G.1.3.5 Water Dispensers (WD)

ADM checked water dispenser (WD) model numbers listed in the program tracking system against the ENERGY STAR® databases to verify that each WD distributed via the program each year was ENERGY STAR® certified.

Deemed savings values for WDs are unavailable in the OKDSD, so the PA TRM was used. The energy savings (kWh) and demand savings (kW) were pulled from Table G-16.

Table G-16: Default Savings for ENERGY STAR® Water Dispensers[139]

Cooler Type	$kWh_{savings}$	kW_{peak}
Cold Only	47.50	0.00532
Hot & Cold Storage	481.80	0.0539
Hot & Cold On-Demand	733.65	0.0821

[135] As stipulated by the IL TRM for standard usage with an unknown minimum and maximum CFM, see pg. 125 of the TRM.
[136] As stipulated by the IL TRM for standard usage with an unknown minimum and maximum CFM, see pg. 125 of the TRM.
[137] As stipulated by the IL TRM for standard usage with an unknown minimum and maximum CFM, see pg. 125 of the TRM.
[138] As stipulated by the IL TRM for standard usage with an unknown minimum and maximum CFM, see pg. 125 of the TRM.
[139] Reproduced after Table 2-95, pg. 165 of the PA TRM.

G.1.3.6 Weatherization Measures (WM)

ADM reviewed all tracking data, tabulating all home weatherization measures (WM) installed via the program each year. Savings from the installation of WMs were calculated based on the PA TRM's Interim Measure Protocol for WS.[140] Energy savings (kWh) and demand savings (kW) were calculated for WMs including door seals, door sweeps, and spray foam insulation using the following equations:

Equation G-26: Energy Savings (WM)

$$WM\ kWh\ savings\ = \mathrm{D}kWh_{cooling} + \mathrm{D}kWh_{heating}$$

Equation G-27: Cooling Energy Savings (WM)

$$\mathrm{D}kWh_{cooling} = \frac{1.08 \times \mathrm{D}CFM_{50} \quad \times CDD \times 24 \times LM \times DUA}{N \times \eta_{cool} \times 1{,}000}$$

Equation G-28: Heating Energy Savings (WM)

$$DkWh_{heating} = \frac{1.08 \times DCFM_{50} \times HDD \times 24}{N \times \eta_{heat} \times 3{,}412}$$

Equation G-29: Peak Demand Savings (WM)

$$WM\ kW\ savings = \frac{\mathrm{D}kWh_{cooling} \times PCF}{1{,}000}$$

Where:

1.08 = Conversion factor between CFM air at 70°F to Btu/hr/°F

$\mathrm{D}CFM_{50}$ = Reduction in air leakage

= 100 (spray foam) or 25.5 (door sweeps and seals)[141]

24 = Days to hours conversion factor

N = Correlation factor (accounts for several variables that could influence air infiltration, such as wind shielding, climate, and building leakiness)

= 16.65[142]

CDD = Cooling degree-days per year

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[140] Addendum document to the 2016 Pennsylvania TRM[126] for weather stripping, caulking, and outlet gaskets.

[141] As stipulated by the PA TRM Weather Stripping IMP, see Table 1-2, pg. 4 of the IMP. For spray foam, this estimate assumes just over 9 piping/plumbing/wiring penetrations per can.

[142] As stipulated by the PA TRM Weather Stripping IMP, see Table 1-1, pg. 3 of the IMP.

= 2,095 [143]

HDD = Heating degree-days per year

= 3,971[144]

η_{cool} = Cooling system efficiency

= 13[145]

η_{heat} = Heating system efficiency

= 2.3[146]

DUA = Discretionary use adjustment (accounts for uncertainty in residential occupants' cooling system usage patterns)

= 0.75[147]

LM = Latent multiplier for conversion of sensible load to total (sensible and latent) load

= Total load ÷ sensible load = 8.5 ÷ 2.0 = 4.3[148]

$1{,}000$ = Conversion factor between kilowatts and watts

$3{,}412$ = Conversion factor between kilowatt hours and Btu

PCF = Peak demand savings conversion factor

= 0.017[149]

G.1.3.7 Room Air Conditioners (RAC)

ADM will check room air conditioner (RAC) model numbers listed in the program tracking system against the ENERGY STAR® databases to verify that each RAC distributed via the program each year was ENERGY STAR® certified.

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143 Average cooling degrees per year derived for the Tulsa International Airport (site #723560) from the National Solar Radiation Data Base, 1991-2005: Typical Meteorological Year 3. Last accessed March 2020 via https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html.

144 Average heating degrees per year derived for the Tulsa International Airport (site #723560) from the National Solar Radiation Data Base, 1991-2005: Typical Meteorological Year 3. Last accessed March 2020 via https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html.

145 Assuming central air conditioning installed after 1/23/2006 – see Table 1-4 on pg. 5 of the PA TRM Weather Stripping IMP.

146 Assuming air-source heat pumps installed after 1/23/2006 – see Table 1-5 on pg. 5 of the PA TRM Weather Stripping IMP.

147 As stipulated by the PA TRM Weather Stripping IMP, see Table 1-1, pg. 3 of the IMP.

148 For Tulsa, OK; *see* Table 2 *in* Harriman III, L. G., Plager, D., and Kosar, D. (1997) Dehumidification and Cooling Loads from Ventilation Air. *ASHRAE Journal*.

149 As stipulated by the PA TRM Weather Stripping IMP, see Table 1-1, pg. 3 of the IMP.

Deemed savings values for RAC are not available in the OKDSD, so the AR TRM was used. The energy savings (kWh) and peak demand savings (kW) for RAC were calculated via Equation G-30 and Equation G-31, respectively.

Equation G-30: Energy Savings (RAC)

$$RAC\ kWhsavings = CAP\ \times 1\frac{kW}{1000\ W} \times RAF\ \times EFLH_C\ \times (\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}})$$

Equation G-31: Peak Demand Savings (RAC)

$$RAC\ kW\ savings = CAP\ \times 1\frac{kW}{1000\ W} \times \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{post}}\right) \times CF$$

Where:

CAP = Rated equipment cooling capacity of the new unit (Btu/hr)

η_{base} = Energy efficiency rating (EER) of the baseline cooling equipment, *see* Table G-17

η_{post} = Energy efficiency rating (EER) of the installed cooling equipment, see Table G-17

RAF = Room AC adjustment factor

= 0.49[150]

$EFLH_C$ = Equivalent full-load cooling hours, see Table G-18.

CF = Coincidence factor

= 0.87[151]

The η_{base} or energy efficiency rating (EER) of the baseline and η_{post} or energy efficiency rating (EER) of the installed cooling equipment is assigned based on the items listed in Table G-17.

Table G-17: RAC Replacement – Baseline and Efficiency Standards152

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr)	Baseline Efficiency (CEER)	Efficiency Standard (EER)
No	Yes	< 8,000	11.0	12.1
		≥ 8,000 and < 14,000	10.9	12.0
		≥ 14,000 and < 20,000	10.7	11.8
		≥ 20,000	9.4	10.3

150 As stipulated by the AR TRM, see derivation described in Table 67, pg. 75 of the TRM.
151 As stipulated by the AR TRM, see pg. 74 and footnote 80 in the TRM.
152 Reproduced after Table 65, pg. 73 of the AR TRM.

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr)	Baseline Efficiency (CEER)	Efficiency Standard (EER)
No	No	< 8,000	10.0	11.0
		≥ 8,000	9.6	10.6
Yes	Yes	< 20,000	9.8	10.8
		≥ 20,000	9.3	10.2
Yes	No	< 14,000	9.3	10.2
		≥ 14,000	8.7	9.6

The equivalent full-load cooling hours are based on weather zone as shown below in Table G-18. Since full-load cooling hours are reported in the OKDSD, ADM will use those locally applicable values instead of those listed in the AR TRM.

Table G-18: RAC Replacement – Equivalent Full-Load Cooling Hours[153]

Weather Zone	$EFLH_C$
9	431
8b	490
7	555
6	573

G.1.3.8 Air Filters (AF)

Deemed savings values for air filters (AF) are not available in the OKDSD, so the TX TRM was used. The energy savings (kWh) and peak demand savings (kW) for AF were calculated via Equation G-32 and Equation G-33, respectively.

Equation G-32: Energy Savings (AF)

$$AF\ kWh\ savings = Capacity \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times\ EFLH_C\ \times\ \frac{1\ kW}{1{,}000\ W} \times FL$$

Equation G-33: Peak Demand Savings (AF)

$$AF\ kW\ savings = Capacity \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times\ DF_C\ \times\ \frac{1\ kW}{1{,}000\ W}$$

Where:

Capacity = Rated equipment cooling capacity

[153] Reproduced after Table 61, pg. 64 of the OKDSD; values shown are pertinent to room air conditioners.

= for unknown models, assumed value of 3.7 tons[154]

= 44,400 Btu/hr

$\mathrm{EER_{pre}}$ = Cooling efficiency prior to tune-up (Btu/hr)

= $(1 - \mathrm{EL}) \times \mathrm{EER_{post}}$

EL = Efficiency loss due to dirty filter

= 0.05[155]

$\mathrm{EER_{post}}$ = Deemed cooling efficiency of the equipment following tune-up

= 11.2[156]

$\mathrm{EFLH_C}$ = Equivalent full load hours for cooling based on weather zone (see *Table G-19)*

$\mathrm{DF_C}$ = Cooling demand factor

= 0.87[157]

FL = Factor to account for air filter useful life

= 0.16667

Table G-19: Equivalent Full Load Hours[158]

Weather Zone	$EFLH_C$
6	1,738
7	1,681
8a	1,436
8b	1,486
9	1,305

G.1.3.9 Heat Pump Water Heaters (HPWH)

ADM checked heat pump water heater (HPWH) model numbers listed in the program tracking system against ENERGY STAR® databases to verify that each HPWH distributed via the program each year was ENERGY STAR® certified and assigned the correct capacity and efficiency ratings.

Deemed energy savings (kWh) values for HPWHs are not available in the OKDSD, so instead ADM has relied on the AR TRM. The variables that affect deemed savings include

[154] As stipulated by the TX TRM, pg. 2-345.
[155] As stipulated by the TX TRM, pg. 2-58.
[156] As stipulated by the TX TRM, pg. 2-58 and 2-60.
[157] As stipulated by the TX TRM, see footnote 122 on pg. 2-61 of the TRM.
[158] Reproduced after Table 61 of the OKDSD, pg. 64.

storage tank volume, energy factor (EF), installation location (conditioned vs. unconditioned space), and weather zone. Weather zones are based on established zones in Arkansas. Energy savings (kWh) for HPWHs were calculated via Equation G-34:

Equation G-34: Energy Savings (HPWH)

$$HPWH\ kWh\ savings = \frac{\rho \times C_p \times V \times (T_{SetPoint} - T_{Supply}) \times \left(\frac{1}{EF_{pre}} - \left(\frac{1}{\left(EF_{post} \times (1 + PA\%)\right)} \times Adj\right)\right)}{3{,}412\ Btu/kWh}$$

Where:

ρ = Water density

= 8.33

C_p = Specific heat of water (Btu/lb·°F)

= 1

V = Estimated annual hot water use (gal) (shown in Table G-21 below)

$T_{SetPoint}$ = Water heater set point

= 120°F[159]

T_{Supply} = Average supply water temperature, determined based on storage volume and draw pattern[160] (shown in Table G-22 below)

EF_{pre} = Baseline energy factor, determined based on storage volume and draw pattern[161]

EF_{post} = Energy Factor of new HPWH

$PA\%$ = Performance adjustment to account for ambient air temperature per DOE guidance

= $0.00008 \times T_{amb}^3 + 0.0011 \times T_{amb}^2 - 0.4833 \times T_{amb} + 0.0857$[162]

T_{amb} = Ambient temperature dependent on location of HPWH (Conditioned or Unconditioned Space) and Weather Zone.

Adj = HPWH-specific adjustment factor to account for Cooling Bonus and Heating Penalty on an annual basis, as well as backup electrical resistance

[159] As stipulated by the AR TRM, pg. 128.
[160] As stipulated by look up Table 138, pg. 122-123 of the AR TRM.
[161] As stipulated by look up Table 138, pg. 122-123 of the AR TRM.
[162] As stipulated by the AR TRM, pg. 128.

heating which is estimated at 0.92 EF. Adjustment factors are listed in Table G-25 below.

Table G-20: Arkansas Weather Zone Equivalents, by County, in Oklahoma

Weather Zone	Counties Included
9	Alfalfa, Craig, Dewey, Ellis, Grant, Harper, Kay, Major, Nowata, Ottawa, Roger Mills, Rogers, Washington, Woods, Woodward
8	Adair, Beckham, Blaine, Caddo, Canadian, Cherokee, Creek, Custer, Delaware, Garfield, Kingfisher, Logan, Mayes, Noble, Oklahoma, Okmulgee, Osage, Pawnee, Payne, Tulsa, Wagoner, Washita
7	Atoka, Bryan, Cleveland, Coal, Comanche, Cotton, Garvin, Grady, Greer, Harmon, Haskell, Hughes, Jackson, Kiowa, Latimer, Le Flore, Lincoln, McClain, McCurtain, McIntosh, Murray, Muskogee, Okfuskee, Pittsburg, Pontotoc, Pottawatomie, Seminole, Sequoyah, Stephens, Tillman
6	Carter, Choctaw, Jefferson, Johnson, Love, Marshall, Pushmataha

Table G-21: Estimated Annual Hot Water Use (gal)[163]

Weather Zone	Tank Size (gal) of Replaced Water Heater			
	40	50	65	80
9 Fayetteville	18,401	20,911	25,093	30,111
8 Fort Smith	18,331	20,831	24,997	29,996
7 Little Rock	18,267	20,758	24,910	29,892
6 El Dorado	17,815	20,245	24,293	29,152

Table G-22: Average Water Main Temperature[164]

Weather Zone	Average Water Main Temperature (°F)
9 Fayetteville	65.6
8 Fort Smith	66.1
7 Little Rock	67.8
6 El Dorado	70.1

Table G-23: Water Heater Replacement Baseline Energy Factors (Calculated)

Minimum Required Energy Factors by NAECA After 4/16/2015				
Fuel Type	40	50	65	80
Natural Gas or Propane	0.62	0.6	0.75	0.74
Electric	0.95	0.95	1.98	1.97

[163] Reproduced after Table 142, pg. 125 of the AR TRM.
[164] Reproduced after Table 143, pg. 126 of the AR TRM.

Table G-24: Average Ambient Temperatures (T_{amb}) by Installation Location[165]

Weather Zone	Conditioned Space	Unconditioned Space
9 Fayetteville	72.2	69.1
8 Fort Smith	73.4	69.4
7 Little Rock	73.4	71.1
6 El Dorado	72.9	73.3

Table G-25: HPWH Adjustment[166]

Weather Zone 9 Fayetteville					
Water Heater Location	***Furnace Type***	***40***	***50***	***65***	***80***
Conditioned Space	Gas	1.02	1.02	1.03	1.04
	Heat Pump	1.46	1.42	1.37	1.33
	Elec.Resistance	2.04	1.94	1.82	1.71
Unconditioned Space	N/A	1.06	1.06	1.06	1.06
Weather Zone 8 Fort Smith					
Water Heater Location	***Furnace Type***	***40***	***50***	***65***	***80***
Conditioned Space	Gas	1.02	1.03	1.03	1.04
	Heat Pump	1.43	1.39	1.35	1.31
	Elec.Resistance	1.95	1.86	1.75	1.66
Unconditioned Space	N/A	1.06	1.06	1.06	1.06
Weather Zone 7 Little Rock					
Water Heater Location	***Furnace Type***	***40***	***50***	***65***	***80***
Conditioned Space	Gas	0.99	1.00	1.01	1.02
	Heat Pump	1.41	1.38	1.34	1.30
	Elec.Resistance	1.96	1.87	1.76	1.66
Unconditioned Space	N/A	1.07	1.07	1.07	1.07
Weather Zone 6 El Dorado					
Water Heater Location	***Furnace Type***	***40***	***50***	***65***	***80***
Conditioned Space	Gas	0.95	0.96	0.98	0.99
	Heat Pump	1.34	1.31	1.28	1.25
	Elec.Resistance	1.84	1.76	1.66	1.58
Unconditioned Space	N/A	1.07	1.07	1.07	1.07

Demand savings (kW) for HPWH were calculated via the following formula:

[165] Reproduced after Table 144, pg. 128 of the AR TRM.
[166] Reproduced after Table 145, pg. 129 of the AR TRM.

Equation G-35: Peak Demand Savings (HPWH)

$$kWsavings = kWh_{savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

Where:

$\mathrm{Ratio}_{\mathrm{Annual\ kWh}}^{\mathrm{Peak\ kW}}$ = 0.0000877[167]

G.1.3.10 Clothes Dryers (CD)

ADM checked clothes dryer (CD) model numbers listed in the program tracking system against the ENERGY STAR® databases to verify that each CD distributed via the program each year was ENERGY STAR® certified and assigned the correct type of dryer type (standard or compact) and the product class.

Deemed energy savings (kWh) values for CDs are unavailable in the OKDSD, so the IL TRM was used. The kWh savings for clothes dryers (CD) were calculated via the following formula:

Equation G-36: Energy Savings (CD)

$$CD\ kWhsavings = \left(\frac{Load}{CEF_{base}} - \frac{Load}{CEF_{eff}}\right) \times N_{cycles} \times \%Electric$$

Where:

$Load$ = The average total weight of clothes per drying cycle (lbs)

= 8.45 (standard CD) or 3 (compact CD)[168]

$\mathrm{CEF}_{\mathrm{base}}$ = Combined energy factor (CEF) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR® analysis.

Table G-26: Combined Energy Factor$_{base}$ by Product Class[169]

Product Class	CEF (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft3)	3.11
Vented Electric, Compact (120 V) (<4.4 ft3)	3.01
Vented Electric, Compact (=240 V) (<4.4 ft3)	2.73
Ventless Electric, Compact (=240 V) (<4.4 ft3)	2.13
Vented Gas	2.84

[167] As stipulated by the AR TRM, pg. 130.
[168] As stipulated by the IL TRM, see pg. 46 and footnote 115 of the TRM.
[169] Reproduced after CEF_{base} look up table on pg. 46 of the IL TRM.

CEF_{eff} = Combined energy factor of the ENERGY STAR® unit based on ENERGY STAR® requirements. Examples are shown below, though actual values will be taken from ENERGY STAR® for each model.

Table G-27: Combined Energy Factor$_{eff}$ by Product Class[9]

Product Class	CEF (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft3)	3.93
Vented Electric, Compact (120 V) (<4.4 ft3)	3.80
Vented Electric, Compact (=240 V) (<4.4 ft3)	3.45
Ventless Electric, Compact (=240 V) (<4.4 ft3)	2.68
Vented Gas	3.48

N_{cycles} = Number of dryer cycles per year

= 283[170]

$\%Electric$ = The percent of overall savings coming from electricity

= 100% (electric dryers) or 16% (gas dryers)[171]

Demand savings were calculated via the following formula:

Equation G-37: Peak Demand Savings (CD)

$$CD\ kWsavings = \frac{kWh_{savings}}{Hours} \times CF$$

Where:

$Hours$ = Annual run hours of clothes dryer

= 283[172]

CF = Summer peak coincidence factor

=0.038[173]

G.1.3.11 Clothes Washers (CW)

ADM checked clothes washer (CW) model numbers listed in the program tracking system against the ENERGY STAR® databases to verify that each CW distributed via the program each year was ENERGY STAR® certified.

Deemed savings values from the AR TRM will be used for CWs as savings values for this measure are not provided in the OKDSD. The energy savings (kWh) and demand savings

170 As stipulated by the IL TRM, see pg. 46 and footnote 120 of the TRM.
171 As stipulated by the IL TRM, see pg. 47 and footnote 121 of the TRM.
172 As stipulated by the IL TRM, see pg. 47 and footnote 122 of the TRM.
173 As stipulated by the IL TRM, see pg. 47 and footnote 123 of the TRM.

(kW) will be estimated for retrofit and new construction applications based on *Table G-28* Since some configurations produce 0 kWh savings, ADM computed a weighted average savings value for clothes washers and applied that single value to all clothes washers rebated through the program.

Table G-28: ENERGY STAR® Clothes Washer – Deemed Savings in Retrofit or New Construction Applications[174]

Application	Baseline Configuration	Efficient Configuration	Water Heater Fuel Type	Dryer Fuel Type	kWh Savings	kW Savings
Retrofit	Top Loading	Top Loading	Gas	Gas	23	0.005
			Gas	Electric	192	0.045
			Electric	Gas	114	0.027
			Electric	Electric	282	0.067
	Top Loading	Front Loading	Gas	Gas	38	0.009
			Gas	Electric	198	0.047
			Electric	Gas	191	0.045
			Electric	Electric	351	0.083
	Front Loading	Front Loading	Gas	Gas	6	0.002
			Gas	Electric	93	0.022
			Electric	Gas	32	0.008
			Electric	Electric	119	0.028
	Front Loading	Top Loading	Gas	Gas	0	0.000
			Gas	Electric	87	0.021
			Electric	Gas	0	0.000
			Electric	Electric	50	0.012
New Construction	Top Loading	Top Loading	Gas	Gas	23	0.005
			Gas	Electric	192	0.045
			Electric	Gas	114	0.027
			Electric	Electric	282	0.067
	Top Loading	Front Loading	Gas	Gas	38	0.009
			Gas	Electric	198	0.047
			Electric	Gas	191	0.045
			Electric	Electric	351	0.083

[174] Reproduced after Tables 172 and 173, pg. 167 of the AR TRM with additional entries calculated via savings equations provided in the TRM.

G.1.3.12 Refrigerators (RF)

Deemed savings values from the AR TRM were used for RFs. The energy savings (kWh) for "replace-on-burnout" RFs was calculated using Equation G-38.

Equation G-38: Energy Savings for Replace-On-Burnout (RF)

$$RF_{ROB}\ kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Where:

$kWh_{baseline}$ = Federal standard baseline average energy usage, *Table G-29*

kWh_{ES} = ENERGY STAR® average energy usage, *Table G-29*

For RFs that are considered "early retirement" replacements, i.e., units that replaced working RFs, the energy (kWh) and demand (kW) savings must be calculated separately for two time periods: (1) the estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL); and (2) the remaining time in the EUL period. For the RUL, kWh savings were calculated via Equation G-39. For the remaining time in the EUL period, the annual savings were calculated as would be done for replace-on-burnout as shown above. Peak demand savings (kW) were calculated via Equation G-40.

Equation G-39: Energy Savings for RUL (RF)

$$RF\ kWhsavings_{ER} = (kWh_{manf} \times (1 + PDF)^{n} \times SLF) - kWh_{ES}$$

Equation G-40: Peak Demand Savings (RF)

$$RF\ kW\ savings = \frac{kWh_{savings}}{8{,}760\ hrs} \times TAF \times LSAF$$

Where:

kWh_{manf} = Annual unit energy consumption from the Association of Home Appliance Manufacturers (AHAM) refrigerator database[175]

PDF = Performance degradation factor

= 0.0125 per year[176]

n = Age of replaced refrigerator (years)

SLF = Site/Lab Factor

= 0.81[177]

TAF = Temperature adjustment factor

[175] As stipulated by the AR TRM, see pg. 179 and footnote 240 in the TRM.
[176] As stipulated by the AR TRM, see pg. 179 and footnote 241 in the TRM.
[177] As stipulated by the AR TRM, see pg. 179 and footnote 242 in the TRM.

= 1.188[178]

$LSAF$ = Load shape adjustment factor

= 1.074[179]

Table G-29: Example Formulas to Calculate the ENERGY STAR® Criteria for Each Refrigerator Product Category by Adjusted Volume[180]

Measure Category	Federal Standard Baseline Energy Usage (kWh/year)	ENERGY STAR® Average Energy Usage (kWh/year)
Refrigerator-only—manual defrost	6.79 × AV + 193.6	6.111 × AV + 174.24
Refrigerator-freezers—manual or partial automatic defrost	7.99 × AV + 225.0	7.191 × AV + 202.5
Refrigerator-only—automatic defrost	7.07 × AV + 201.6	6.363 × AV + 181.44
Built-in refrigerator-only—automatic defrost	8.02 × AV + 228.5	7.218 × AV + 205.65
Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85 × AV + 317.0	7.965 × AV + 285.3
Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	9.40 × AV + 336.9	8.46 × AV + 378.81
Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	8.85 × AV + 401.0	7.965 × AV + 360.9
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	10.22 × AV + 357.4	9.198 × AV + 321.66
Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	8.51 × AV + 381.8	7.659 × AV + 343.62
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	10.22 × AV + 441.4	9.198 × AV + 397.26
Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	8.54 × AV + 432.8	7.686 × AV + 389.52
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	10.25 × AV + 502.6	9.225 × AV + 452.34
Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	8.07 × AV + 233.7	7.263 × AV + 210.33

178 As stipulated by the AR TRM, see pg. 180 and footnote 244 in the TRM.
179 As stipulated by the AR TRM, see pg. 180 and footnote 245 in the TRM.
180 Reproduced, in part, after Table 177 on pg. 176-177 of the AR TRM.

G.1.3.13 Electric Vehicle Chargers (EVC)

ADM reviewed all tracking data to ensure that all Level 2 electric vehicles rebated via the program each year were ENERGY STAR® certified. Since there are no established deemed savings calculations for Level 2 electric vehicle chargers in the OKDSD, ADM developed a well-researched approach to estimate energy savings (kWh) for this measure (no appreciable demand savings (kW) were recorded). For each unit rebated through the program, energy savings was calculated using *Equation G-41*.

Equation G-41: Energy Savings (EVC)

$$EVC\ kWh\ savings = VMT_{OK} * \ avgMPG_e * \left(\frac{1}{EER_{base}} - \frac{1}{EER_{efficient}}\right) + ES_{gain}$$

Where:

VMT_{OK} = Vehicle miles traveled per year for Oklahoma residents

= 14,382[181]

$avgMPG_e$ = Average MPG_e (kWh/100 miles) of electric vehicles currently on the market

= 32[182]

EER_{base} = Energy efficiency rating of the base technology (Level 1 EVC)

= 0.822[183]

$EER_{efficient}$ = Energy efficiency rating of the efficient technology (Level 2 EVC)

= 0.853[184]

ES_{gain} = Efficiency gain of an ENERGY STAR® certified Level 2 EVC[185]

= 56

[181] State and Urbanized Area Statistics (2018) U.S. Department of Transportation, Federal Highway Administration. *Last accessed June 2019 via:* https://www.fhwa.dot.gov/ohim/onh00/onh2p11.htm

[182] Value provided by the Implementor, CLEAResult; corroborated by ADM via 2011-2017 sales data from U.S. Department of Energy: Energy Efficiency & Renewable Energy Alternative Fuels Data Center – *Last accessed July 2019 via:* www.afdc.energy.gov/data/ in addition to 2018 and partial 2019 sales data collected from Tesla Quarterly Reports and www.goodcarbadcar.net.

[183] Based on results of Level 1 charger high energy (>2kWh) events occurring at temperatures > 70°F – see Table 2 *in* Forward, E., Glitman, K., and Roberts, D. *for* Vermont Energy Investment Corporation (2013) EVT NRA R&D Electric Vehicle Supply Equipment Project Report: An Assessment of Level 1 and Level 2 Electric Vehicle Charging Efficiency, *Efficiency Vermont*.

[184] Based on results of Level 2 charger high energy (>2kWh) events occurring at temperatures > 70°F – see Table 2 *in* Forward, E., Glitman, K., and Roberts, D. *for* Vermont Energy Investment Corporation (2013) EVT NRA R&D Electric Vehicle Supply Equipment Project Report: An Assessment of Level 1 and Level 2 Electric Vehicle Charging Efficiency, *Efficiency Vermont*.

[185] Environmental Protection Agency (2013) ENERGY STAR® Market and Industry Scoping Report: Electric Vehicle Supply Equipment.

G.1.4 Home Rebates Program – Single Upgrade and Multiple Upgrades Components

This section includes the measure level algorithms and deemed savings values utilized for the verified gross kWh and kW savings calculations.

G.1.4.1 Air Infiltration Reduction

The AR TRM 7.0 was utilized to calculate energy and demand impacts of air sealing measures. Savings were calculated by multiplying the air infiltration reduction (CFM), with the energy savings factor corresponding to the climate zone and HVAC type. The air infiltration reduction estimate in cubic feet per minute (CFM at 50 Pascal) was obtained through blower door testing performed by the program contractor for each home serviced. ADM utilized the AR TRM for the savings algorithms and deemed savings values shown in Section G.1.2.1 (Equation G-15 and Equation G-16).

G.1.4.2 Duct Sealing and Duct Replacement

All savings for duct replacement projects were captured in the corresponding duct sealing savings. This measure involves replacing/sealing leaks in ducts of the distribution system of homes with either a central AC or a ducted heating system. The post-installation duct leakage is measured by the contractor. Savings were estimated by updating the inputs to the savings algorithm listed in the AR TRM 7.0 for duct sealing, with full load hours and the coincidence factor (CF) value from the OKDSD. Deemed savings factors were based on the location of the ducts (attic or crawlspace). Savings were calculated by multiplying the duct leakage reduction results with the outdoor/indoor seasonal specific enthalpy (OKDSD) corresponding to the climate zone and HVAC type and are divided by the HVAC unit efficiency. The algorithms for cooling and energy saving listed in the OKDSD for duct sealing can be found in Section G.1.2.2 (Equation G-17, Equation G-18, and Equation G-19).

G.1.4.3 Ceiling/Attic Insulation

Savings were estimated by updating the savings algorithm inputs listed in the AR TRM 7.0 for attic insulation and are based on the R-value of the baseline insulation. The savings factor was climate zone specific, determined by the pre-insulation thickness R-value compared to the post-installation thickness R-value. The savings algorithms require new insulation to meet a minimum R-value of R-38. Savings were scaled for installed thickness between the table values of R-38 and R-49. As the AR TRM 7.0 energy and demand savings factors are based on multiple starting insulation R-values, and just two final insulation R-values, an interpolation was completed for those values between R-38 and R-49. Savings were calculated by multiplying the applicable savings value (based on the pre- and post-insulation thickness R-value) by the square footage insulated.

Table G-30: Deemed Savings for R-38 Ceiling Insulation

Climate Zone	Baseline Insulation R-Value	AC/Gas Heat kWh/SF	Gas Heat (No AC) kWh/SF	AC/Electric Resistance kWh/SF	Heat Pump kWh/SF	AC Peak Savings kW/SF
9	1 or less	1.716	0.254	9.366	5.071	0.0014
	>1 and <=5	0.969	0.141	5.212	2.764	0.0008
	>5 and <=8	0.586	0.084	3.136	1.653	0.0005
	>8 and <=15	0.364	0.052	1.926	1.013	0.00032
	>15 and 22	0.172	0.025	0.931	0.486	0.00014
8	1 or less	1.8642	0.2203	8.734	4.572	0.00107
	>1 and <=5	1.0497	0.1215	4.846	2.495	0.00061
	>5 and <=8	0.6330	0.0728	2.909	1.495	0.00038
	>8 and <=15	0.3909	0.0446	1.784	0.917	0.00025
	>15 and 22	0.1847	0.0216	0.858	0.439	0.00011
7	1 or less	1.8820	0.1933	7.936	4.067	0.00201
	>1 and <=5	1.0505	0.107	4.401	2.252	0.00118
	>5 and <=8	0.6315	0.0643	2.643	1.355	0.00073
	>8 and <=15	0.3901	0.0394	1.624	0.834	0.00047
	>15 and 22	0.1854	0.019	0.781	0.4	0.00022
6	1 or less	2.1230	0.1703	7.482	3.873	0.00203
	>1 and <=5	1.1967	0.0954	4.2	2.18	0.00118
	>5 and <=8	0.7242	0.0578	2.545	1.324	0.00073
	>8 and <=15	0.4497	0.0356	1.574	0.82	0.00047
	>15 and 22	0.2116	0.0172	0.753	0.391	0.00021

Table G-31: Deemed Savings for R-49 Ceiling Insulation

Climate Zone	Baseline Insulation R-Value	AC/Gas Heat kWh/SF	Gas Heat (No AC) kWh/SF	AC/Electric Resistance kWh/SF	Heat Pump kWh/SF	AC Peak Savings kW/SF
9	1 or less	1.756	0.260	9.578	5.1820	0.00143
	>1 and <=5	1.009	0.146	5.424	2.8760	0.00084
	>5 and <=8	0.626	0.090	3.348	1.7640	0.00053
	>8 and <=15	0.404	0.057	2.139	1.1240	0.00036
	>15 and 22	0.212	0.031	1.143	0.0597	0.00018
8	1 or less	1.907	0.225	8.931	4.673	0.00109
	>1 and <=5	1.093	0.126	5.043	2.596	0.00064
	>5 and <=8	0.676	0.077	3.105	1.596	0.00040
	>8 and <=15	0.434	0.049	1.981	1.018	0.00027
	>15 and 22	0.228	0.026	1.055	0.539	0.00013

Climate Zone	Baseline Insulation R-Value	AC/Gas Heat kWh/SF	Gas Heat (No AC) kWh/SF	AC/Electric Resistance kWh/SF	Heat Pump kWh/SF	AC Peak Savings kW/SF
7	1 or less	1.925	0.198	8.115	4.159	0.00207
	>1 and <=5	1.093	0.111	4.581	2.344	0.00124
	>5 and <=8	0.674	0.069	2.822	1.447	0.00079
	>8 and <=15	0.433	0.044	1.803	0.926	0.00053
	>15 and 22	0.228	0.023	0.96	0.492	0.00027
6	1 or less	2.173	0.174	7.657	3.964	0.00208
	>1 and <=5	1.247	0.099	4.375	2.271	0.00123
	>5 and <=8	0.774	0.061	2.719	1.415	0.00078
	>8 and <=15	0.500	0.039	1.748	0.911	0.00053
	>15 and 22	0.262	0.021	0.928	0.482	0.00027

G.1.4.4 Floor Insulation

Savings were estimated by updating the savings algorithm inputs listed in the OKDSD for floor insulation, along with project-specific data, installed square feet, and insulation R-value. The OKDSD prototype home model considered cell foam insulation for the measure, which is the product used for the insulation rebate. The cell foam insulation provides both sensible and latent cooling season savings. The same algorithm as knee wall insulation was used, with the savings factor from the OKDSD. The savings factor was climate zone specific, and HVAC equipment specific, then factored by the installed area. The deemed savings values are outlined in the following table:

Table G-32: Deemed Savings Values for Floor Insulation

Climate Zone	HVAC Type	kWh savings/SF	kW savings/SF
9	Electric AC with Gas Heat	0.265	0.0001
	Electric AC with Electric Resistance Heat	3.231	0.0001
	Heat Pump	1.981	0.0001
8A	Electric AC with Gas Heat	0.274	0.0001
	Electric AC with Electric Resistance Heat	3.897	0.0001
	Heat Pump	2.257	0.0001
8B	Electric AC with Gas Heat	0.390	0.0001
	Electric AC with Electric Resistance Heat	3.712	0.0001
	Heat Pump	2.208	0.0001
7	Electric AC with Gas Heat	0.309	0.0001
	Electric AC with Electric Resistance Heat	2.944	0.0001

Climate Zone	HVAC Type	kWh savings/SF	kW savings/SF
	Heat Pump	1.713	0.0001
6	Electric AC with Gas Heat	0.358	0
	Electric AC with Electric Resistance Heat	2.520	0
	Heat Pump	1.440	0

G.1.4.5 Wall Insulation

Savings were estimated by updating the savings algorithm inputs listed in the AR TRM 7.0 for wall insulation. The savings algorithm requires new insulation to meet a minimum R-value of R-13. Deemed savings provided in the AR TRM 7.0 are based on the heating and cooling system type of the home and the R-value of the insulation installed. Savings were calculated by multiplying the corresponding savings value by the insulated square footage. The deemed savings values are outlined in the following table:

Table G-33: Deemed Savings Values for Wall Insulation

Climate Zone	Equipment	Savings kWh/SF		Peak Demand Savings kW/SF	
		R-13	R-23	R-13	R-23
9	Electric AC with Gas Heat	0.527	0.563	0.00041	0.00048
	Gas Heat Only (no AC)	0.206	0.226	NA	NA
	Elec. AC with Resistance Heat	6.644	7.324	0.00041	0.00048
	Heat Pump	3.424	3.447	0.00041	0.00048
8	Electric AC with Gas Heat	0.586	0.625	0.00027	0.00029
	Gas Heat Only (no AC)	0.179	0.197	NA	NA
	Elec. AC with Resistance Heat	60.59	6.689	0.00027	0.00029
	Heat Pump	2.946	2.980	0.00023	0.00025
7	Electric AC with Gas Heat	0.570	0.607	0.00047	0.00071
	Gas Heat Only (no AC)	0.156	0.173	NA	NA
	Elec. AC with Resistance Heat	5.315	5.900	0.00047	0.00072
	Heat Pump	2.479	2.592	0.00047	0.00061
6	Electric AC with Gas Heat	0.712	0.751	0.00046	0.00084
	Gas Heat Only (no AC)	0.134	0.151	NA	NA
	Elec. AC with Resistance Heat	4.798	5.389	0.00046	0.00084
	Heat Pump	2.223	2.388	0.00046	0.00071

G.1.4.6 Knee Wall Insulation

Savings were estimated by updating the savings algorithm inputs listed in the AR TRM 7.0 for knee wall insulation. The savings factor was dependent upon climate zone and HVAC equipment type. Additionally, deemed savings are driven by the heating and cooling system type of the home and the post-installation R-value. The TRM table was modeled for a home starting at zero insulation going to a R-19 or R-30 value. The savings estimated considered the initial insulation R-value and adjusted the savings value. The program tracking data indicated an open cell or closed cell foam applied to attic vertical walls. The final R-value was interpolated for the R-values between R-19 and R-30 and all the projects reached a minimum R-value of R-19. Savings were calculated by multiplying the applicable savings value (based on the pre- and post-insulation thickness R-value) by the square footage insulated. The deemed savings values are outlined in the following table:

Table G-34: Deemed Savings Value for Knee Wall Insulation

Climate Zone	Insulation Level Installed	AC/Gas Heat kWh/SF	Gas Heat (No AC) kWh/SF	AC/Electric Resistance kWh/SF	Heat Pump kWh/SF	AC Peak Savings kW/SF
9	R-19	1.104	0.131	5.073465	2.682	0.00079
	R-30	1.166	0.139	5.372651	2.839	0.00083
8	R-19	1.219	0.114	4.804000	2.489	0.00090
	R-30	1.289	0.121	5.086000	2.634	0.00094
7	R-19	1.230	0.100	4.405000	2.298	0.00090
	R-30	1.300	0.106	4.662000	2.430	0.00095
6	R-19	1.389	0.089	4.215000	2.255	0.00091
	R-30	1.468	0.094	4.461000	2.384	0.00096

G.1.4.7 Central Air Conditioner, Air Source Heat Pump, and Ductless Mini-Split Heat Pump Retrofits

Savings were estimated by updating the savings algorithm inputs in the OKDSD blended with the Federal Minimum Efficiency Requirements.[186] Savings calculations considered right-sizing savings up to a 1-ton difference and are based on the size/efficiency of each unit. ADM utilized the following OKDSD for the savings algorithms:

Equation G-42: Annual Energy Savings – Cooling

$$kWh_{\boldsymbol{savings,Clg}} = \left(Cap_{base}\ X \frac{1}{SEER_{Base}} - CAP_{AC}\ X\ \frac{1}{SEER_{post,AC}} \right) X\ \frac{1\ kW}{1{,}000\ W}\ X\ EFLH_C$$

[186] Federal minimum regulations equipment for Southeast region, https://www.energy.gov/sites/prod/files/2015/11/f27/CAC%20Brochure.pdf

Equation G-43: Annual Energy Savings – Heating

$$kWh_{\boldsymbol{savings,Htg}} = \left(Cap_{base}\,X\,\frac{1}{HSPF_{Base}} - CAP_{AC}\,X\,\frac{1}{HSPF_{HP}}\right)X\,\frac{1\,kW}{1{,}000\,W}\,X\,EFLH_H$$

Equation G-44: Peak Demand Reduction

$$kW_{\boldsymbol{savings}} = \left(Cap_{base}\,X\,\frac{1}{EER_{Base}} - CAP_{AC}\,X\,\frac{1}{EER_{post,AC/HP}}\right)X\,\frac{1\,kW}{1{,}000\,W}\,X\,CF$$

Where:

Cap_{base} = Rated equipment cooling capacity of the existing unit (BTU/hr)

$Cap_{AC/HP}$ = Rated equipment cooling/heating capacity of the new unit (BTU/hr)[187]

$SEER_{Base}$ = Season Energy Efficiency Ratio of existing cooling equipment

$SEER_{post}$ = Season Energy Efficiency Ratio of installed cooling equipment

EER_{Base} = Energy Efficiency Ratio of the existing equipment

EER_{post} = Energy Efficiency Ratio of the installed equipment

$EFLH_C$ = Equivalent full load hours for cooling

$EFLH_H$ = Equivalent full load hours for heating

$HSPF_{Base}$ = Heating Seasonal Performance Factor for existing heating equipment

$HSPF_{post,}$ = Heating Seasonal Performance Factor for installed heating equipment

CF = Coincidence Factor

= 0.87 (default)

G.1.4.8 Ground Source Heat Pumps

Savings were estimated by updating the savings algorithm inputs in the OKDSD blended with the Federal Minimum Efficiency Requirements.[188.]

Equation G-45: Annual Energy Savings (Ground Source Heat Pump)

$$kWh_{\boldsymbol{savings,Clg}} = Cap\,X\,\frac{1\,kW}{1{,}000\,W}\,X\,EFLH_C\,X\,\left(\frac{1}{EER_{Base}} - \frac{1}{EER_{GSHP}}\right)$$

$$kWh_{\boldsymbol{savings,Htg}} = Cap\,X\,\frac{1\,kW}{3{,}412\,Btu}\,X\,EFLH_H\,X\,\left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right)$$

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[187] Rated capacity of the new unit shall not exceed capacity of the existing unit; if completing this with other measures, use existing unit capacity.
[188] Federal minimum regulations equipment for Southeast region, https://www.energy.gov/sites/prod/files/2015/11/f27/CAC%20Brochure.pdf

Equation G-46: Peak Demand Reduction (Ground Source Heat Pump)

$$kW_{\boldsymbol{savings}} = CAP\ X\ \frac{1\ kW}{1{,}000\ W}\ X \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{post,AC/HP}}\right) X\ CF$$

Where:

CAP = Rated equipment cooling capacity of the new unit (Btu/hr)

$EFLH_C$ = Equivalent full load hours for cooling

$EFLH_H$ = Equivalent full load hours for heating

EER_{base} = Energy Efficiency Ration of the baseline cooling equipment

EER_{GSHP} = Energy Efficiency Ration of the installed GSHP

COP_{Base} = Coefficient of Performance for the baseline heating equipment

COP_{GSHP} = Coefficient of Performance of the GSHP

CF = Coincidence Factor

= 0.87

G.1.4.9 ENERGY STAR® Pool Pumps

Savings were estimated using the deemed savings method in the OKDSD. The savings algorithms inputs are dependent upon the horsepower of the motor, and the seasonal usage (summer or year-around). ADM applied the deemed savings table values from the OKDSD but used the same annual operating days as the tracking data algorithm. The deemed savings values are outlined in the following table:

Table G-35: Deemed Savings for VSD Pumps

Annual Operation	Horsepower (HP)	kWh Savings	kW Savings
Summer only	<1.0 HP	576	0.130
	≥1.0 HP and ≤2.0 HP	1,428	0.395
	>2.0 HP	1,829	0.474
Year round	<1.0 HP	1,256	0.130
	≥1.0 HP and ≤2.0 HP	3,116	0.395
	>2.0 HP	3,991	0.474

G.1.4.10 HVAC Tune-Ups

ADM used Method 2[189] from the AR TRM v7 algorithm and is a change in efficiency based on pre- and post- measurement of the system. This measure involves tuning up existing

[189] Calculation of savings based on pre or pre and post measurement of system efficiency, and age of equipment.

HVAC units and deemed savings factors were based on the pre- and post-EER of the HVAC unit. For each unit rebated through the program, energy savings and peak demand reduction were calculated using *Equation G-47* and *Equation G-48.*

Equation G-47: Annual Energy Savings (HVAC Tune-Up)

$$\mathrm{kWh}_{savings,c} = \mathrm{CAP}_c \times \frac{1\ \mathrm{kW}}{1{,}000\ W} \times \mathrm{EFLH}_c \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right)$$

$$\mathrm{kWh}_{savings,H} = \mathrm{CAP}_H \times \frac{1\ \mathrm{kW}}{1{,}000\ W} \times \mathrm{EFLH}_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right)$$

$$\mathrm{kWh}_{savings,HP} = \mathrm{kWh}_{savings,C} + \mathrm{kWh}_{savings,H}$$

Where:

CAP_C = Rated or calculated equipment cooling capacity (Btu/hr)

CAP_H = Rated or calculated equipment heating capacity (Btu/hr)

EER_{pre} = Calculated or measured efficiency of the equipment for cooling before tune-up

EER_{post} = Measured or calculated efficiency of the existing equipment for cooling; if unknown, use 11.2 EER (default)

$\mathrm{HSPF}_{\mathrm{pre}}$ = Calculated or measured efficiency of the equipment for heating before tune-up

$\mathrm{HSPF}_{\mathrm{post}}$ = Measured or calculated efficiency of the existing equipment for heating; if unknown, use 7.7 HSPF (default)

$EFLH_C$ = Equivalent full-load cooling hours

$EFLH_H$ = Equivalent full-load heating hours

Equation G-48: Peak Demand Reduction (HVAC Tune-Up)

$$\mathrm{kW}_{savings,} = \mathrm{CAP}_c \times \frac{1\ \mathrm{kW}}{1{,}000\ W} \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times \mathrm{CF}$$

Where:

CF = Coincidence Factor

= 0.87 (default)

Other variables as define above.

G.1.4.11 Drop-Off Energy Kits

Drop-off Energy Kits contained 9W LED lightbulbs, LED nightlights, and filter tone furnace filter alarms. Savings for the premium 9W LED bulb were estimated using algorithms found in the ARM TRM 7.0. A modification to the hours of use per year (960.61 HOU per year) was utilized by ADM. Modification of the hours of use was sourced from a lighting benchmarking study performed in 2016 by ADM and found daily hours of use of 2.63 blended hours for indoor/outdoor applications, or 960.61 hours per year.[190] The algorithm used to determine savings for FilterTone® Alarms is based on the Pennsylvania Technical Reference Manual (PA TRM). The source for the equivalent full load hours (EFLH) for the FilterTone® alarms calculation was the PY2019 – PY2021 Demand Portfolio Model. The algorithm used to determine savings for LED nightlights was from the PA TRM. The savings algorithms and deemed savings are shown in Section G.1.5.1 (Equation G-49 and Equation G-50) for the 9W LED lightbulbs, Section G.1.5.3 (Equation G-51 and Equation G-52) for the filter tone furnace filter alarms, and Section G.1.5.4 (Equation G-53) for the LED nightlight.

G.1.4.12 New Home Construction RESNET Standards

The New Homes Construction savings methodology is followed by the Residential Energy Services Network (RESNET) standards. RESNET standards are industry wide standards that are recognized for verification of building energy performance by the EPA. Savings methodology that is in conformance with these standards are built into the Ekotrope modeling software and approved by RESNET.

G.1.5 Education Program

G.1.5.1 ENERGY STAR® LEDs

The energy savings for ENERGY STAR® LEDs were calculated by using the following equations as specified in the AR TRM, 7.0. Inputs for lighting calculations were determined from the data from the participant surveys in combination with algorithms and inputs found in the AR TRM.

Equation G-49: Energy Savings for LED bulbs

$$kWh_{savings} = \left(\frac{\Delta Watts}{1{,}000}\right) x\ Hours\ x\ ISR\ x\ IEF_E$$

Equation G-50: Demand Reduction LED bulbs

$$kW_{demand\ reduction} = \left(\frac{\Delta Watts}{1{,}000}\right)\ x\ CF\ x\ ISR\ x\ IEF_D$$

190 ADM HOU Memo, 2016.

Where:

$\Delta Watts$ = The difference in watts between a baseline bulb and the distributed LED. Baseline wattages will be determined based on the wattage and brightness (lumen) of the measure and the EISA baseline standards.

$Hours$ = Average hours of use per year

= 960.61 hours[191]

ISR = In-service rate, the percentage of LEDs distributed that are installed.

CF = Summer Peak Coincidence Factor for measure.[192] An average coincident factor is calculated based on the reported installation location from student survey.

Lamp Location	CF
Indoor	10%
Outdoor	0%

IEF_E = Interactive effects factor to account for cooling energy savings and heating energy penalties as specified in the AR TRM, based on home heating and cooling condition reported in student survey responses.

IEF_D = Interactive effects factor to account for cooling demand savings as specified in the AR TRM, based on home heating and cooling condition reported in student survey responses.

G.1.5.2 Advanced Power Strips (APS)

ADM utilized the deemed savings values for "residential" applications from the AR TRM, version 7.0.

Table G-36: Demand and Annual Energy Savings for Advanced Power Strips[193]

System Type	kW Demand Reduction	kWh Savings
Residential		
Home Entertainment System	0.030	252.2
Home Office	0.008	82.5
Average APS	0.019	167.4

191 Based on the ADM 2016 benchmarking study.
192 As stipulated in the AR TRM Version 7.0, Vol. 2, page 220.
193 As stipulated in the AR TRM, Version 7.0, Vol. 2, page 188.

G.1.5.3 FilterTone® Alarm

The energy savings and peak demand reductions for FilterTone® Alarms were calculated by using the following equations from the PA TRM. Inputs to algorithms were determined from the data from the participant surveys in combination with algorithms and inputs found in the PA TRM.[194]

Equation G-51: Energy Savings for FilterTone® Alarms

$$kWh_{savings} = (EFLH_{Heat} + EFLH_{Cool})\ x\ kW_{motor}\ x\ EI\ x\ ISR$$

Equation G-52: Peak Demand Reduction for FilterTone® Alarms

$$kW_{demand\ reduction} = kW_{motor}\ x\ EI\ x\ ISR\ x\ CF$$

Where:

$EFLH_{Heat}$ = Assumed to be 800 hours[195]

$EFLH_{Cool}$ = Assumed to be 800 hours

kW_{motor} = Average motor full load electric demand (kW), assumed to be 0.5 kW.[196]

EI = Efficiency improvement

= 15%[197]

CF = Coincidence factor for peak demand reduction

= 0.87[198]

ISR = In-service rate, or percentage of units that get installed, from student survey.

G.1.5.4 LED Night Light

ADM utilized the following equation for calculating the kWh savings from the PA TRM.[199] There are no peak demand reductions associated with LED night lights.

Equation G-53: Energy Savings for LED Night Lights

$$kWh_{savings} = \left[\left(W_{base} - W_{post}\right) \times \left(\frac{Hours \times 365\,\frac{days}{year}}{1000\,\frac{W}{kW}}\right)\right] \times ISR$$

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[194] As stipulated in the 2016 PA TRM, pg 70.
[195] $EFLH_{Heat}$ and $EFLH_{Cool}$ based on PSO's 2019-2021 DSM Portfolio Plan
[196] As stipulated in the 2016 PA TRM, pg 71
[197] As stipulated in the 2016 PA TRM, page 72.
[198] Coincidence factor for demand reduction HVAC systems, as stipulated in the AR TRM Version 8.1, Vol 2, page 542.
[199] 2016 PA TRM, page 28.

Where:

W_{base} = Baseline wattage, assume incandescent night light

= 7 W[200]

W_{post} = Wattage of installed LED night light

= 1 W[201]

$Hours$ = Number of hours per day the nightlight is assumed to operate

= 12 hours[202]

ISR = In-Service Rate, or percentage of delivered units that get installed, based on student survey responses.

G.1.6 Multifamily Program

G.1.6.1 Air Infiltration

ADM utilized the AR TRM for the savings algorithms shown in Section G.1.2.1: Equation G-15 was used annual energy savings (kWh) and Equation G-16 was used to calculate peak demand savings (kW).

G.1.6.2 Ceiling Insulation

ADM utilized the AR TRM for the deemed savings shown in Section G.1.2.3: Table G-7.

G.1.6.3 Duct Sealing

ADM utilized the OKDSD for the savings algorithms shown in Section G.1.2.2: Equation G-17 is used to determine annual cooling savings, and Equation G-18 and Equation G-19 are used to determine heating savings for electric resistance heat and gas heat, respectively.

G.1.6.4 Faucet Aerator

ADM utilized the deemed savings values from the AR TRM for faucet aerator annual savings. Savings are calculated by multiplying the applicable savings value by the number of installed faucet aerators. Deemed savings were calculated under the assumption that all faucet aerators in a home were replaced. All faucet aerators in a home must have been replaced for savings to be applicable.

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[200] 2016 PA TRM, page 27.
[201] Ibid
[202] Ibid

Equation G-54: Energy Savings (Faucet Aerator)

$$kWh_{savings} = \frac{\left[\rho \times \mathrm{C_p} \times \mathrm{V} \times \left(\mathrm{T_{Mixed}} - T_{Supply}\right) \times \left(\frac{1}{RE}\right)\right]}{Conversion\ Factor} \times ISR$$

Where:

ρ = Water Density = 8.33 lb/gallon

C_p = Specific heat of water = 1 BTU/lb*˚F

V = gallons of water saved per year per faucet

Flow Rate	Gallons of Water Saved Per Year
1.5 gpm	381
1.0 gpm	636

T_{Mixed} = Mixed water temperature, 104.3 ˚F, see = 0.000104

Table G-37

T_{Supply} = Average supply water temperature, see = 0.000104

Table G-37

RE = Recovery Efficiency; if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.79 for natural gas water heaters

Conversion Factor = 3,412 Btu/kWh

ISR = In-service rate, or percentage of units that get installed.

Equation G-55: Peak Demand Savings (Low Flow Shower Head)

$$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$ = 0.000104

Table G-37: Mixed Water Temperature Calculation (Faucet Aerator)

Weather Zone	Average Water Main Temperature (˚F)	Percent Hot Water	Mixed Water Temperature (˚F)
9 Fayetteville	65.6	66.9%	102.0
8 Fort Smith	66.1	66.9%	102.2
7 Little Rock	67.8	66.9%	102.7
6 El Dorado	70.1	66.9%	103.5
Average for Arkansas (T_{mixed})			**102.6**

G.1.6.5 Heat Pump

ADM utilized the OKDSD for the savings algorithms shown in Section G.1.4.7, Equation G-42 and Equation G-43 are used to calculate annual energy savings (kWh) and Equation G-44 for peak demand reduction (kW).

G.1.6.6 Low Flow Shower Head

The following equations were used to calculate energy savings for Low Flow Shower Heads. The values used in the calculations come from the AR TRM.

Equation G-56: Energy Savings (Low Flow Shower Head)

$$kWh_{savings} = \frac{\left[\rho \times \mathrm{C_p} \times \mathrm{V} \times \left(\mathrm{T_{Mixed}} - T_{Supply}\right) \times \left(\frac{1}{RE}\right)\right]}{Conversion\ Factor} \times ISR$$

Where:

ρ = Water Density = 8.33 lb/gallon

C_p = Specific heat of water = 1 BTU/lb*˚F

V = Showerhead water gallons saved per year = 2.0 gpm

T_{Mixed} = Mixed water temperature, 104.3 ˚F, see 0.000104

Table G-38

T_{Supply} = Average supply water temperature, see 0.000104

Table G-38

RE = Recovery Efficiency; if unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.79 for natural gas water heaters

Conversion Factor = 3,412 Btu/kWh

ISR = In-service rate, or percentage of units that get installed.

Equation G-57: Peak Demand Savings (Low Flow Shower Head)

$$kW_{savings} = kWh_{savings} \times Ratio_{Annual\ kWh}^{Peak\ kW}$$

Where:

$Ratio_{Annual\ kWh}^{Peak\ kW}$ = 0.000104

Table G-38: Mixed Water Temperature Calculation (Low Flow Shower Head)

Weather Zone	Average Water Main Temperature (˚F)	Percent Hot Water	Mixed Water Temperature (˚F)
9 Fayetteville	65.6	70.1%	103.7
8 Fort Smith	66.1	70.1%	103.9
7 Little Rock	67.8	70.1%	104.4
6 El Dorado	70.1	70.1%	105.1
Average for Arkansas (T_{mixed})			**104.3**

G.1.6.7 ENERGY STAR® Pool Pump

ADM utilized the AR TRM for calculating energy savings and demand reductions. The following algorithms are sourced from the AR TRM.

Equation G-58: Energy Savings (Pool Pumps)

$$kWh_{savings} = kWh_{conv} - kWh_{ES}$$

Where:

kWh_{conv} = Conventional single-speed pool pump energy (kWh)

kWh_{ES} = ENERGY STAR® variable-speed pool pump energy (kWh)

Algorithms to calculate the above parameters are defined as:

$$kWh_{conv} = \frac{PFR_{conv} * 60 * hours_{conv} * days}{EF_{conv} * 1000}$$

$$hours_{conv} = \frac{V_{pool} * PT}{PFR_{conv} * 60}$$

$$kWh_{ES} = kWh_{HS} + kWh_{LS}$$

$$kWh_{HS} = \frac{PFR_{HS} * 60 * hours_{HS} * days}{EF_{HS} * 1000}$$

$$kWh_{LS} = \frac{PFR_{LS} * 60 * hours_{LS} * days}{EF_{LS} * 1000}$$

$$PFR_{LS} = \frac{V_{pool}}{t_{turnover} * 60}$$

Where:

kWh_{HS} = ENERGY STAR® variable speed pool pump energy at high speed (kWh)

kWh_{LS} = ENERGY STAR® variable speed pool pump energy at low speed (kWh)

$hours_{conv}$ = Conventional single-speed pump daily operating hours (Table G-39)

$hours_{HS,VS}$ = ENERGY STAR® variable speed pump high speed daily operating hours

= 2 hours

$hours_{LS,VS}$ = ENERGY STAR® variable speed pump low speed daily operating hours

= 10 hours

$hours_{HS,MS}$ = ENERGY STAR® multi-speed pump high speed daily operating hours

= 2 hours

$hours_{LS,MS}$ = ENERGY STAR® multi-speed pump low speed daily operating hours (Table G-40)

days = Operating days per year = 7 months x 30.4 days/month

= 212.8 days (default)

PFR_{conv} = Conventional single-speed pump flow rate (gal/min) (Table G-39)

$PFR_{HS,VS}$ = ENERGY STAR® variable speed pump high speed flow rate = 50 gal/min (default)

$PFR_{LS,VS}$ = ENERGY STAR® variable speed pump low speed flow rate (gal/min)

= 30.6 (default)

$PFR_{HS,MS}$ = ENERGY STAR® multi-speed pump high speed flow rate (gal/min) (Table G-40)

$PFR_{HS,MS}$ = ENERGY STAR® multi-speed pump low speed flow rate (gal/min) (Table G-40)

EF_{conv} = Conventional single-speed pump energy factor (gal/W·hr) (Table G-39)

$EF_{HS,VS}$ = ENERGY STAR® variable speed pump high speed energy factor

= 3.75 gal/W·hr (default)

$EF_{LS,VS}$ = ENERGY STAR® variable speed pump low speed energy factor

= 7.26 gal/W·hr (default)

$EF_{HS,MS}$ = ENERGY STAR® multi-speed pump high speed energy factor (gal/W·hr) (Table G-40)

$EF_{LS,MS}$ = ENERGY STAR® multi-speed pump low speed energy factor (gal/W·hr) (Table G-40)

V_{pool} = Pool volume

= 22,000 gal (default)

PT = Pool turnovers per day

= 1.5 (default)

$t_{turnover,VS}$ = Variable speed pump time to complete 1 turnover

= 12 hours (default)

$t_{turnover,MS}$ = Multi-speed pump time to complete 1 turnover (Table G-40)

60 = Constant to convert between minutes and hours

1000 = Constant to convert W to kW

Table G-39: Conventional Pool Pumps Assumptions

Pump HP	$hours_{conv}$	PFR_{conv}(gal/min)	EF_{conv}(gal/W*h)
0.5	11	50.0	2.71
0.75	10.4	53.0	2.57
1	9.2	60.1	2.40
1.5	8.6	64.4	2.09
2	8.5	65.4	1.95
2.5	8.1	68.4	1.88
3	7.5	73.1	1.65

Table G-40: Multi-Speed Pool Pumps Assumptions

Pump HP	$t_{turnover,MS}$	$hours_{MS,LS}$	$PFR_{HS,MS}$ (gal/min)	$EF_{HS,MS}$ (gal/min)	$PFR_{LS,MS}$ (gal/min)	EF_{conv} (gal/W*h)
1	11.8	9.8	56.0	2.40	31.0	5.41
1.5	11.5	9.5	61.0	2.27	31.9	5.43
2	11.0	9.0	66.4	1.95	33.3	5.22
2.5	10.8	8.8	66.0	2.02	34.0	4.80
3	9.9	7.9	74.0	1.62	37.0	4.76

Demand savings were derived using the following:

Equation G-59: Peak Demand Savings (Pool Pumps)

$$kW_{savings} = \left[\frac{kWh_{conv}}{hours_{conv}} - \frac{kWh_{HS} + kWh_{LS}}{hours_{HS} + hours_{LS}}\right] * \frac{CF}{days}$$

Where:

CF = Coincidence factor

= 0.31

G.1.6.8 Clothes Dryer

For the Multifamily program, ADM utilized the deemed values for energy savings and algorithm for demand reduction from the Mid-Atlantic TRM. Energy savings are made available for ENERGY STAR® certified Clothes Dryers.

Table G-41: ENERGY STAR® Windows Deemed Savings

Product Class	Algorithm	ΔkWh
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	= ((8.45/3.11 – 8.45/3.93) * 311 * 100%	176.3
Vented or Ventless Electric, Compact (120V) (< 4.4 ft^3)	= ((3/3.01 – 3/3.80) * 311 * 100%	64.4
Vented Electric, Compact (240V) (< 4.4 ft3)	= ((3/2.73 – 3/3.45) * 311 * 100%	71.3
Ventless Electric, Compact (240V) (< 4.4 ft3)	= ((3/2.13 – 3/2.68) * 311 * 100%	89.9
Vented Gas	= ((8.45/2.84 – 8.45/3.48) * 311 * 16%	27.2

Demand reduction was derived using the following equation:

Equation G-60: Peak Demand Savings (Poop Pumps)

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

ΔkWh = Energy Savings

Hours = Annual run hours of clothes dryer.

= 290 hours per year.

CF = Summer Peak Coincidence Factor for measure

= 2.9%

G.1.6.9 ENERGY STAR® Clothes Washers

ADM utilized the AR TRM for the deemed savings values shown in Section G.1.3.11: Table G-28.

G.1.6.10 ENERGY STAR® Windows

ADM utilized the OKDSD for the ENERGY STAR® Window deemed savings values. ADM used the deemed savings values from climate zone 8B.

Table G-42: ENERGY STAR® Windows Deemed Savings

Existing Windowpane Type	AC/Gas Heat kWh	Gas Heat (no AC) kWh	Gas Heat (no AC) Therms	AC/Electric Resistance kWh	Heat Pump kWh	AC Peak Savings kW
	Per sq. ft.	Per sq. ft.	Per sq. ft.	Per sq. ft.	Per sq. ft.	Per sq. ft.
Single Pane	6.9022	0.3863	0.5562	17.8098	13.3434	0.0044
Double Pane	5.0567	0.1777	0.2666	10.4856	8.4996	0.0031

G.1.7 Lighting Measures

ADM utilized the AR TRM for the savings algorithms and deemed savings values for the lighting measures as detailed in Section G.1.1.1.

G.1.8 Behavioral Modification Program

G.1.8.1 Calculation of Average Daily kWh Savings

ADM utilized the mixed effects panel regression model specified in *Equation G-61* to determine daily average electricity savings for treatment group members.

Equation G-61: Mixed Effects Panel Regression Model

$$AEC_{i,t} = \alpha_i \mathrm{Customer_i} + \beta_1 CDD_{i,t} + \beta_2 HDD_{i,t} + \beta_3 Post_{i,t} + \beta_4 Post_{i,t} * Treat_{i,t} + \beta_5 Post_{i,t} * CDD_{i,t} + \beta_6 Post_{i,t} * HDD_{i,t} + E_{i,t}$$

Where the subscript i denotes individual customers and t = 1. $T_{(i)}$ serves as a time index, where $T_{(i)}$ is the number of bills available for customer i. The model is defined as "mixed effects" because the model decomposes its parameters into fixed-effects (i.e., Heating Degree Days (HDD), Cooling degree days (CDD), Post-Installation period (Post), treatment (Treat), and various interactions) and random effects (i.e., the individual customer's baseline period usage). A fixed effect is assumed to be constant and independent of the sample, while random effects are assumed to be sources of variation (other than natural measurement error) that are uncorrelated with the fixed effects.

The program implementer provided ADM with a dataset that included the participation start date for each treatment group member and their corresponding control group. The first billing period after the beginning of treatment is considered the "deadband period".

Observations that occur in the deadband period are not included in the mixed effects panel regression as they contain a mix of pre-treatment and post-treatment data. For the treatment and control group members, the post period begins in the first billing period following the deadband period. The post variable is defined as a 0 in the billing periods prior to the beginning of treatment and a 1 for billing periods following the deadband period.

Heating degree day (HDD) and cooling degree day (CDD) were used in the model to control for energy demand based on outside temperature. HDD is defined as the monthly average difference between 65 degrees (the outside temperature above which it is assumed that a building needs no heating) and the actual outside air temperature. CDD is defined as the monthly average difference between the actual outside air temperature and 65 degrees (the outside temperature under which it is assumed that a building needs no cooling). A minimum value of 0 is used for both HDD and CDD. A description of the variables used in the regression model is shown in Table G-43.

Table G-43: Description of Variables Used in the Regression Model

Variable	Variable Description
Average Electricity Consumption ($AEC_{i,t}$)	Average daily use of electricity (kWh) for period t for a customer (determined by dividing total usage in a period by number of days in that period)
Customer	A panel of dummy variables that is a 1 for customer i or a 0 if not
Cooling Degree Days (CDD)	The mean cooling degree days per day during the billing period
Heating Degree Days (HDD)	The mean heating degree days per day during the billing period
Post	Post is a dummy variable that is 1 if the monthly period is after the customer received their first energy report and 0 for the periods before
Treatment	Treatment is a dummy variable that is 1 if the customer is a member of the treatment group and a 0 if the customer is a member of the control group
E_t	E_t is the error term

Table G-44 describes the coefficients that were determined by using the mixed effects panel model shown in Equation G-61.

Table G-44: Description of the Coefficients Estimated by the Regression Model

Coefficient	Coefficient Description
α_i	α_i is a coefficient that represents the grand mean of the customer specific intercepts used to control for any customer specific differences
β_1	β_1 is a coefficient that adjusts for the main effect of cooling
β_2	β_2 is a coefficient that adjusts for the main effect of heating
β_3	β_3 is a coefficient for the main effect of time, i.e., whether an observation falls in the pre-period or post-period
β_4	β_4 is a coefficient that represents the interactive effect of whether an observation falls in the post-period and the treatment effect. This coefficient represents savings attributable to the program.
β_5	β_5 is a coefficient that adjusts for the interactive effect between the post-period and cooling
β_6	β_6 is a coefficient that adjusts for the interactive effect between the post-period and heating

G.1.8.2 Calculation of Annual Energy Savings

The average daily annual energy savings for the post period treatment group is defined as coefficient β_4 in the regression model. To determine per participant annualized savings, the average daily energy savings value is multiplied by 365. The verified annual energy savings for the program is determined by multiplying the annualized energy savings by the number of participants in the treatment group who had existing accounts in 2021 and had not opted out of the program.

G.1.8.3 Calculation of Coincident Peak Demand Reduction

The peak demand reduction was determined by applying the program annual energy savings to a normalized hourly load shape that represents typical residential energy consumption, resulting in an 8,760 hourly annual savings curve. The selected load shape was the same used to determine estimates for the Behavioral Modification Program during portfolio planning. An average value across the peak demand window was drawn from the energy savings curve. The peak demand window is defined as consumption non-holiday weekdays between 2 PM and 6 PM in the months of June through September.

G.2 Demand Response Programs

G.2.1 Power Hours Program

The impact of the Power Hours Program is measured in two parts. The first is measuring the peak reduction (kW) and energy savings (kWh) during DLC events. The second is measuring the annual energy savings from the smart thermostat incentives. The following section defines how these savings are calculated.

G.2.1.1 Direct Load Control Events

Two Power Hours subprograms include a direct load control component: DLC and DLC + 2T-TOD. Tracking data for these subprograms, provided by PSO, is used to identify which devices are available to participate in each event. An available device is defined as a device registered with PSO as part of either the DLC or DLC + 2T-TOD subprogram. An available device could become unavailable only if the customer in possession of the device decided to permanently opt out of the subprogram.

The impact of DLC events is analyzed using 15-minute interval AMI billing consumption data provided by PSO. Software written in the statistical programming language R is used to process and analyze the data. Local temperature data was retrieved from the National Oceanic and Atmospheric Administration (NOAA). Temperature values were converted to cooling degree days (CDD). This was done because CDD values can quantify how power consumption relates to the weather more effectively than temperature values. Equation 4-1 shows how temperature is converted to CDD.

Equation G-62: Temperature to CDD Conversion

$$CDD_t = \begin{cases} 0 & if\ temp_t < cddbase \\ (temp_t - cddbase)\ /\ 48 & if\ temp_t \geq cddbase \end{cases}$$

Where,

$temp_t$ = temperature at time t

$cddbase$ = determined CDD base temperature

To calculate the most accurate CDD values, the optimal CDD base temperature for the evaluated population was determined. Intuitively, the CDD base temperature can be thought of as the coolest temperature in which energy usage begins increasing due to the operation of A/C units. The optimal CDD base temperature for the participant population was determined by running several possible CDD base temperature values through the following process.

- Temperature values are converted to CDD using the hypothetical CDD base.
- A linear regression model is fit to predict energy usage during the months of May through August, using only the CDD values.

- The model is scored by calculating the root mean squared error of its predictions.

The CDD base temperature that produced the model with the smallest root mean squared error score is the value chosen. In PY2021, the optimal CDD base temperature for the participant population was determined to be 70°. All weather data is retrieved from airports in the following Oklahoma cities: Tulsa, Lawton, Bartlesville, Chickasha, Elk City, and Okmulgee. Each household is matched with weather data from the location it was nearest to geographically.

Once the necessary data is processed, the devices that participate in the DLC events are identified. Two Power Hours subprograms include a direct load control component: DLC and DLC + 2T-TOD. Tracking data for these subprograms, provided by PSO, is used to identify which devices are available to participate in each event. An available device is defined as a device registered with Honeywell as part of either the DLC or DLC + 2T-TOD subprogram. An available device could become unavailable only if the customer in possession of the device decided to permanently opt out of the subprogram.

Because customers can manually override the DLC curtailment signal or various technical failures may occur, not every available device participates in the events. Thus, devices that are non-responsive to the called events need to be identified so that the calculation of energy savings included only devices that participate in the event.

A device is considered a non-responsive device (NRD) if it does not respond to the curtailment signal sent by PSO. NRDs are identified using a combination of three tests. A device is considered non-responding for an event day only if all three tests identify the device as non-responding. These three tests are run on every available device for every event date.

Test 1 and 2 analyze the cumulative sum (CSUM) change in energy usage of each device to check for a significant change in energy usage before and during an event. To do this, the cumulative sum of each site's energy usage is calculated (Equation G-63).

Equation G-63: Cumulative Sum Function

$$x = (i_1, i_2, i_3, \ldots, i_{48})$$

$$CSUM(x) = (i_1, i_1 + i_2,\ i_1 + i_2, + i_3, \ldots, i_1 + \ldots + i_{48})$$

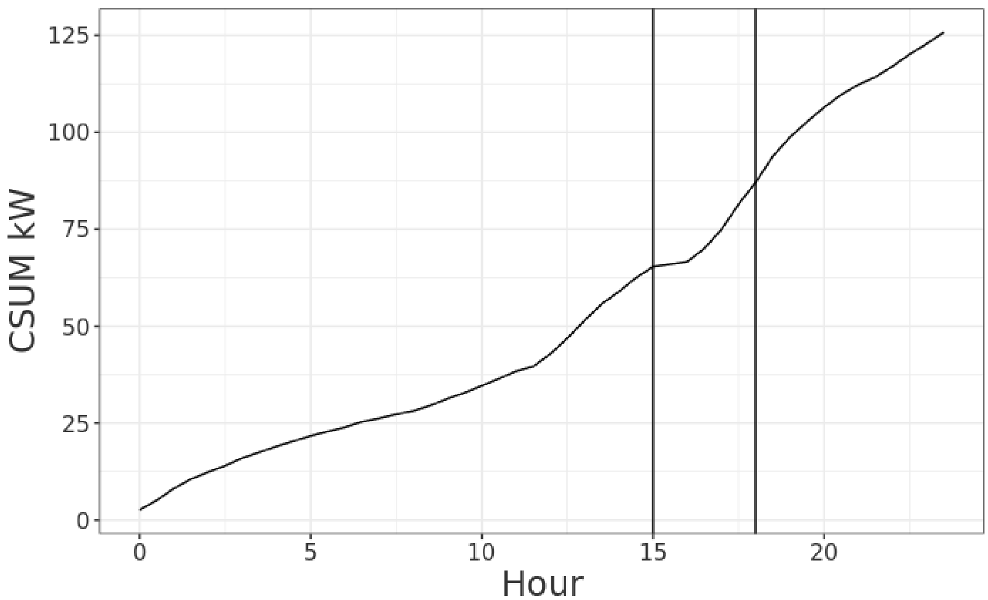
Where,

x = a vector of kW measures taken at 30-minute intervals,

$i_1 : i_{48}$ = the 24-hour interval from 12am to 12am the following day.

This creates a "running total" of power used throughout the day providing a way to quantify how the rate of energy consumption changed throughout the day. Figure G-14 shows an example of the CSUM curve for one responding device during a DLC event. The vertical lines represent the start and end of the event period.

Figure G-14: Example of Site-level CSUM Changes



To quantify how the rate of energy usage changes once the event started, a slope ratio is calculated for the CSUM curve of each device on each event day (Equation G-64).

Equation G-64: Slope Ratio Calculation

$$SlopeRatio = s_{event}/s_{pre.event}$$

Where,

s_{event} = slope of the CSUM curve during the event

$s_{pre.event}$ = slope of the CSUM curve three hours prior to the start of the event

For Test 1, if the slope ratio was greater than or equal to 1 the device was identified as non-responding.

Equation G-65: NRD Test 1

$$NRD_{T1} = SlopeRatio_{event} \geq 1$$

Where,

$SlopeRatio_{event}$ = Slope ratio of the CSUM curve

For Test 2 an expected (or site normal) CSUM curve is created for each site using the average hourly consumption of the previous seven non-event weekdays. Next, the slope ratio is calculated for the actual CSUM curve and the site normal CSUM curve. If the slope ratio for the actual curve is greater than or equal to the slope ratio for the site-normal curve, the device is considered non-responding.

Equation G-66: NRD Test 2

$$NRD_{T2} = SlopeRatio_{event} \geq \; SlopeRatio_{site.normal}$$

Where,

$SlopeRatio_{event}$ = Slope ratio of the CSUM curve

$SlopeRatio_{site-normal}$ = Slope ratio of the site normal CSUM curve

Finally, Test 3 tests for a 10% reduction in hourly consumption. For each device, the consumption one hour before the event started and the consumption one hour after the event started are tested for a drop greater than 10% (Equation G-67). The value of 10% is the average value found from an extensive review of drop percentages found in similar programs.

Equation G-67: NRD Test 3

$$NRD_{T3} = \; T1_{kWh} \leq T2_{kWh}$$

Where,

$PreHr_{kW}$ = kW measured one hour before the event start

$EventHr_{kW}$ = kW measured one hour after the event start

$T1_{kWh} = \; PreHr_{kWh} - EventHr_{kWh}$

$T2_{kWh} = PreHr_{kWh} * 10\%$

Next, baseline energy usage curves are developed. These are used to estimate what energy usage would have been during an event day had the event not occurred. For each event, this counterfactual baseline is developed using AMI data from all responding devices during non-event, non-holiday weekdays that had similar weather to that of the event day being analyzed.

The k-means clustering algorithm is used to identify similar weather days to each event day. Average daily temperature and humidity is calculated for every non-holiday weekday from June to August. Then the k-means clustering algorithm is applied to the daily weather data. This method splits every day into one of three clusters (or similar groups) of dates. Any non-event day that was placed into the same cluster as the event day is used to calculate that event’s baseline.

When determined what data is used to calculate each event’s baseline curve, a linear regression model is calculated using that data (Equation G-68).

Equation G-68: Baseline Energy Usage Curve Regression Model

$$kW_t = \; CDD_t + \; CDD_{t-2} + t$$

Where:

t = the 30-minute interval for which kW usage is being predicted

CDD_t = cooling degree days at time t

CDD_{t-2} = cooling degree days one hour before t

To ensure the baseline curves are as accurate as possible, a normalizing factor is calculated and applied to the baseline curve of each event day (Equation G-69).

Equation G-69: Normalization Factor Calculation

$$nf = kW_{actual.hour=es-2} \,/\, kW_{baseline.hour=es-2}$$

Where:

$kW_{actual.hour=es-2}$ = kW measured two hours before the event

$kW_{baseline.hour=es-2}$ = kW predicted by the baseline two hours before the event

With the baseline curve determined, demand reduction can be calculated. Demand reduction represents the average decrease in energy usage that occurs for the average event participant during a given time interval. Demand reduction is calculated for the event period and the snapback period. Equation G-70 shows the formula for calculating demand reduction.

Equation G-70: Demand Reduction Calculation

$$kW_t^{reduction} = kW_t^{baseline} - kW_t^{actual}$$

Where:

t = the 30-minute interval for which demand reduction is being calculated

$kW_t^{baseline}$ = kW demand predicted by the baseline at time t

kW_t^{actual} = kW demand measured at time t

Demand reduction is then used to calculate average annual energy savings for each event. The equation is shown in Equation G-71.

Equation G-71: DLC Event Energy Savings (kWh) Calculation

$$kWh_{saved} = \sum_{t \in EventPeriod} \left(\frac{kW_t^{reduction}}{2}\right)$$

Where:

t = the 30-minute interval for which energy savings is being calculated

$EventPeriod$ = all time intervals from event start to two hours after the event end

$kW_t^{reduction}$ = demand reduction calculated at time t

Peak reduction is calculated for each event, representing the maximum drop in energy usage that occurred for the average event participant. The equation is shown in Equation G-72.

Equation G-72: Verified Peak Reduction (kW) Calculation

$$kW_{reduced} = max_{\,t \in EventPeriod}\ (kW_t^{\ reduction})$$

Where,

t = the 30-minute interval for which energy savings is being calculated

$EventPeriod$ = all time intervals from event start hour to the event end hour

$kW_t^{\ reduction}$ = demand reduction calculated at time t

G.2.1.2 Smart Thermostat

The Power Hours smart thermostat annual savings is based on the AR TRM. The smart thermostats measure involves the replacement of a manually operated or programmable thermostat with a smart programmable thermostat. This measure applies to all residential applications. For homes with both electric cooling and heating, the deemed savings presented below are additive. Savings values were calculated using an average square footage of 1,832 ft^2 based on county assessor data average size of homes in a population of 202,962 homes in Tulsa County.

Table G-45: Deemed Energy Savings for Smart Thermostats

Baseline	% of population	Electric Cooling Energy Savings (kWh/SF)	Electric Resistance Heating Energy Savings (kWh/SF)	Electric HP Heating Energy Savings (kWh/SF)
Manual or manually operated T'stat	85%	0.45	0.845	0.395
Properly programmed Programmable T'stat	15%	0.113	0.212	0.099
Default	-	0.399	0.75	0.351

G.2.2 Peak Performers Program

G.2.2.1 PSO Methodology for Estimating Customer Baselines

For the purposes of financial settlement with Peak Performer participants, PSO uses a "top 3-of-10 baseline days" methodology to estimate participants' baseline load, or the demand that participants would have used had no Peak Performer event been called. Reported program impacts were calculated based on this baseline estimation methodology. For each premise, one applies the following algorithm:

1. For an event day *D*, *D(h)* is the participant's actual electric demand at hour h on *D*.
2. Starting with the day before *D*, the eligible baseline days are the most recent 10 non-weekend, non-holiday, non-Peak Event days.
3. For each of the eligible baseline days, the average midday electric demand during the hours corresponding to the peak event (usually 2 PM – 6 PM but can be any two to four-hour period between 1 PM and 7 PM) is calculated. The eligible baseline days are ranked in descending order of this average peak time demand.
4. The hourly loads are averaged for the top three days identified in the previous step. This is the unadjusted baseline, *B(h)*.
5. If, on average, the ratio of *B(h)/D(h)*, between 10 AM and 12 PM, is less than 1 (that is, the baseline is too low), *B(h)* is multiplied by the reciprocal of that ratio so that the baseline and event loads match prior to the event. The most *B(h)* can be adjusted upward is 30%; no downward adjustments are made.

Reported demand reduction and payments made to Peak Performers participants depend on the difference, B(h)-D(h).

PSO provided hourly interval data for all the facilities involved in the Peak Performers Program. PSO staff also provided internal audits for all the events, which are produced by a database script that implements the 3-of-10 baseline. ADM used these audits and interval data to independently verify that the baseline loads reported by PSO were calculated according to the algorithm described above.

G.2.2.2 ADM Baseline Methodology

In the case of evaluating demand reduction impacts associated with the Peak Performers Program baselines or counterfactuals represent what participants' usage would have been if the event had not occurred. In 2021, ADM employed multiple baseline methodologies and selected the best fitting models for each premise number (i.e., models that produced load profiles which best represented each participant's usage in absence of the program as determined by objective statistical test). These methodologies included the following models:

Table G-46: Peak Performers Baseline Models

Model Name	Description
3 of 10 Unadjusted	Model described in Section G.2.2.1 without the adjustment described in step 5.
3 of 10 Scalar Adjusted	Model described in Section G.2.2.1 but allows for a ±30% day of adjustment.
3 of 10 Additive Adjusted	Model described in Section G.2.2.1 but allows an adjustment of the actual demand difference in kW between *B(h)* and *D(h)* described in Section G.2.2.1.
5 of 10 Unadjusted	Model described in Section G.2.2.1, but with 5 baseline days selected and without the adjustment described in step 5.
5 of 10 Scalar Adjusted	Model described in Section G.2.2.1, but with 5 baseline days selected and allows for a ±30% adjustment.
5 of 10 Additive Adjusted	Model described in Section G.2.2.1, but with 5 baseline days selected and allows an adjustment of the actual demand difference in kW between *B(h)* and *D(h)* described in the section.
7 of 10 Unadjusted	Model described in Section G.2.2.1, but with 7 baseline days selected and without the adjustment described in step 5.
7 of 10 Scalar Adjusted	Model described in Section G.2.2.1Section G.2.2.1, but with 7 baseline days selected and allows for a ±30% adjustment.
7 of 10 Additive Adjusted	Model described in Section G.2.2.1, but with 7 baseline days selected and allows an adjustment of the actual demand difference in kW between *B(h)* and *D(h)* described in the section.
7 of 10 Weather Sensitive	The 7 of 10 unadjusted model with a weather sensitivity adjustment based on temperature's impact on energy usage for each premise from June through September.
9 of 10 Unadjusted	Model described in Section G.2.2.1, but with 9 baseline days selected and without the adjustment described in step 5.
9 of 10 Scalar Adjusted	Model described in Section G.2.2.1, but with 9 baseline days selected and allows for a ±30% adjustment.
9 of 10 Additive Adjusted	Model described in Section G.2.2.1, but with 9 baseline days selected and allows an adjustment of the actual demand difference in kW between *B(h)* and *D(h)* described in the section.

ADM matched test event day usage to the five most similar event eligible non-event days. The days selected serve as a good proxy for the test event days and will be referred to as proxy event days. The proxy event days were then used to identify baseline "best fits" for each premise ID using residual root mean squared error (RRMSE) scores.

It has been ADM's experience that baseline estimation methodologies often produce generally consistent results, but in some cases, these estimations can produce divergent results. To minimize calculation bias, we combined results as a weighted average of the best three models for each premise number. The weights were the inverse squares of the model RRMSEs. For example, if the three best fitting models have RRMSEs of 5%, 11%, and 52% respectively, their relative weights will be 79%, 20%, and 1% respectively.

G.2.2.3 Baseline Methodology for Small Sites

All models with less than or equal to 550 kW reported reduction were compared to the proxy test event days using RRMSE with the three best fitting models being selected and weighted in the way described in Section G.2.2.2.

G.2.2.4 Baseline Methodology for Large Sites

For the twenty sites with the largest kW reductions in the program (greater than 600 kW reported reduction), ADM chose to modify the models considered for RRMSE testing based on premise level information such as business type and pre-event energy usage. Weather sensitive models were dropped if a premise’s energy usage was determined to not be weather dependent. Adjusted models were dropped if the premise showed an abnormal dip or spike pre-event. The modified selection of models was then compared to the proxy test event days using RRMSE with the three best fitting.

Appendix H. Telensa Information

Telensa provided informational and training sessions to PSO and project stakeholders. Trainings reviewed the technology used for the smart street lighting pilot as well as operability of the PLANet software. The system consists of two main pieces of hardware, the telecell, controlling an individual light fixture, and the base station, used to communicate to the telecells.

H.1 System Components

Individual light fixtures are controlled by a unit known as a telecell. When installed and powered, a telecell performs start up self-test, going through a full switch on followed by 50% dim cycle. This is visible to the installer and verified the telecell is electrically installed and that the luminaire is functioning. The telecell then starts a process of scanning for, then connecting to, the UNB radio network. This is automatic and results in self-commissioning to the best base station.

The further commissioning required is the association of the individual telecell (with its unique ID) to the individual streetlight (with its unique ID, if it has one). There are several methods and tools for this association, which range in degrees of sophistication and automation:

- A “low tech” approach is largely “paper based” and involves some manual information entry into the software program PLANet. In the field the installer takes one of the peel-off ID labels from the telecell and sticks it on a sheet (listing the lights), next to the relevant light. Back in the office, information from these completed sheets is then input into PLANet. Additional configurations are also done in PLANet, for example setting the lamp type for each light. See Figure I-1.

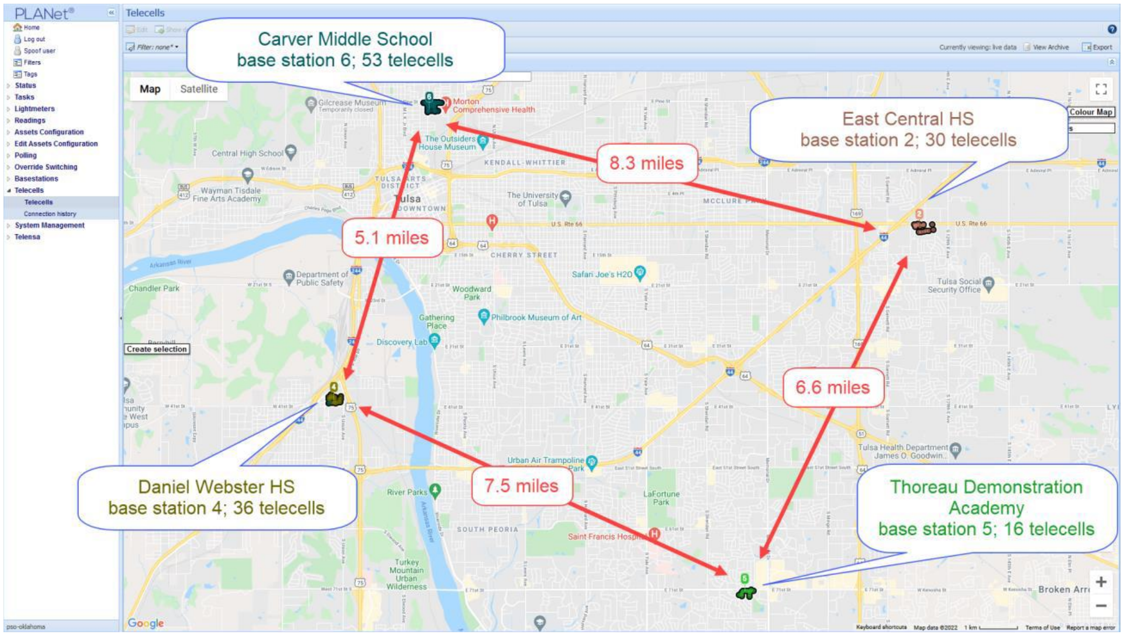
Figure I-1: Telensa Telecell

Peel off barcode ID labels	Permanent ID label on underside
	

- For a more advanced and automated method, and to simplify the telecell commissioning process, Telensa has created an “installer app”, which is available for download from the “Play Store” and has been designed to run on a range of handheld devices running the Android OS. In the broadest terms, the ‘Installer App’ can be installed to the handheld device, is license driven and will match the scanned telecell IDs with the corresponding pole and lamp information held in the PLANet system. There re several possible workflows that may be applicable, according to what information on lights exists or not, and/or customer working preferences.
- In addition to the Telensa app, there are also other 3rd party apps for handheld devices for capturing asset related information. These can be adapted to include required fields such as telecell ID.

In the Tulsa Public Schools system, we have a base station at each of the four schools and the telecells connect to their local base station. While telecells connect to the “best” base station they can “hear”, they will understand which others are possible to connect to. This revealed when looking at the technical information in the PLANet software. See Figure I-2.

Figure I-2:Telecell Connectivity



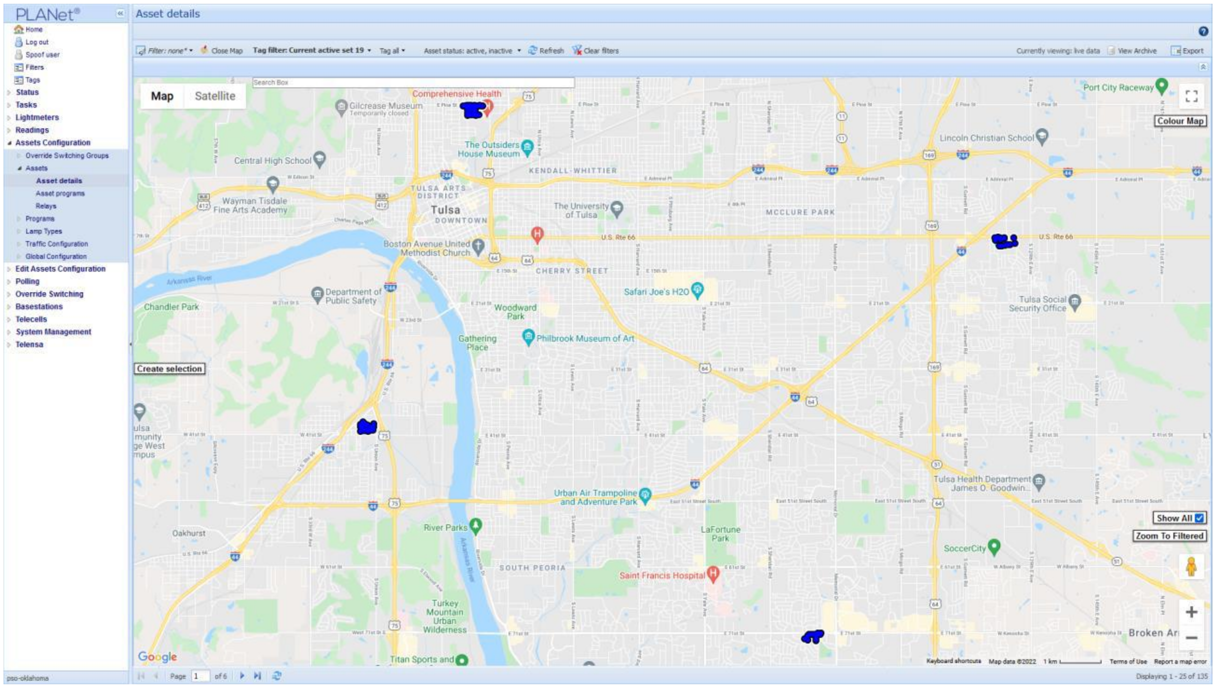
Radio signal strengths of telecells to their preferred base station, and second preferred base station can be viewed in PLANet. With this information retained by the telecells, if they lose connection to their preferred base station for whatever reason, they automatically re-connect to the other base station(s) available to them.

The extent of coverage is determined, in part, by the good siting of base stations. Before deploying a system, Telensa runs a radio planning exercise to work out how many base stations would be needed, and on which poles they should optimally be mounted. Generally, the taller the mounting the better. In the PSO system, we can see how bases have been mounted, and that they are generally on good, prominent poles.

H.2 PLANet Software

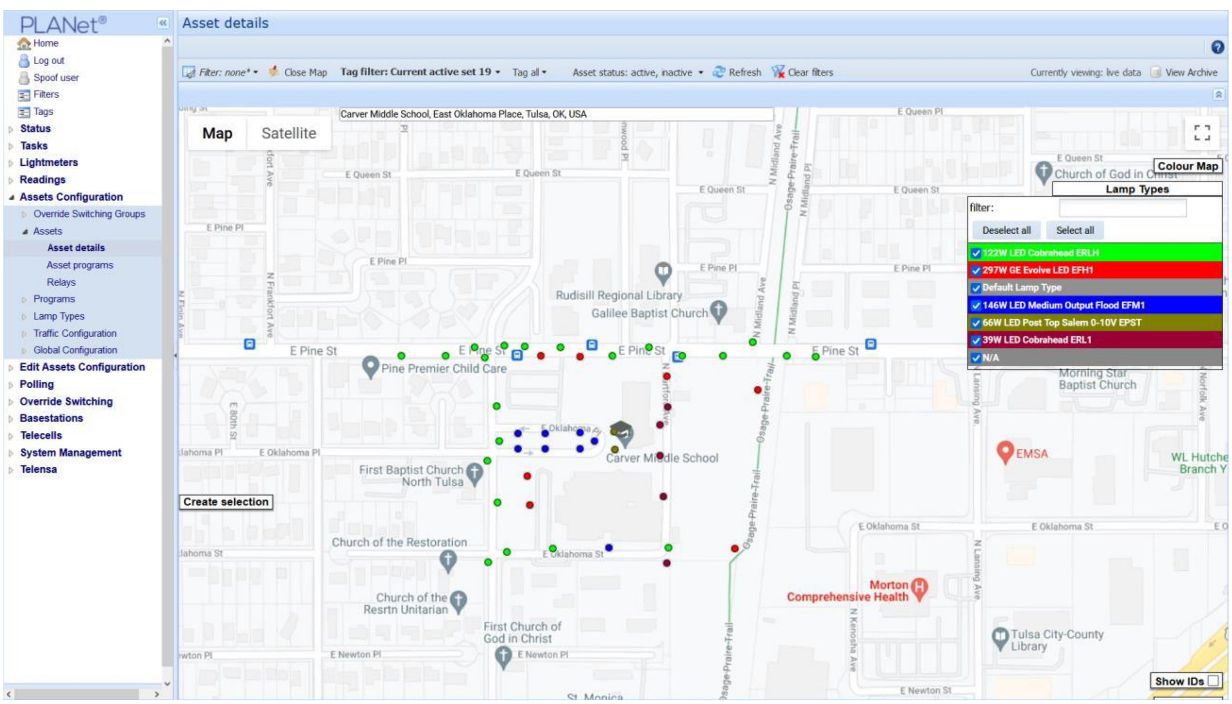
PLANet allows for access to individual light operation and controls. It is a feature rich application comprising approximately 120 web pages. In Telensa's large customer systems, some users are in the PLANet daily, and therefore undergo extensive training. Also in large systems, customers increasing want and need PLANet to be integrated into other systems, such as asset and/or field crew management systems. Telensa has available several API's than enable such integrations. An example screenshot is shown in Figure I-3. The figure demonstrates the locations of light fixtures in blue.

Figure I-3: PLANet Screenshot



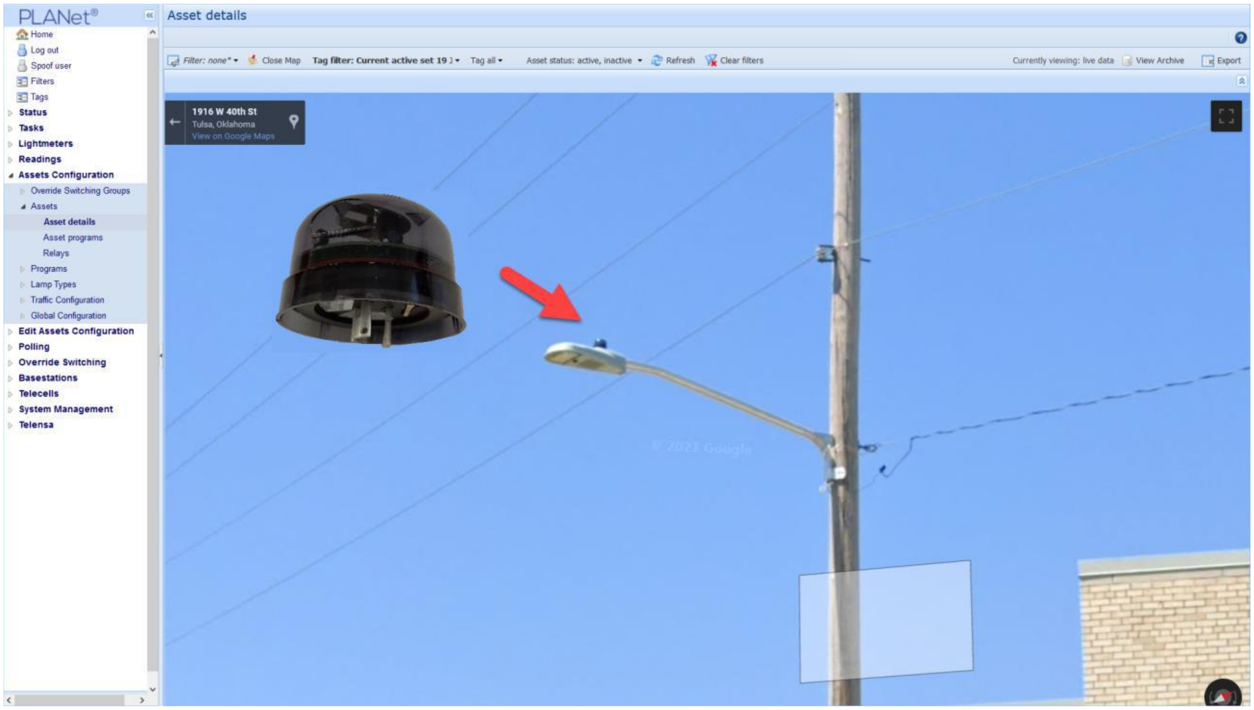
When zoomed in, the operation of each light can be easily determined, as shown in Figure I-4.

Figure I-4: PLANet Detailed Screenshot



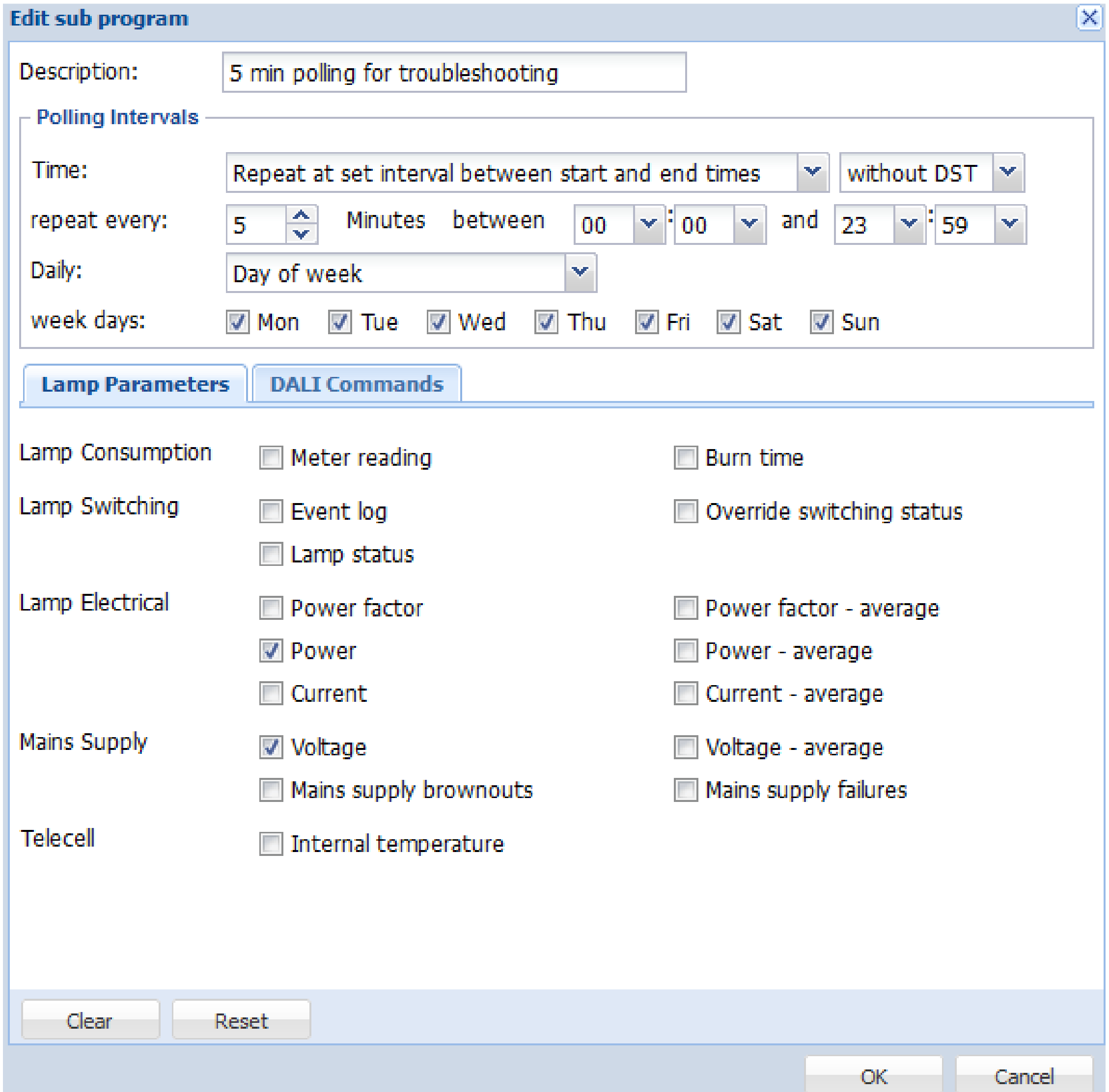
Telecells can be identified within PLANet. Figure I-5 demonstrates the ability to view the system as well as show what the hardware looks like.

Figure I-5: PLANet Telecell Appearance



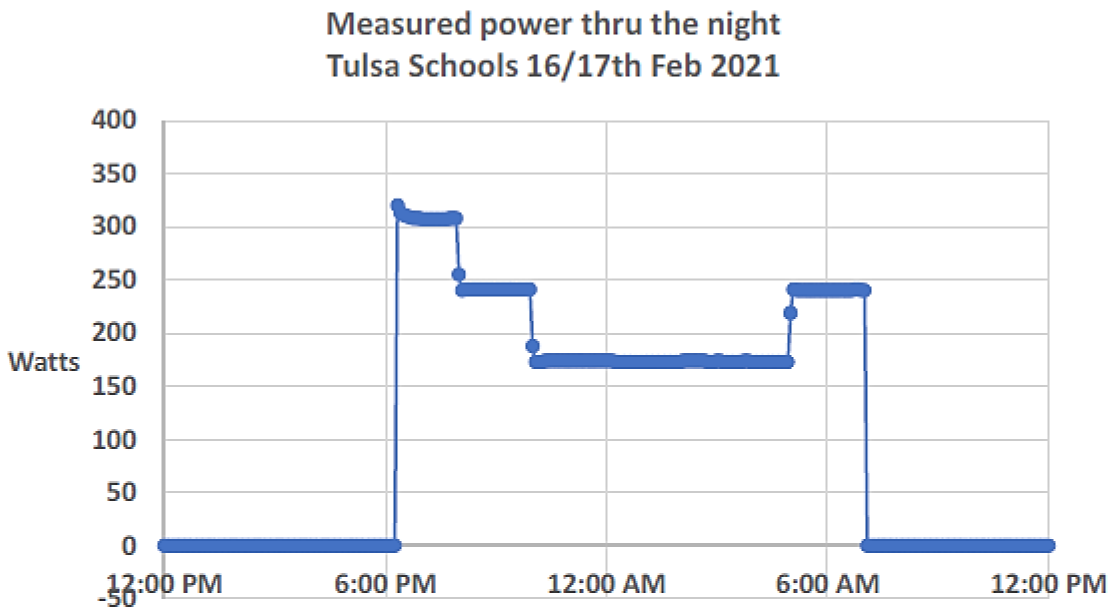
One of the features in the Telensa system is the ability to take electrical measurements as frequently as every 5 minutes from selected lights. This is done using "programmed polling", as shown in Figure I-6.

Figure I-6: PLANet Measurements



The provided continuous power measurements can be used to show how the dimming schedule adjusts power in practice, on a given light (see Figure I-7). Provided data and control functionality in PLANet gives street light operators a valuable capability in “scrubbing clean” their inventory i.e., ensuring the correct lamp type is allocated to a light pole. The system can then identify inaccuracies and discrepancies. When operating, the telecall is continuously monitoring the power consumed by the light. If the power deviates from an expected normal operating band, the system creates an event called a “power level warning”.

Figure I-7: Dimming Schedule Example



Appendix I. Overview of ADM Associates

ADM Associates is a professional services corporation providing research and consulting services in applied energy engineering and economics to utilities and other clients nationwide. The services ADM provides primarily relate to comprehensive energy research and energy-efficiency program implementation and evaluation. ADM's headquarters are in Sacramento, California with regional field offices in Nevada (Reno) and the California Bay Area (Fremont). ADM has remote staff located throughout the country. From these offices, ADM conducts energy-related studies and projects throughout the United States and Canada for utility companies, government agencies and other clients.

ADM has been performing energy research and evaluation activities for forty (40) years and has demonstrated its commitment to quality and customer service. ADM is currently conducting evaluations of residential, commercial, and industrial programs for utilities across the United States.

ADM is dedicated to creating a safe work environment and to provide training for our employees. All ADM employees undergo general safety training. Our field technicians and engineers undergo additional safety training related to fieldwork. We encourage all our employees to be responsible and alert to identify hazardous conditions wherever they may exist be it in transportation to the customer or at the customer’s facility. If hazardous conditions are found, they are to report them immediately to their supervisor or the ADM Safety Officer. Never are they to proceed to work in an identified hazardous situation. ADM follows Cal/OSHA rules and guidelines for safety in the workplace and these rules are as or more stringent than the federal OSHA rules.

Personal Protective Equipment (PPE) is provided and the procedures to use it as appropriate for the work expected. Our field staff is provided training to safely conduct activities they may encounter. Specifically, this includes the use of ladders and the rules associated with working at heights. Three points of contact on ladders are always required. It is trained that body harnesses are required when being lifted by a man lift or bucket, although we also train to avoid the use of lifts. If rooftops need to be accessed, our field staff is trained to identify if it is safe to be there and the requirements for perimeter protection. For those that will make electrical measurements, electrical safety training is given for new hires and periodically reviewed for all employees working in such conditions. Electrical safety training includes the use of PPE and the voltage the PPE is appropriate for use around. Arc flash training reinforces the reason for using PPE. ADM does not conduct any measurement activity on systems over 500 Volts. Other training includes exposure to asbestos, lead, and hydrogen sulfide. Employees are trained to follow safety procedures and there are consequences for not following proper procedures which can include termination of employment.